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Clinical efficacy and pharmacological basis of Mongolian medicine Manggari hot compress therapy for cervical spondylotic radiculopathy: a randomized controlled trial and serum pharmacochemistry study

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ABSTRACT

Objective To systematically evaluate the clinical efficacy of topical preparations of Mongolian medicine Manggari hot compress therapy (hereafter referred to as Manggari hot compress therapy) in treating cervical spondylotic radiculopathy (CSR) and explore the possible pharmacological material basis in the formula, providing evidence for the clinical application of Mongolian medicine in the treatment of CSR.

Methods The clinical trial employed a randomized, controlled, open-label, and outcome-assessor-blinded design. The CSR patients who were treated at the Department of Traditional Therapeutics Outpatient Clinic, Xilinguole Meng Mongolian General Hospital between July 1, 2024 and August 31, 2025, were enrolled. They were randomly assigned to three groups: an oral control group (administration of oral administration of mecobalamin tablets combined with cervical electric traction), an experimental group (Manggari external hot compress), and a patch control group (flurbiprofen gel plaster). The intervention lasted two weeks. Before and after treatment, the following subjective indicators were recorded: Mongolian Medicine Syndrome (MMS) score, Visual Analog Scale (VAS) score, Northwick Park Neck Pain Questionnaire (NPQ) score, and tongue morphology. Serum levels of inflammatory markers [tumor necrosis factor (TNF)-α, interleukin (IL)-6, and IL-1β)] and oxidative stress markers [malondialdehyde (MDA) content, superoxide dismutase (SOD) activity, and glutathione peroxidase (GSH-Px) activity] were measured using enzyme-linked immunosorbent assay (ELISA). Overall therapeutic efficacy was evaluated. One month after treatment completion, a follow-up assessment was conducted, and the MMS, VAS, and NPQ scores were recorded again for all patients. For the pharmacological substance exploration, ultra-high-performance liquid chromatography-Q-exactive orbitrap-mass (UHPLC-QE-MS) was employed to analyze blood-absorbed prototype components of Manggari, under both positive and negative ion modes. The targeting relationship between the core active compounds and the target protein was validated using molecular docking.

Results This study ultimately included 90 patients with CSR for analysis. Baseline characteristics showed no statistically significant differences among the three groups ($P > 0.05$).

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(i) Symptom scores. After treatment, the MMS, VAS, and NPQ scores decreased significantly from baseline in all three groups ($P < 0.001$). At follow-up, there was no significant difference in MMS, VAS, and NPQ scores of the experimental group compared with those at the end of the treatment ($P > 0.05$). After treatment, the experimental group showed significantly greater reductions in MMS, VAS, and NPQ scores than oral control and patch control groups ($P < 0.001$). At follow-up, these differences remained significant ($P < 0.001$). (ii) Inflammatory and oxidative stress markers. After treatment, serum levels of TNF-α, IL-6, and IL-1β, and MDA activity decreased significantly from baseline in all three groups ($P < 0.001$), and SOD content and GSH-Px activity increased significantly from baseline ($P < 0.05$). After treatment, the experimental group had significantly lower serum levels of TNF-α, IL-6, and IL-1β than oral and patch control groups. Additionally, it exhibited lower MDA activity and higher SOD content and GSH-Px activity compared with the two control groups. ($P < 0.05$). (iii) Overall efficacy. The total effective rate was 93.33% in the experimental group, 86.66% in the oral control group, and 83.33% in the patch control group. (iv) Pharmacological substance analysis. A total of 152 compounds were identified in the blood-absorbed components of Manggari. Among them, the core compounds—4-hydroxycoumarin, N-methylanthranilic acid, genistein, and ginsenoside-Rk1—showed binding energies to the key target proteins TNF-α and IL-1β range from − 4.7 to − 7.1 kcal/mol, with the majority of the binding energies being below − 5.0 kcal/mol, suggesting that it generally has a good binding affinity.

Conclusion Mongolian medicine hot compress therapy effectively modulates inflammatory and oxidative stress responses through the combined action of its thermal effects and active pharmaceutical ingredients Manggari. It inhibits cervical nerve root inflammation and alleviates radicular pain, improving clinical symptoms, reducing pain severity, and alleviating neck functional disability.

1 Introduction

Cervical spondylosis (CS) is a condition characterized by degenerative changes in the cervical intervertebral discs, which may lead to lesions in adjacent structures, including the spinal cord and nerve roots, thereby causing a variety of clinical manifestations, such as neck and shoulder pain, upper limb numbness, and motor dysfunction [1]. It is reported to affect approximately one-quarter to one-third of adults worldwide at some point in their lives, varying in severity and duration according to population and study methodology [2, 3]. Cervical spondylosis radiculopathy (CSR) accounts for about 60% – 70% of all CS cases, making it the most common form of the disease [4]. CSR typically results from the compression or inflammation of the cervical nerve roots and primarily presents with neck and upper limb pain, sensory disturbances, motor dysfunction, and altered reflexes [5]. The pain often radiates along the distribution of the affected nerve root, potentially leading to radiating pain, numbness, and muscle weakness [6]. Although various treatments are available, including physiotherapy, pharmaceutical interventions, and surgery, their efficacy remains limited, with high recurrence rates and no substantial improvement in patient prognosis [7, 8]. In CSR, inflammatory responses and oxidative stress are recognized as fundamental mechanisms driving pain development. Research demonstrates that chronic neuroinflammation reduces endogenous antioxidant responses, thereby increasing oxidative stress, which is closely linked to pain progression [9]. Furthermore, the compression of cervical nerve roots can elicit both local and systemic inflammatory reactions, including cytokine release and alterations in leukocyte phenotypes, both of which may heighten pain perception [10, 11]. Although steroid injections combined with local anesthetics can provide some short-term relief of persistent neck pain, their long-term efficacy is limited and may be insufficient for certain patients. This underscores the need to explore adjunctive or combination therapeutic strategies to further improve patient outcomes [12, 13].

Traditional Mongolian medicine is a medical system that originated and evolved within a nomadic cultural framework. It embodies the collective experience of the Mongolian people in disease management across generations and is an essential component of Eastern traditional medicine. Mongolian medicine hot compress therapy is a traditional external treatment in Mongolian medicine that combines medicinal application with thermal stimulation at the affected site. In this study, the topical preparations of Mongolian medicine Manggari (hereafter referred to as Manggari) was used as the medicinal preparation and applied to the affected area using the hot compress procedure. Therefore, this intervention is hereafter referred to as Manggari hot compress therapy. The thermal effects raise local tissue temperature, dilate capillaries, promote blood circulation, and enhance local metabolism. This produces anti-inflammatory and anti-edema effects while alleviating reflex muscle spasms. The Manggari hot compress therapy reduces muscle tension, relieves fatigue and discomfort, and helps restore

dynamic equilibrium [14]. By utilizing heat to deliver active pharmaceutical ingredients directly to acupoints and afflicted areas, Manggari hot compress therapy increases the concentration of medicinal activity in the cervical region. The integration of thermal effects with the pharmacological action of Mongolian medicine achieves therapeutic outcomes that promote blood circulation and relieve pain [15, 16].

Specifically, Manggari consists of Zhicaowu (Aconiti Kusnezoffii Radix Cocta), Biba (Piperis Longi Fructus), Sanqi (Notoginseng Radix et Rhizoma), Zhangnao (Camphor), and so on [17]. Zhicaowu (Aconiti Kusnezoffii Radix Cocta) serves as the principal analgesic component, exhibiting therapeutic or palliative effects on inflammatory and painful conditions [18, 19]. When combined with Sanqi (Notoginseng Radix et Rhizoma), Biba (Piperis Longi Fructus), and Zhangnao (Camphor), it promotes blood circulation, alleviates stasis, exerts anti-inflammatory effects, and provides analgesia [20, 21]. This formulation has been extensively used in the management of chronic synovitis in Mongolian medical practice and represents a traditional Mongolian medicine preparation with considerable potential for further investigation. Given the limited existing evidence in this field, the present study adopted a dual-method design: (i) a prospective clinical trial to rigorously evaluate the efficacy of Mongolian medicine hot compress therapy in alleviating pain, paresthesia, and other radicular neurological symptoms; and (ii) a serum pharmacology study to identify and characterize its potential bioactive constituents. These integrated efforts aim to validate the therapeutic rationale of this traditional Mongolian formulation and generate translational evidence to support its clinical application in CSR. The assessment tools used in this study, including the Mongolian Medicine Symptom (MMS) score, tongue manifestation evaluation, and Mongolian medicine diagnostic criteria, are primarily based on Mongolian medicine theory. They incorporate selected Western medical evaluation methods and reference traditional Chinese medicine (TCM) efficacy standards, providing a framework that integrates Mongolian medical concepts with modern clinical assessment approaches.

2 Materials and methods

2.1 The composition and preparation of Manggari

The preparation method of Manggari is as follows: accurately weigh 200 g of processed Zhicaowu (Aconiti Kusnezoffii Radix Cocta), 125 g of Zhangnao (Camphor), 50 g of Shihuihua (Travertine), 50 g of Biba (Piperis Longi Fructus), 50 g of Chuanwu (Aconiti Radix), and 50 g of Sanqi (Notoginseng Radix et Rhizoma). Grind each herb separately into fine powder; combine all powders and mix thoroughly; then sieve the mixture through a No. 6 sieve (100 mesh, 150 μm), ensuring that ⩾ 95% of the final powder passes through, to obtain the compound [17]. It has now become a characteristic in-house preparation of Xilinguole Meng Mongolian General Hospital.

2.2 Reagents and instruments

The main instruments used in this study were as follows: cervical electric traction machine (Haobro Medical Devices, A24734F4014200), ultra-high performance liquid chromatography (Thermo Fisher Scientific, Vanquish), and high-resolution mass spectrometry (Thermo Fisher Scientific, Q Exactive Focus).

The reagents included enzyme-linked immunosorbent assay (ELISA) kits purchased from Wuhan Genmei Technology Co., Ltd., China, including human tumor necrosis factor (TNF)-α ELISA kit, human interleukin (IL)-6 ELISA kit, human IL-1β ELISA kit; human malondialdehyde (MDA) ELISA kit, human superoxide dismutase (SOD) ELISA kit, and human glutathione peroxidase (GSH-Px) ELISA kit.

The study also employed the following pharmaceutical preparations: Manggari (Xilinguole Meng Mongolian General Hospital, China), Mecobalamin (Jiangxi Qingfeng Pharmaceutical Co., Ltd., China), flurbiprofen gel patch (Beijing Taidi Pharmaceutical Co., Ltd., China), and ibuprofen sustained-release capsules (Zhuhai Rundu Pharmaceutical Co., Ltd., China).

2.3 Participants

Between July 1, 2024 and August 31, 2025, CSR patients who were treated at the Department of Traditional Therapeutics Outpatient Clinic, Xilinguole Meng Mongolian General Hospital were enrolled. The study protocol was approved by the Ethics Committee of the Xilinguole Meng Mongolian General Hospital (Approval No. YJ20240304) and was registered with the International Traditional Medicine Clinical Trial Registry (Registration No. ITMCTR2025000413).

2.4 Diagnostic criteria

Patients enrolled in this study were required to meet both the diagnostic criteria for CSR in Mongolian medicine and the corresponding Western medicine diagnostic criteria.

According to Diagnostic and Therapeutic Criteria for Mongolian Medicine Diseases [22], the diagnosis of CSR (Hu Zhu Nai Hu Ying Disease, 胡朱乃胡英病) requires the fulfillment of the following criteria: (i) neck stiffness and pain, restricted mobility, neck and shoulder pain, upper limb weakness, and numbness; (ii) positive findings on the head compression test and ipsilateral brachial plexus traction test; (iii) radiographic findings showing reduction or loss of normal cervical lordosis, narrowed intervertebral spaces, osteophyte formation along the

anterior and posterior vertebral borders, degenerative changes including hypertrophy of the uncovertebral and facet joints, and constricted intervertebral foramina; (iv) computed tomography (CT) or magnetic resonance imaging (MRI) findings showing cervical disc protrusion, narrowing of the spinal canal and neural foramen, and compression of the cervical nerve roots.

In addition, the Methodological and reporting quality evaluation of clinical practice guidelines and expert consensus for cervical spondylotic radiculopathy [23] specify that the diagnosis of CSR requires the following: (i) localized radicular compression symptoms, including unilateral or bilateral upper limb paresthesia and/or radiating pain along the affected nerve root distribution, decreased sensation, muscle weakness, tenderness, and diminished or absent tendon reflexes in the affected nerve root territory; positive cervical compression test or positive brachial plexus traction test; (ii) anteroposterior radiographs showing significant enlargement of the vertebral bodies and uncovertebral joints; (iii) lateral views showing loss of cervical lordosis, narrowed intervertebral spaces, osteophytes, bone spurs, or calcification of the nuchal ligament, oblique views showing diminished intervertebral foramina; radiographic and CT findings indicating foraminal stenosis or perineural bone proliferation surrounding osteophytes of the affected nerve root; MRI findings indicating nerve root compression.

2.5 Inclusion, exclusion, and withdrawal criteria

2.5.1 Inclusion criteria Patients were included if they met all of the following criteria: (i) fulfilled the combined Mongolian medicine and Western diagnostic criteria for CSR and were aged between 25 and 60 years; (ii) were conscious and compliant, with the ability to complete all required questionnaires; (iii) had a comprehensive understanding of the study procedures and potential risks; (iv) consented to participate and were able to receive regular treatment as assigned; (v) voluntarily signed the informed consent form and agreed to follow-up.

2.5.2 Exclusion criteria Patients were excluded if any of the following applied: (i) did not meet the diagnostic or inclusion criteria; (ii) had cervical spine injuries requiring surgical intervention; (iii) had concurrent autoimmune or hematological disorders, including hepatitis B, metabolic bone disease, osteoarticular tuberculosis, osteomyelitis, or advanced osteoporosis; (iv) had concurrent severe cardiac conditions, high fever, altered mental status, generalized edema, widespread skin disease, coagulopathy, or malignant neoplasms.

2.5.3 Withdrawal criteria Patients were withdrawn from the study if any of the following occurred: (i) poor compliance, inability to follow the randomized protocol, or failure to complete the entire treatment and follow-up after randomization; (ii) receipt of treatments outside the study protocol during the observation period, voluntary withdrawal, occurrence of unforeseen circumstances, or erroneous inclusion due to non-adherence to selection criteria; (iii) discontinuation of treatment due to severe adverse events or other medical conditions that developed during the intervention period.

2.6 Randomization and grouping

After recruiting patients who met the selection criteria, they were sequentially numbered according to their order of visit. A random number generator in SPSS 27.0 was used with a fixed seed value of 11111111 to generate a random allocation list. This procedure assigned a random group and a corresponding number to each patient. The attending physician then used the random numbers matched to the patient's visit sequence to complete the randomization process. Patients were divided into three groups: oral control group, experimental group, and patch control group.

2.7 Interventions

2.7.1 Oral control group The oral control group received conventional Western medicine treatment, including cervical electric traction, analgesia, and neurotrophic drugs. Mecobalamin tablets were administered orally at a dose of 0.5 mg three times daily for 14 d to nourish the nerves. Ibuprofen sustained-release capsules were used for pain relief, taken once daily only when pain was unbearable. Cervical electric traction was applied once per week for a total of two sessions. The specific procedure was as follows. (i) The patient assumed an upright sitting position, with the upper body straight, the head and neck centered without tilting, and the whole body naturally relaxed. Then the chin pillow strap was used to support the head, with the back of the strap pressed firmly against the occipital protuberance, gently lifting the neck, and the chin was adjusted to a comfortable position. (ii) An intermittent mode was used: 5 min of traction followed by 1 min of rest. Each traction lasted 60 – 80 s, followed by a relaxation period of 10 – 20 s. This cycle continues for 20 min. (iii) The initial traction force was set at 7% – 10% of the patient's body weight and could be gradually increased to 10% – 15% of body weight.

2.7.2 Experimental group The experimental group received Manggari hot compress therapy. A 40 g portion of the powder was heated to approximately 50 °C and then allowed to cool until the temperature was tolerable for the patient and did not cause burning discomfort before application. The powder was applied onto absorbent cotton and then placed on the affected area. This procedure was performed once every 2 d, for 2 h per application. A complete treatment course lasted for 14 d (Figure 1A).

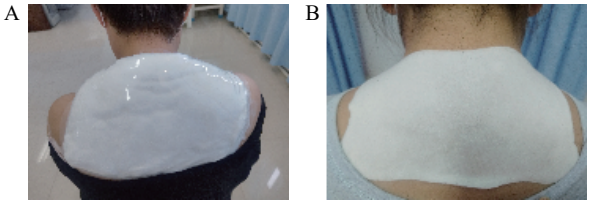

Figure 1 Topical application of medication in the (A) experimental group and (B) patch control group

2.7.3 Patch control group The patch control group received flurbiprofen gel plaster, applied to the affected neck and shoulder area once daily for 6 h per application, for a total of 14 d. The specific procedure was as follows. (i) The neck skin was cleaned with purified water and patted thoroughly dry. (ii) The flurbiprofen gel plaster was removed from its packaging. Both lateral edges were held with both hands, and the plaster was gently stretched horizontally to facilitate gel expansion and natural separation of the protective liner. (iii) Once the liner was fully detached, the adhesive gel layer was smoothly applied to the neck skin, starting from the center and extending outward to both sides. (iv) The entire surface and periphery of the plaster were pressed with the palm to ensure complete, wrinkle-free, and bubble-free adhesion (Figure 1B).

2.8 Outcome measures

2.8.1 Mongolian medicine tongue morphology assessment Tongue morphology diagnosis according to Mongolian medicine was performed by two senior Mongolian medicine practitioners who were blinded to group allocation and assessment time point, according to *Mongolian Medical Diagnosis* [24]. Mongolian medicine tongue diagnosis is a method of disease assessment that examines the color, coating, and texture of the tongue. Normal tongue morphology is characterized by a bright, moderately red color, a moist texture, an appropriately sized and flexible tongue body, and an evenly distributed, thin, white, and wet coating. The therapeutic response classification was independently assessed by two senior Mongolian medicine practitioners, and any discrepancies were resolved through discussion until a consensus was reached. The findings were documented as part of the comprehensive syndrome evaluation. To quantify chan ges in tongue morphology and provide more objective indicators, scores were assigned based on the criteria shown in Table 1. Among these parameters, tongue morphology diagnosis is primarily used to monitor dynamic changes throughout the treatment period. Therefore, tongue morphology was evaluated only at baseline and after treatment and was not included in follow-up evaluation.

2.8.2 Evaluation of clinical outcomes and symptom severity The MMS score was used to evaluate the improvement of clinical symptoms before and after treatment.

Table 1 Grading scale for Mongolian medicine tongue morphology assessment

Type	Manifestation	Score
Tongue coating color	White coating	1 – 4
	Light yellow coating	5 – 8
Tongue coating texture	Thin coating	1 – 4
	Thick coating	5 – 8
Tongue color	Light white tongue	1 – 4
	Red tongue	5 – 8

The following symptoms were specifically recorded: neck pain with limited mobility; radiating pain on one or both sides of the neck, shoulders, and upper limbs; finger numbness; chills; weakness; dropping objects; worsening after prolonged sitting; and worsening after exposure to cold. Each syndrome item was scored on a scale of 1 – 10 according to severity, with higher scores indicating more severe manifestations. Lower scores after treatment reflected greater improvement. Specifically, scores of 1 – 3 indicated marked improvement, 4 – 6 indicated improvement, 7 – 9 indicated slight improvement, and 10 indicated no improvement [25].

Patients were asked to rate their pain intensity using a 10-cm Visual Analog Scale (VAS), where each centimeter corresponded to 1 point. Higher scores indicated more severe pain: 0 represented no pain, and 10 represented extreme pain [26]. The VAS scores were then classified into four pain severity categories: 0 indicated no pain, 1 – 3 indicated mild pain, 4 – 6 indicated moderate pain, and 7 – 10 indicated severe pain.

The Northwick Park Neck Pain Questionnaire (NPQ) is a quantitative scale consisting of nine items used to evaluate the impact of neck pain on daily activities, including pain intensity, sleep disturbance, duration of symptoms, numbness/tingling at night, carrying, watching television, work housework, social activities, and driving. Each scored from 0 to 4, with higher scores reflecting greater disability. The total score was calculated by summing the scores of all completed items and then converted into a percentage. When all nine items were completed, the NPQ percentage score was calculated as (total score/36) × 100%. If the driving item was not applicable (e.g., the patient did not drive), the percentage score was calculated as (total score/32) × 100% [27].

All the above-mentioned indicators were evaluated immediately before and after treatment. In addition, these indicators were also followed up and evaluated one month after the end of treatment to assess the sustainability of the therapeutic effect.

Adverse events were systematically monitored and recorded throughout the treatment period. Safety evaluation included treatment-related adverse events associated with Mongolian medicine hot compress therapy and topical application therapy, such as skin burns, local

redness, itching, allergic reactions, and dizziness during treatment, as well as gastrointestinal reactions potentially associated with oral medication, including nausea, abdominal discomfort, and diarrhea.

2.8.3 Measurement of serum inflammatory factors and oxidative stress markers using ELISA Serum levels of inflammatory cytokines (TNF-α, IL-6, and IL-1β) and oxidative stress markers (MDA, SOD, and GSH-Px) were quantitatively measured using ELISA kits. Venous blood (5 mL) was collected from each participant and allowed to clot at room temperature for 30 min. Samples were then centrifuged at 3 000 rpm for 15 min, and the supernatant serum was carefully collected and stored at – 80 °C until analysis. ELISA assays were performed following the manufacturers' protocols: standard solutions were serially diluted, and blank, standard, and sample wells were prepared. Serum samples or standards were added and incubated, followed by washing and addition of biotinylated detection antibody and horseradish peroxidase (HRP)-conjugated streptavidin. After further incubation and washing, 3,3′,5,5′-tetramethylbenzidine (TMB) substrate solution was added for color development in the dark, and the reaction was terminated with stop solution. Absorbance was measured at 450 nm using a microplate reader, and concentrations or enzyme activities were calculated based on standard curves. The aforementioned indicators are primarily intended to reflect serum biomarker changes during the treatment period. Therefore, they were excluded from longitudinal follow-up assessments.

2.8.4 Criteria for efficacy evaluation The total effective rate was calculated based on baseline and after treatment MMS score according to the following formula: efficacy index (%) = [(baseline score – after treatment score)/baseline score] × 100% [22, 24].

Treatment response was categorized based on the percentage improvement in MMS score: complete recovery was defined as an efficacy index ⩾ 90%, indicating full resolution of symptoms and signs with restoration of physiological function; marked improvement corresponded to 60% – 89% improvement, reflecting significant alleviation of symptoms and associated signs with noticeable functional recovery; improvement corresponded to 30% – 59% improvement, indicating moderate alleviation of symptoms and signs; and no response was defined as < 30% improvement, indicating minimal or no change or worsening of symptoms and signs. This single and standardized quantitative approach allowed for objective evaluation of clinical outcomes and therapeutic efficacy during the treatment period.

2.9 Preparation of serum from mice treated with Manggari hot compress therapy

To elucidate the pharmacological basis of Manggari hot compress therapy in the treatment of CSR, drug-containing serum was prepared, and its blood-absorbed components were analyzed using TCM metabolomics. Twelve healthy male BALB/c mice, specific pathogen-free (SPF) grade, aged 6 – 8 weeks and weighing 20 – 22 g, were used [Laboratory Animal License No. SCXK (Liao) 2020-0001]. All animal procedures were conducted in accordance with the approved protocol, which was reviewed and approved by the Animal Ethics Committee of Inner Mongolia Medical University (Approval No. YKD202002038). They were randomly divided into three groups (n = 4 per group): blank group, 1-h blood collection group (1-h group), and 2-h blood collection group (2-h group). The 1-h and 2-h groups received Manggari at a dose of 52.6 mg per 20 g body weight, applied to the nape of the neck twice daily for 7 consecutive days. The blank group received no intervention. On day 6 of treatment, the mice were fasted overnight with free access to water. Blood samples were collected from the blank group and the treatment groups at 1 h and 2 h after the final administration. Blood was obtained via retro-orbital bleeding and immediately transferred into chilled ethylenediaminetetraacetic acid (EDTA)-coated disposable tubes. The samples were allowed to stand at room temperature for 30 min to clot, then centrifuged at 3 000 rpm for 15 min at 4 °C. The resulting serum supernatant was aliquoted and stored at – 80 °C until analysis.

2.10 Ultra-high-performance liquid chromatography-Q-exactive orbitrap-mass (UHPLC-QE-MS) analysis of blood-absorbed components of Manggari

Drug-containing serum of Manggari was analyzed using UHPLC-QE-MS. The chromatographic conditions were as follows. Column: Waters ACQUITY UPLC BEH C18 column (1.7 μm, 2.1 × 100 mm). Mobile phase: 0.1% formic acid in water (A) and 0.1% formic acid in acetonitrile (B). Gradient elution program: 0 – 11 min, 85% A/15% B; 11 – 12 min, 25% A/75% B; 12 – 14 min, 2% A/98% B; 14.1 – 16 min, 85% A/15% B). Flow rate: 0.5 mL/min. Injection volume: 50 μL. Column temperature: 35 °C.

The mass spectrometry conditions were as follows. Sheath gas flow rate: 45 Arb. Auxiliary gas flow rate: 15 Arb. Capillary temperature: 400 °C. Full MS resolution: 70 000. MS/MS resolution: 17 500. Collision energy: 15/30/45 in normalized collision energy (NCE) mode. Spray voltage: 4.0 kV (positive ion mode) or – 3.6 kV (negative ion mode).

2.11 Molecular docking analysis

This study integrated the literature evidence with the UHPLC-QE-MS analysis results to screen out the core active components of Manggari, and simultaneously identified the key therapeutic targets of CSR [28]. The molecular formulas and related information of each compound were

obtained from the MedChemExpress (MCE) database (https://www.medchemexpress.cn/). Molecular docking analyses were performed between these components and targets. The structures of the candidate compounds were obtained from the PubChem database, and the crystal structures of the target proteins were downloaded from the Protein Data Bank (PDB). Protein structures with high resolution, derived from Homo sapiens, and containing co-crystallized ligands were preferentially selected. Water molecules and original ligands were removed from the proteins using PyMOL 3.0. The receptors and ligands were then prepared with AutoDockTools 1.5.7 by adding hydrogen atoms, assigning Gasteiger charges, and converting them into pdbqt format. The co-crystallized ligand-binding site was defined as the active pocket, and molecular docking was performed using AutoDock Vina 1.1.2. The lowest binding energy was used as the evaluation criterion, with lower binding energy indicating more stable binding. In general, a binding energy < 0 kcal/mol suggests spontaneous binding, ⩽ – 5.0 kcal/mol indicates good binding activity, and a binding energy ⩽ – 7.0 kcal/mol indicates strong binding affinity [29]. The docking results were analyzed for hydrogen-bonding and hydrophobic interactions using LigPlot+ and visualized with PyMOL 3.0.

2.12 Statistical methods

Statistical analyses were conducted using SPSS 27.0. Continuous variables were assessed for normality and are presented as mean ± standard deviation (SD) when normally distributed, or as median (interquartile range, IQR) when not normally distributed. Categorical variables were expressed as frequencies and percentages. For within-group comparisons, when comparing two time points (baseline vs. after treatment), paired-sample *t* tests were used for normally distributed variables, and the Wilcoxon signed-rank test for non-normally distributed variables. For comparisons involving three time points, repeated-measures analysis of variance (ANOVA) was applied for normally distributed data, and the Friedman test for non-normally distributed data. For between-group comparisons among the three treatment groups, one-way ANOVA was performed for normally distributed continuous variables after confirmation of homogeneity of variance using Levene's test. The Kruskal-Wallis test was applied when the data were not normally distributed. All statistical tests were two-sided, and $P < 0.05$ was considered statistically significant.

3 Results

3.1 Participant flow and baseline characteristics

A total of 99 patients with CSR were assessed for eligibility. During the trial, 3 participants withdrew from the oral control group (2 due to professional obligations, and 1 due to mild gastrointestinal pain), 3 participants withdrew from the experimental group (1 due to an allergy to medical tape, and 2 due to non-compliance with drug application), and 3 participants discontinued from the patch control group (1 due to failure to attend scheduled patch application visits, 1 due to travel, and 1 lost follow-up). Consequently, 90 patients were included in the statistical analysis: 30 in the oral control group, 30 in the experimental group, and 30 in the patch control group. Among the remaining participants, no treatment-related serious adverse events, including skin burns, local allergic reactions, or significant gastrointestinal disturbances were observed throughout the study period.

The three groups were comparable with respect to baseline characteristics, including sex and age, with no statistically significant differences among the groups ($P > 0.05$) (Table 2).

Table 2 Baseline characteristics of the three groups

Group	*n*	Sex		Age (year)
		Male	Female	
Oral control	30	11	19	40.8 ± 11.1
Experimental	30	5	25	42.8 ± 14.7
Patch control	30	17	13	41.7 ± 13.8

3.2 Clinical efficacy evaluation of Manggari hot compress therapy in the treatment of CSR

3.2.1 Tongue morphology assessment After treatment, tongue coating color scores decreased compared with baseline in all three groups ($P < 0.05$). Tongue coating texture scores increased compared with baseline ($P < 0.001$). Tongue color scores decreased compared with baseline (oral control group, $P < 0.05$; experimental group, $P < 0.01$; patch control group, $P < 0.05$). These findings indicate that tongue morphology improved after treatment in all three groups. After treatment, the experimental group demonstrated greater improvement in tongue coating texture compared with patch control group ($P < 0.01$), whereas no significant differences were observed in tongue coating color or tongue color between the groups ($P > 0.05$) (Figure 2).

3.2.2 MMS, VAS, and NPQ scores At baseline, no significant differences were observed among the three groups in MMS, VAS, or NPQ scores, indicating comparability of the groups ($P > 0.05$). After treatment, the MMS, VAS, and NPQ scores were significantly reduced compared with baseline in all three groups ($P < 0.001$, $P < 0.001$ and $P < 0.01$, respectively), indicating improvements in clinical symptoms, pain, and cervical spine functional limitation in each group. Significant differences

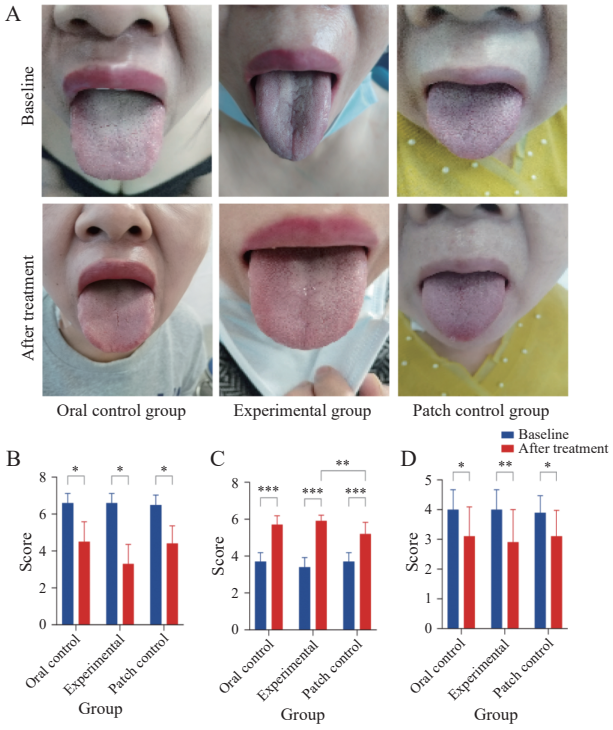

Figure 2 Changes in tongue morphology at baseline and after treatment

A, representative tongue morphology images of the three groups. B, tongue coating color scores. C, tongue coating texture scores. D, tongue color scores of the three groups at baseline and after treatment. $^{*}P < 0.05$, $^{**}P < 0.01$, and $^{***}P < 0.001$.

among the three groups were observed in MMS, VAS, and NPQ scores, with the experimental group showing greater improvement than both the patch control group and the oral control group ($P < 0.001$ or $P < 0.01$) (Table 3 and Figure 3).

During follow-up, MMS, VAS, and NPQ scores in the experimental group did not differ significantly from the after treatment values ($P > 0.05$) (Table 3 and Figure 3).

No treatment-related serious adverse events were observed in any group; all remaining participants tolerated the interventions well without notable skin irritation, allergic reactions, or gastrointestinal discomfort.

3.2.3 Serum inflammatory factors At baseline, no significant differences were observed among the three groups in serum levels of TNF-α, IL-6, or IL-1β ($P > 0.05$), indicating comparability of the groups. After treatment, serum levels of TNF-α, IL-6, and IL-1β were significantly reduced compared with baseline in all three groups ($P < 0.001$). Significant differences among the three groups were observed in serum levels of TNF-α, IL-6, and IL-1β, with the experimental group showing significantly lower levels than both the patch control group and the oral control group ($P < 0.001$) (Table 4 and Figure 4A – 4C).

3.2.4 Serum oxidative stress markers At baseline, no significant differences were observed among the three groups in serum SOD content, MDA activity, and GSH-Px activity ($P > 0.05$), indicating comparability of the groups. After treatment, serum MDA activity was significantly reduced compared with baseline in all three groups ($P < 0.001$). Meanwhile, SOD content and GSH-Px activity were significantly increased in all three groups ($P < 0.001$). Significant differences were observed among the groups, with the experimental group demonstrating greater reduction in MDA activity than the oral control group and patch control group ($P < 0.001$). Similarly, the experimental group exhibited significantly greater increases in SOD content and GSH-Px activity compared with the two control groups ($P < 0.001$) (Table 4 and Figure 4D – 4F).

3.2.5 Overall clinical efficacy The total effective rate was 93.33% in the experimental group, which was higher than that in the oral control group (86.66%) and the patch control group (83.33%) ($P < 0.05$). No statistically significant difference was observed in the total effective rate between the patch control group and the oral control group ($P > 0.05$) (Table 5).

Table 3 Within-group and between-group comparisons of MMS, VAS, and NPQ scores at baseline, after treatment, and follow-up

Variable	Time point	Oral control group	Experimental group	Patch control group	Between-group *P* value
MMSS	Baseline	19 (17, 26)	21 (18, 26)	19 (17, 25)	0.636
	After treatment	8.5 (6, 10)***	5 (3, 9)***	11 (9, 13)***	< 0.001
	Follow up	8.5 (7, 10)***	5 (3, 9)***	11 (9, 13)***	< 0.001
VAS	Baseline	6 (5, 7)	6 (5, 7)	6 (5, 7)	0.565
	After treatment	3 (3, 4)***	2 (1, 2)***	4 (4, 5)***	< 0.001
	Follow up	3 (3, 4)***	2 (1, 2)***	4 (4, 5)***▲	< 0.001
NPQ	Baseline	0.53 (0.31, 0.62)	0.52 (0.31, 0.60)	0.47 (0.32, 0.58)	0.963
	After treatment	0.31 (0.19, 0.35)**	0.19 (0.14, 0.30)**	0.36 (0.28, 0.45)**	< 0.001
	Follow up	0.31 (0.194, 0.36)**	0.19 (0.14, 0.23)**	0.36 (0.28, 0.45)**	< 0.001

$^{**}P < 0.01$ and $^{***}P < 0.001$, compared with baseline. $^{▲}P < 0.05$, compared with after treatment.

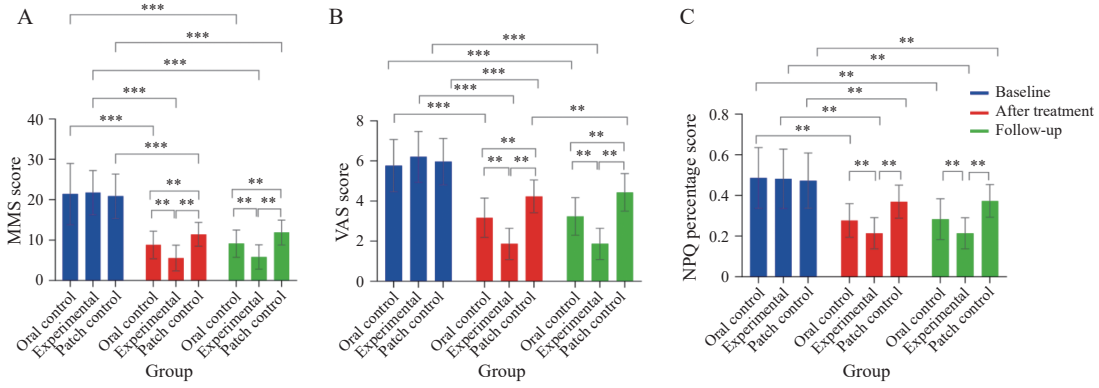

Figure 3 Within-group and between-group comparisons of MMS, VAS, and NPQ scores among the three groups

A, MMS score. B, VAS score. C, NPQ percentage score. $^{**}P < 0.01$ and $^{***}P < 0.001$.

Table 4 Within-group and between-group comparisons of inflammatory factors and oxidative stress markers at baseline and after treatment

Variable	Time point	Oral control group	Experimental group	Patch control group	Between-group *P* value
TNF-α	Baseline	30.89 ± 6.56	30.88 ± 6.20	30.63 ± 6.47	0.984
	After treatment	15.49 ± 2.89***	13.71 ± 2.48***	17.06 ± 3.23***	< 0.001
IL-6	Baseline	9.67 (8.59, 11.75)	9.96 (8.67, 11.80)	10.11 (8.99, 11.60)	0.889
	After treatment	6.72 (5.84, 7.31)***	6.00 (5.03, 7.39)***	6.90 (6.05, 8.06)***	< 0.001
IL-1β	Baseline	22.62 ± 3.09	22.26 ± 3.26	22.25 ± 3.34	0.879
	After treatment	11.82 ± 2.21***	8.80 ± 2.85***	11.27 ± 2.64***	< 0.001
SOD	Baseline	39.83 (36.85, 46.87)	39.28 (31.79, 45.53)	40.68 (34.87, 47.87)	0.718
	After treatment	54.64 (45.39, 68.63)***	67.59 (58.69, 75.98)***	53.42 (42.98, 68.29)***	< 0.001
MDA	Baseline	4.86 (4.54, 4.99)	4.83 (4.65, 5.05)	4.81 (4.56, 4.99)	0.765
	After treatment	3.49 (3.18, 3.69)***	3.09 (2.95, 3.41)***	4.32 (4.21, 4.65)**	< 0.001
GSH-Px	Baseline	3.12 (2.80, 3.66)	3.10 (2.69, 3.83)	3.13 (2.90, 3.62)	0.813
	After treatment	4.95 (4.55, 5.05)***	5.78 (4.79, 6.41)***	3.89 (3.29, 4.46)***	< 0.001

$^{*}P < 0.01$ and $^{**}P < 0.001$, compared with baseline.

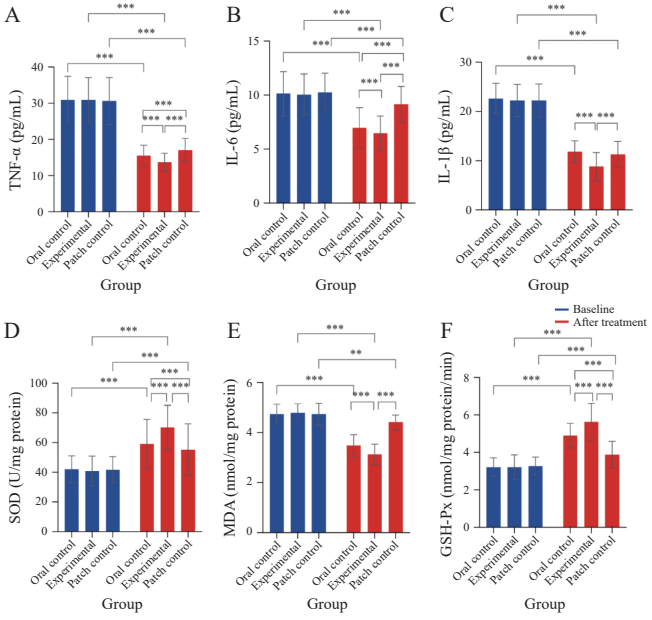

Figure 4 Within-group and between-group comparisons of inflammatory and oxidative stress markers among the three groups

A, TNF-α. B, IL-6. C, IL-1β. D, SOD. E, MDA. F, GSH-Px. $^{**}P < 0.01$ and $^{***}P < 0.001$.

3.3 Identification of blood-absorbed components of Manggari

Using UHPLC-QE-MS serum pharmacochemical analysis, a total of 4 917 metabolites were detected. Following 1 h of drug action, 318 serum components were extracted, of which 170 were identified as prototype components. Following 2 h of drug action, 265 serum components were extracted, of which 152 were identified as prototype components. Among these, based on the literature evidence [28] and verification through the MCE database, these active components include: 4-hydroxycoumarin, N-methylanthranilic acid, genistein, and ginsenoside-Rk1. At the same time, TNF-α and IL-1β were selected as the key therapeutic targets for CSR, and molecular docking verification was conducted subsequently (Figure 5).

3.4 Molecular docking validation

Molecular docking results showed that all tested compounds exhibited favorable binding affinity for both TNF-α and IL-1β, with binding energies below – 4.7 kcal/mol, indicating stable interactions between most active

Table 5 Comparison of clinical efficacy among the three groups

Group	Complete recovery	Marked improvement	Improvement	No response	Total effective rate (%)
Oral control	0	10	16	4	86.66
Experimental	0	16	12	2	93.33
Patch control	0	8	17	5	83.33

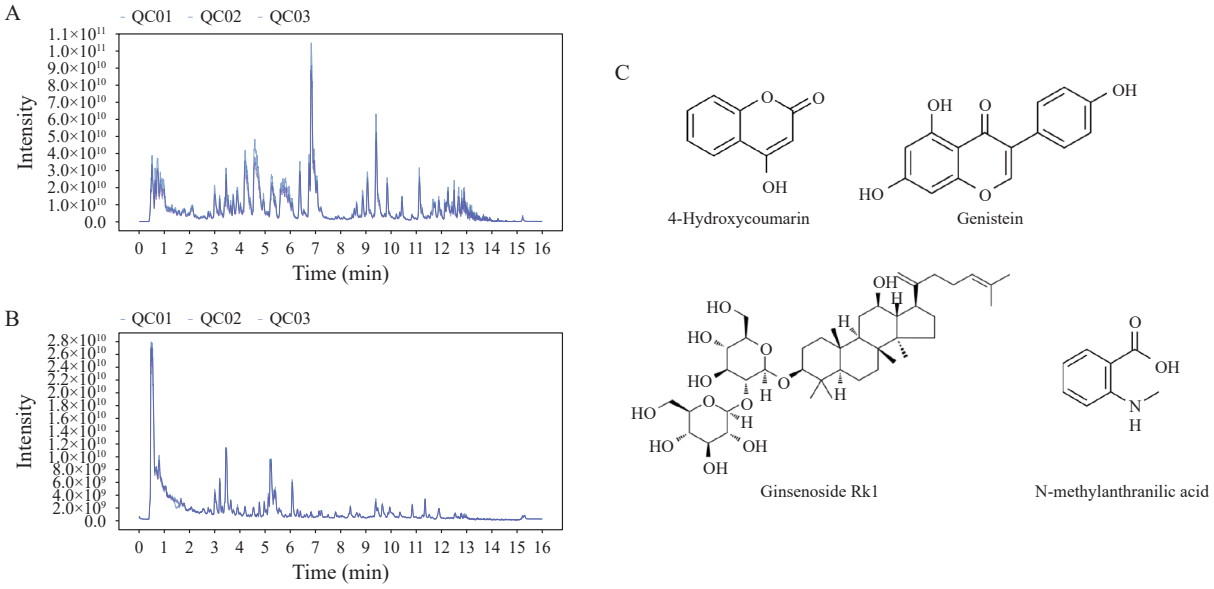

Figure 5 UHPLC-QE-MS analysis of the blood-absorbed components

A and B, total chemical composition fingerprint of Manggari in negative and positive ion electrospray ionization (ESI–) mode, respectively. C, chemical structures of the four identified small-molecule compounds with anti-inflammatory activity.

compounds and the target proteins. Among the compounds, ginsenoside-Rk1 showed the lowest binding energy with TNF-α, suggesting the strongest binding stability (Table 6 and Figure 6).

Table 6 Molecular docking binding energies of the main active compounds with core target proteins

Small molecule	PubChem ID	Binding energy (kcal/mol)	
		IL-1β	TNF-α
4-Hydroxycoumarin	54682930	– 5.7	– 5.6
N-methylanthranilic acid	67069	– 5.2	– 4.7
Genistein	5280961	– 7.1	– 6.5
Ginsenoside-Rk1	11499198	– 6.6	– 6.9

4 Discussion

Mongolian medicine is an essential element of traditional Chinese medicine culture. Several Mongolian medicine formulations have been identified in ethnomedical studies on cervical spondylosis and have been shown to positively affect the prognosis of patients with CSR [30-32]. The Manggari used in this study is an external formulation developed by Mongolian practitioners based on disease characteristics and core Mongolian medical principles, specifically targeting symptoms of "Baimai disease of the limbs". Our results demonstrated that patients receiving Manggari hot compress therapy showed considerable improvements in clinical symptoms, including neck pain, finger numbness, and limited mobility, compared with those receiving conventional treatment. Furthermore, the therapy reduced serum levels of pro-inflammatory factors, balanced oxidative and antioxidant levels, exhibited anti-inflammatory and antioxidant properties, and alleviated cervical radicular pain.

4.1 Clinical and tongue morphology effects of Manggari hot compress therapy in CSR

In Mongolian medicine, tongue morphology is highly sensitive and reflects subtle alterations in the body's three humors and internal organs. Tongue morphology diagnosis is therefore valuable for clinical assessment, differentiation, and evaluation of disease severity and prognosis in Mongolian medicine. Differences in tongue coating manifestations in CSR patients are often attributed to maladaptive lifestyle changes associated with chronic pain, such as irritability, anxiety, and insomnia. These factors may lead to dry and rough tongue coating, bright red coloration, central fissures, and involuntary tremors upon tongue extension—findings indicative of the "Excess of Hei" (vital energy) type in Mongolian medicine. In

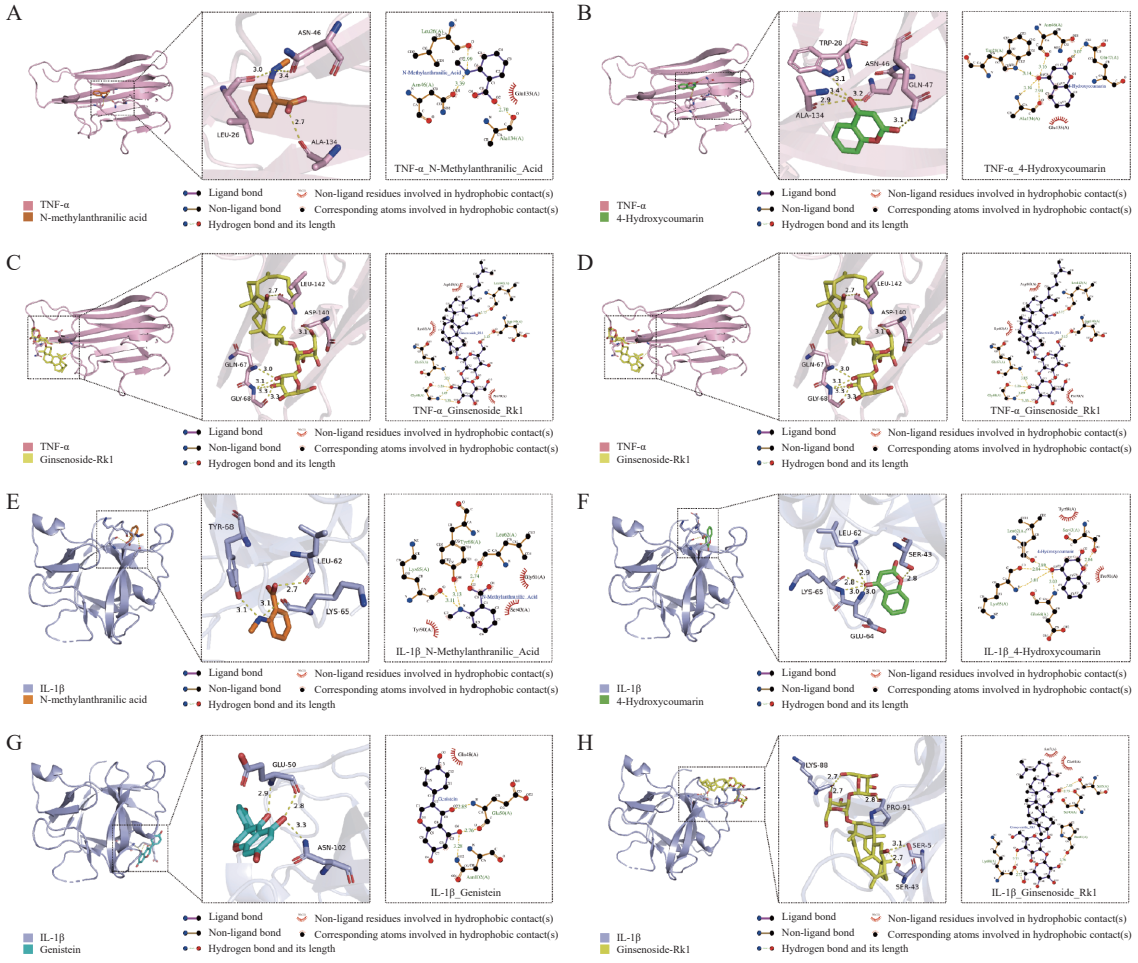

Figure 6 Molecular docking of the core active components with TNF-α and IL-1β

A, 4-hydroxycoumarin with TNF-α. B, genistein with TNF-α. C, ginsenoside-Rk1 with TNF-α. D, N-methylanthranilic acid with TNF-α. E, 4-hydroxycoumarin with IL-1β. F, genistein with IL-1β. G, ginsenoside-Rk1 with IL-1β. H, N-methylanthranilic acid with IL-1β.

this study, experienced Mongolian medicine practitioners evaluated and quantified differences in coating color, coating texture, and tongue color. The results showed that Manggari hot compress therapy significantly improved tongue morphology, particularly by promoting the restoration of a normal, thin, white coating in patients who initially presented with no coating or a reduced coating thickness. Manggari hot compress therapy promotes blood circulation, alleviates pain, regulates bodily functions, and mitigates clinical symptoms. In addition, neck pain was notably relieved, and the therapeutic effect was stable in the short term. A simple physical hot compress does not exert therapeutic effects on CSR, and no statistically significant difference was observed between the simple physical hot compress intervention and baseline in each group. In contrast, Manggari hot compress therapy has a positive effect on CSR treatment. Therefore, we propose that during Manggari hot compress therapy, the heat application serves as an adjunctive means of drug delivery, promoting the local action of the medicine. Collectively, these findings demonstrate the beneficial effects of Manggari hot compress therapy in treating CSR. Compared with conventional treatments, this therapy may avoid or reduce drug side effects, drug resistance, and postoperative adverse reactions.

4.2 The Manggari hot compress therapy reduces the expression of serum inflammatory factors

The clinical manifestations of CSR include pain patterns aligned with the distribution of the affected spinal nerve roots, predominantly presenting as pain, numbness, and sensory deficits. In severe cases, radicular weakness and muscular atrophy may occur. Following the onset of CSR, damaged tissues release inflammatory mediators that activate the nerve roots and elicit radicular pain [33]. This process simultaneously stimulates multiple cellular signaling pathways and receptor proteins, leading to the release of pro-inflammatory cytokines such as TNF-α, IL-6, and IL-1β, which facilitate inflammation [34]. Manggari hot compress therapy produces a thermal effect that promotes vasodilation and muscular relaxation, enhancing blood circulation, and relieves local muscle spasms. These effects complement the analgesic and anti-inflammatory properties of the Mongolian medicine

preparation, collectively alleviating radicular pain. The poultice used in this study contains processed Zhicaowu (Radix Aconiti Kusnezoffii Preparata) as its principal component. Aconite-derived drugs can be toxic when administered in large doses or without proper processing [35, 36]. However, the poultice employed here is a standardized finished pharmaceutical product in which the toxic diester alkaloids (aconitine) are converted into less toxic monoester alkaloids, significantly reducing toxicity. Moreover, the transdermal delivery route of Mongolian medicine hot compress therapy bypasses hepatic and renal first-pass metabolism and helps regulate blood levels of potentially hazardous constituents, thereby improving the safety profile of the formulation. Several other components of the formulation also exhibit anti-inflammatory and analgesic effects. In this study, serum levels of the pro-inflammatory cytokines TNF-α, IL-6, and IL-1β decreased after Manggari hot compress therapy. This finding indicates that the therapy may exert anti-inflammatory and analgesic benefits by inhibiting the release of pro-inflammatory mediators, thereby alleviating radicular pain associated with cervical spondylosis.

4.3 Effects of Manggari hot compress therapy on serum inflammatory factors

Inflammatory responses and oxidative stress play critical roles in the pathogenesis process of CSR. The condition is characterized by increased inflammatory reactions and mechanical compression, which can lead to excessive formation of oxygen-free radicals. During CSR, reduced SOD activity impairs the dismutation of superoxide anion into hydrogen peroxide and oxygen. Simultaneously, a marked reduction in the antioxidant GSH-Px compromises free-radical scavenging capacity [37]. Furthermore, levels of MDA, the end product of lipid peroxidation, are significantly elevated [38]. The increase in this marker, together with decreased SOD and GSH-Px levels, indicates exacerbated oxidative stress-induced damage to biological membrane lipids. The corresponding clinical manifestation is radicular pain in the cervical and shoulder regions resulting from nerve root involvement. In this study, Manggari hot compress therapy significantly diminished serum levels of the pro-inflammatory cytokines IL-6, IL-1β, and TNF-α in patients with CSR, while concurrently suppressing MDA activity, increasing GSH-Px activity, and SOD content. Comparative studies have shown that oxidative stress triggers inflammatory responses through the activation of inflammatory signaling pathways, resulting in overexpression of mediators such as TNF-α, IL-6, and IL-1β [39, 40]. These findings are consistent with our results. Serum pharmacochemical analysis identified 318 active constituents in the circulation. The small molecules 4-hydroxycoumarin, genistein, ginsenoside-Rk1, and N-methylanthranilic acid exhibited binding energies with the inflammation-related target proteins IL-1β and TNF-α below – 4.7 kcal/mol. Moreover, the binding energy of most ligand-target combinations is lower than – 5.0 kcal/mol, indicating strong binding affinity. The active ingredients identified through mouse serum pharmacochemistry were predicted via molecular docking to have favorable binding affinity for inflammatory targets such as TNF-α and IL-6. This in silico evidence, combined with the observed reduction of these cytokines in patient serum, suggests a plausible pharmacological pathway contributing to the clinical effects. However, this proposed mechanism requires direct validation in human biological samples and through *in vitro* or *in vivo* functional assays. Taken together, our findings demonstrate that Mongolian medicine hot compress therapy effectively suppresses MDA activity, enhances GSH-Px activity, increases SOD levels, and simultaneously reduces the levels of pro-inflammatory factors TNF-α, IL-6, and IL-1β. These anti-inflammatory and antioxidant actions contribute to the alleviation of radicular pain and support the therapeutic efficacy of Manggari hot compress therapy in CSR.

4.4 Limitations and future prospects

The study has several limitations, some of which are inherent to the clinical randomized controlled trial design. First, the inherent differences between the three interventions—oral medication (mecobalamin), Mongolian medicine hot compress (Manggari), and flurbiprofen gel plaster—made it impossible to blind the operators to the assigned treatments. Second, the perceived temperature differences between the two topical treatments (Manggari and flurbiprofen gel plaster) may have allowed patients to identify which treatment they were receiving, making complete blinding of participants difficult to achieve. Third, we were unable to completely prohibit patients from using additional medications during the follow-up period. Fourth, the assessment of Mongolian tongue morphology in this study relied on subjective visual observation. Future research would benefit from incorporating digital image analysis techniques—such as colorimetry and texture segmentation—to objectively quantify tongue features, including color and coating thickness. Finally, the serum pharmacochemical analysis in this study was conducted using a mouse model to preliminarily identify the prototype components of Manggari that can be absorbed into the systemic circulation. Although this provides initial evidence for potential bioactive constituents, it is important to note that metabolic profiles may differ between species. Future studies involving direct analysis of human serum are warranted to confirm the translational relevance of these findings.

5 Conclusion

Manggari hot compress therapy demonstrates remarkable clinical efficacy in treating CSR. It effectively alleviates CRS-related symptoms, including pain, restricted neck movement, and finger numbness, reduces VAS and NPQ scores, and significantly improves the quality of life of CSR patients in the short term, with sustained therapeutic effects. The therapy alleviates radicular pain in CSR patients by reducing serum levels of inflammatory factors (TNF-α, IL-6, and IL-1β), and restoring the balance between oxidation and antioxidation systems (inhibiting MDA activity, increasing SOD levels, and enhancing GSH-Px activity). Furthermore, the core compounds of Manggari exhibit strong binding affinity to CSR mechanism-related proteins. In this study, patients tolerated the therapy well, and no serious adverse events were observed, suggesting that this intervention is safe and feasible for clinical application in CSR. This distinctive therapy holds promising potential for further development and clinical application.

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Ethical statement

The clinical study protocol was reviewed and approved by the Ethics Committee of Xilinguole Meng Mongolian General Hospital (Approval No. YJ20240304), and written informed consent was obtained from all participants before enrollment. The study was registered with the International Traditional Medicine Clinical Trial Centre (Registration No. ITMCTR2025000413). The animal experimental protocol was reviewed and approved by the Animal Ethics Committee of Inner Mongolia Medical University (Approval No. YKD202002038), and all animal procedures were conducted in accordance with the approved protocol.

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Author contributions

Xiong Ling: visualization and writing – original draft. Sachula Baoyin: methodology, writing – original draft, and funding acquisition. Desi Aobi: investigation. Ha Ni: investigation. Zhiheng Dong: data curation. Lan Wu: conceptualization, and writing – review & editing. Bao Jin: methodology, and funding acquisition. Linbayaer Ji: conceptualization, and methodology. All authors approved the submission and take responsibility for this manuscript.

Competing interests

The authors declare no conflict of interest.

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(Editor-in-Charge Siyi Wei)

蒙药盲嘎日热敷疗法治疗神经根型颈椎病的临床疗效及药效物质基础：一项随机对照试验和血清药理化学研究

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【摘要】目的 本研究旨在系统评价蒙药盲嘎日外用敷剂热敷疗法（以下简称盲嘎日热敷疗法）治疗神经根型颈椎病（CSR）的临床疗效，并探索该方中可能的药效物质基础，为蒙医学在 CSR 治疗中的临床应用提供依据。**方法** 本临床试验采用随机对照、开放标签、结局评价盲法设计，选取 2024 年 7 月 1 日至 2025 年 10 月 31 日期间就诊于锡林郭勒盟蒙医医院传统疗术科门诊的 CSR 患者。患者随机分为 3 组：口服对照组（甲钴胺片联合颈椎电牵引）、试验组（盲嘎日外用热敷）和贴敷对照组（氟比洛芬凝胶贴敷），干预周期为两周。记录患者治疗前后蒙医证候（MMS）评分、视觉模拟评分法（VAS）评分、颈痛量表（NPQ）评分以及舌象；采用酶联免疫吸附试验（ELISA）检测患者治疗前后血清炎症指标 [肿瘤坏死因子（TNF）-α、白细胞介素（IL）-6、IL-1β] 及氧化应激指标 [丙二醛（MDA）含量、超氧化物歧化酶（SOD）活性、谷胱甘肽过氧化物酶（GSH-Px）活性]；最后对总体疗效进行评定。治疗结束 1 个月后随访，再次记录患者 MMS、VAS、NPQ 评分。在药效物质基础方面，采用超高效液相色谱-四极杆静电场轨道阱质谱（UH-PLC-QE-MS）技术，在正负离子模式下对盲嘎日的入血成分进行分析，并通过分子对接验证核心活性化合物与靶蛋白之间的靶向关系。**结果** 本研究最终纳入 90 例 CSR 患者，三组患者的基线资料无统计学差异（$P > 0.05$）。（1）症状评分：三组患者治疗后 MMS、VAS、NPQ 评分较基线均明显下降（$P < 0.001$）；随访时，试验组的 MMS、VAS、NPQ 评分与治疗结束时相比无显著差异（$P > 0.05$）。试验组较口服对照组和贴敷对照组在 MMS、VAS、NPQ 评分下降显著（$P < 0.001$），随访时差异仍显著（$P < 0.001$）。（2）炎症及氧化应激指标：三组患者治疗后血清中 TNF-α、IL-6、IL-1β 含量及 MDA 活性均较基线明显下降（$P < 0.05$），SOD 含量、GSH-Px 活性均较基线明显上升（$P < 0.05$）。治疗后试验组较口服对照组和贴敷对照组可显著降低 TNF-α、IL-6及 IL-1β 含量，同时降低 MDA 活性，升高 SOD 含量及 GSH-Px 活性（$P < 0.05$）。（3）总体疗效：试验组总有效率为 93.33%，口服对照组为 86.66%，贴敷对照组为 83.33%。（4）药效物质分析：盲嘎日的入血成分共筛选出 152 种化合物，其中核心化合物 4-羟基香豆素、N-甲基蒽酸、染料木素及人参皂苷-Rk1 与关键靶蛋白 TNF-α、IL-1β 之间的结合能范围为 –4.7 至– 7.1 kcal/mol，其中大多数结合能低于 – 5.0 kcal/mol，提示其总体具有较好的结合亲和力。**结论** 蒙医热敷疗法通过其热效应和活性药物成分盲嘎日的共同作用，有效调节炎症和氧化应激反应，抑制颈神经根炎症，缓解神经根性疼痛，从而在 CSR 中取得疗效，改善患者临床症状、疼痛程度及颈椎功能障碍。

【关键词】蒙医学；蒙医热敷疗法；盲嘎日；随机对照试验；循证医学；药效物质基础