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Original Article

Effect of interference electrotherapy combined with rotary traction manipulation on cervical function and recurrence in patients with cervical spondylotic radiculopathy

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Abstract: Objective: To evaluate the clinical efficacy of combining interference electrotherapy with rotary traction manipulation in treating cervical spondylotic radiculopathy (CSR), and to assess its impact on cervical function and prognosis. Methods: A retrospective analysis was conducted on the clinical data from 214 CSR patients who were treated at Yueyang Central Hospital, Hunan University of Chinese Medicine, from April 2021 to October 2023. The observation group (n=110) received combined therapy using interference electrotherapy and rotary traction manipulation, while the control group (n=104) received rotary traction manipulation alone. Before treatment, and at 2 and 4 weeks post-treatment, cervical function was assessed using the Neck Disability Index (NDI), and pain intensity was measured using components of the Simplified McGill Pain Questionnaire (SF-MPQ), including Visual Analog Scale (VAS), Present Pain Intensity (PPI), and Pain Rating Index (PRI). Clinical efficacy was evaluated using the modified Macnab criteria, and treatment safety was assessed. Both groups were followed up for one year to record recurrence rates. Logistic regression was used to identify risk factors for recurrence. Results: Baseline characteristics were similar between groups (P>0.05). After 2 and 4 weeks, the observation group showed significantly greater improvements in NDI, VAS, PRI, and PPI scores compared to the control group (P<0.001). The total effective rate was higher in the observation group (92.7%) than in the control group (80.8%) (P=0.017). However, the recurrence rate was significantly higher in the observation group (7.3%) compared to the control group (20.2%) (P=0.006). Logistic regression identified treatment regimen, patient age, and pillow height as independent risk factors for recurrence (P<0.05). A recurrence risk scoring model based on these factors achieved an AUC of 0.897 (95% CI: 0.844-0.951). Conclusion: Combining interference electrotherapy with rotary traction manipulation significantly improves cervical function and alleviates pain in CSR patients, yielding higher overall efficacy. However, this combination is associated with an increased risk of recurrence, influenced by treatment method, patient age, and pillow height.

Keywords: Interference electrotherapy, rotary traction manipulation, cervical spondylotic radiculopathy, cervical function, prognosis

Introduction

Cervical spondylosis is one of the most prevalent degenerative spinal diseases worldwide [1]. A 2018 global epidemiological survey ranked cervical spondylosis as the fourth leading cause of disability, following cardiovascular, cerebrovascular, and respiratory diseases, affecting over 300 million individuals with chronic neck pain lasting more than three months [2]. According to WHO data, cervical spondylosis is the second most common chronic disease globally, with peak incidence between the ages of 40 and 60, particularly in the fifth decade of life [3]. In China, the prevalence ranges from 3.8% to 17.6%, with an increasing trend, affecting younger populations [4]. Cervical spondylotic radiculopathy (CSR) accounts for approxi-

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mately 60% of cervical spondylosis cases, making it the most common subtype. CSR significantly impairs patients' quality of life and work efficiency [5].

CSR primarily results from degenerative changes in intervertebral discs, ligament calcification, and bone hyperplasia, leading to compression or irritation of nerve roots. Additionally, inflammatory factors released from intervertebral discs may cause nerve dysfunction [6]. Clinically, CSR presents neck and shoulder pain, upper limb numbness, reduced muscle strength, and limited neck mobility. An aging population and modern lifestyle factors - such as prolonged desk work, excessive use of electronic devices, poor posture, and lack of exercise - contribute to the increasing incidence of CSR [7]. While most patients experience symptom relief through conservative treatments, recurrence rates remain high, and some cases may worsen, necessitating surgical intervention [8]. However, surgery carries high risks, costs, and uncertainties, making it suitable only for patients with severe, refractory symptoms, or significant radiological damage. Studies suggest that conservative treatments should be the first-line approach for CSR, with symptom improvement or recovery rates of 90%-95% [9].

Current conservative treatments for CSR include medication, cervical traction, acupuncture, manual therapy, and physical therapy [10]. Cervical traction effectively decompresses nerve roots, increases intervertebral space, and improves cervical curvature, yielding satisfactory outcomes [11]. Interference electrotherapy, a common physical therapy modality, delivers low-frequency modulated currents through medium-frequency currents in tissues, relieving pain, enhancing local blood circulation, and promoting tissue repair [12]. Rotary traction manipulation, a traditional manual therapy technique, adjusts cervical spine structures through traction and rotation, alleviating nerve root compression, restoring cervical lordosis, and mitigating clinical symptoms [13]. However, single therapies offer limited functional improvement and pain relief, with unresolved risks of recurrence. Recently, the combined use of interference electrotherapy and manual therapy has gained attention, yet clinical evidence remains insufficient, particularly regarding its effect on reducing recurrence risk. Moreover, risk factors for recurrence are not well defined. Accurately predicting recurrence risk using scientific methods and implementing targeted interventions remain significant challenges in clinical practice.

This study aims to evaluate the clinical efficacy of combining interference electrotherapy with rotary traction manipulation in treating CSR and to analyze its impact on cervical function and recurrence rates. By comparing outcomes between the combined treatment group and the single treatment group in terms of cervical function, pain relief, and clinical efficacy, the advantages of combined therapy will be further assessed. Additionally, this study will utilize logistic regression analysis to identify major risk factors influencing patient recurrence.

Materials and methods

Sample size calculation

The sample size for this study was determined based on the findings of Xie et al. [14], who reported a recurrence rate of 17.8% in patients with CSR. Utilizing the formula $NN = Z^2 [P (1-P)]/E^2$, where Z is the standard normal quantile at a 95% confidence level (1.96), PPP is the estimated recurrence rate (0.178), and E is the allowable margin of error (0.05), the required sample size was calculated to be approximately 225 cases (224.768 rounded up). This sample size ensures statistical significance at a 95% CI, though the actual number of participants was subject to clinical data availability.

Study design

This retrospective study included 214 patients diagnosed with CSR who received treatment at Yueyang Central Hospital between April 2021 and October 2023. Participants were divided into two groups based on their treatment regimen: the observation group (n=110) received a combination of interference electrotherapy and rotary traction manipulation, while the control group (n=104) underwent rotary traction manipulation alone. The study was approved by the Yueyang Central Hospital Ethics Committee.

Inclusion and exclusion criteria

Inclusion Criteria: (1) Diagnosis of CSR based on established criteria [15]. (2) Presence of neck and shoulder pain, radiating upper limb

pain, or numbness. (3) Imaging evidence of disc herniation, bone hyperplasia, or nerve root compression. (4) Age between 18-75 years. (5) Symptoms persisting for ≥4 weeks without prior interventions. (6) Compliance with treatment and follow-up protocols. (7) Complete clinical and functional scoring records.

Exclusion Criteria: (1) Other types of cervical spondylosis (e.g., myelopathy, sympathetic, or mixed types). (2) History of cervical surgery or treatments such as acupuncture or massage. (3) Severe cardiovascular, neurological, or malignant diseases. (4) Pregnant or breastfeeding women. (5) Acute cervical trauma or fracture-related pain.

Treatment protocol

Control group (rotary traction manipulation): (1) Patients were positioned supine with their neck relaxed. (2) Practitioners performed manipulation techniques, including kneading and stretching cervical muscles, side-bending toward the healthy side, and rotational traction at 45° on the affected segment. (3) The manipulation involved flexion, extension, and lateral bending movements to decompress the nerve root and restore cervical alignment.

Observation group (interference electrotherapy + rotary traction manipulation): (1) In addition to the rotary traction manipulation described above, patients received dynamic interference electrotherapy using YSG02C-V dynamic interferential therapy device (Henan Xiangyu Medical Equipment Co., Ltd., License No. 20150020). (2) Four adhesive electrodes (two red, two white) were cross-placed over the most painful region. (3) Treatment parameters were set at a frequency of 4000 Hz (±100 Hz), a beat frequency of 0-100 Hz, and a current intensity of 0.5-2 mA. (4) Each session lasted 30 minutes and was administered twice daily.

Treatment duration: Both groups underwent continuous treatment for 2 weeks, with 5 sessions per week.

Clinical data collection

Clinical data were obtained from electronic medical records and follow-up records. Baseline data included age, sex, body mass index (BMI), disease duration, educational level, history of cervical trauma, sleep duration, pillow height, and frequency of physical exercise. Disease-related metrics included baseline cervical function (NDI score), pain intensity (VAS score), pain rating (PRI score), and present pain intensity (PPI score). Follow-up assessments at post-treatment 2 weeks, 4 weeks, and 1 year evaluated functional recovery, pain relief, clinical efficacy, and recurrence.

Functional scoring

1. NDI Score: Assesses cervical functional disability (range: 0-50), with higher scores indicating greater impairment [16]. 2. VAS Score: Measures pain intensity (range: 0-10), with higher scores indicating greater pain [17]. 3. PRI Score: Evaluates the nature, location, and severity of pain (range: 0-45), with higher scores indicating more severe and diverse pain [18]. 4. PPI Score: Assesses current pain intensity (range: 0-5), with higher scores indicating greater pain severity [19].

Efficacy assessment

Clinical efficacy was evaluated using criteria adapted from the *Criteria of Diagnosis and Therapeutic Effects of Diseases and Syndromes in Traditional Chinese Medicine* [20]. Categories included: (1) Clinical Recovery: Complete disappearance of dysfunction and symptoms, with normal cervical mobility. (2) Markedly Effective: Substantial disappearance of dysfunction and symptoms, with normal cervical mobility. (3) Effective: Partial disappearance of dysfunction and symptoms, with cervical and shoulder mobility essentially restored to normal, and minimal impact on daily life and work. (4) Ineffective: No improvement in dysfunction or symptoms, limited cervical mobility, a positive brachial plexus traction test, and inability to perform normal daily activities and work.

The total effective rate was calculated as the sum of the clinical recovery, markedly effective, and effective rates [14].

Follow-up

Follow-up data were collected via phone calls and clinical visits to ensure completeness. Recurrence was defined as the reappearance

or worsening of symptoms (e.g., neck or shoulder pain, numbness, restricted mobility) during the follow-up period, significantly impacting daily life or work. Recurrence was determined based on: 1. Patient-reported reappearance or significant worsening of pain, numbness, or functional impairment affecting daily activities. 2. Recurrence of objective signs, such as a positive brachial plexus traction test or decreased muscle strength. 3. Comprehensive clinical assessment confirming recurrence based on patient-reported symptoms, physical examination findings, and medical history review. This combined approach ensured a robust and clinically meaningful evaluation of recurrence.

Observation indicators

Primary indicators: Improvements in NDI, VAS, PRI, and PPI scores; clinical efficacy (cure rate, effective rate, inefficacy rate, and total effective rate); recurrence rate evaluation.

Secondary indicators: Adverse reactions (e.g., skin irritation, dizziness, muscle soreness, numbness); analysis of recurrence risk factors (treatment protocol, age, pillow height).

Statistical analysis

Statistical analyses were performed using SPSS 25.0. Data normality was assessed using the Kolmogorov-Smirnov test (D). Normally distributed data were expressed as mean ± standard deviation (Mean ± SD) and analyzed using independent sample t-tests (t) or paired t-tests (t). Non-normally distributed data were expressed as medians (IQR) and analyzed using Mann-Whitney U tests (U). Categorical variables were compared using chi-square tests (χ^2) or Fisher's exact tests where appropriate. For repeated measurements, repeated measures analysis of variance (RM-ANOVA) was applied to evaluate changes over time within and between groups. When significant differences were detected, post hoc Bonferroni tests were used for pairwise comparisons. Multivariate analysis was conducted using logistic regression, and odds ratios (OR) with 95% confidence intervals (CI) were calculated. The predictive efficacy of the recurrence risk scoring model was assessed using receiver operating characteristic (ROC) curves and area under the curve (AUC) values. A p-value of <0.05 was considered statistically significant.

Results

Comparison of baseline data between the two groups

Baseline characteristics between the two groups showed no statistically significant differences, including age distribution (P=0.716), sex ratio (P=0.716), BMI classification (P=0.651), disease duration (P=0.388), education level (P=0.251), history of cervical trauma (P=0.441), sleep duration (P=0.467), pillow height (P=0.941), desk work duration (P=0.853), exercise frequency (P=0.436), hypertension (P=0.713), diabetes (P=0.514), and hyperlipidemia (P=0.473). Detailed information is presented in **Table 1**.

Changes in NDI scores before and after treatment

Pre-treatment NDI scores showed no significant difference between the two groups (P=0.422). After 2 weeks of treatment, both groups exhibited a significant decrease in NDI scores, with the observation group demonstrating a significantly greater reduction than the control group (P<0.001). At 4 weeks, NDI scores further decreased, and the observation group continued to show superior improvement compared to the control group (P<0.001). Compared to pre-treatment scores, both groups showed significant improvement 2 weeks and 4 weeks after treatment (P<0.05), with scores at 4 weeks being significantly lower than at 2 weeks (P<0.05). Detailed results are shown in **Table 2**.

Changes in simplified McGill pain questionnaire scores

Pre-treatment VAS, PRI, and PPI scores showed no significant differences between the two groups (P>0.05). After 2 weeks of treatment, both groups exhibited significant reductions in VAS, PRI, and PPI scores (P<0.001), with the observation group showing significantly greater improvements (P<0.001). At 4 weeks, scores further improved, with the observation group demonstrating superior improvement compared to the control group (P<0.05). Both groups showed significant reductions in VAS, PRI, and PPI scores at 2 weeks and 4 weeks

Table 1. Comparison of baseline characteristics between the two groups

Factors	Control Group (n=104)	Observation Group (n=110)	Statistic	*P*-value
Age				
≥50	57 (54.81%)	63 (57.27%)	0.132	0.716
<50	47 (45.19%)	47 (42.73%)		
Gender			0.132	0.716
Male	47 (45.19%)	47 (42.73%)		
Female	57 (54.81%)	63 (57.27%)		
BMI			0.857	0.651
18-21.9	24 (23.08%)	20 (18.18%)		
22-24.9	59 (56.73%)	68 (61.82%)		
≥25	21 (20.19%)	22 (20%)		
Disease duration			0.744	0.388
≥6 months	44 (42.31%)	53 (48.18%)		
<6 months	60 (57.69%)	57 (51.82%)		
Education level			2.766	0.251
≤ Junior high school	26 (25%)	32 (29.09%)		
High school	56 (53.85%)	64 (58.18%)		
≥ College	22 (21.15%)	14 (12.73%)		
History of neck trauma			0.593	0.441
Yes	29 (27.88%)	36 (32.73%)		
No	75 (72.12%)	74 (67.27%)		
Sleep duration			0.53	0.467
≥8 h	66 (63.46%)	75 (68.18%)		
<8 h	38 (36.54%)	35 (31.82%)		
Pillow height (cm)			0.122	0.941
0-4.9	36 (34.62%)	39 (35.45%)		
5-9.9	43 (41.35%)	43 (39.09%)		
≥10	25 (24.04%)	28 (25.45%)		
Desk work duration (h/day)			0.317	0.853
0-3.9	28 (26.92%)	32 (29.09%)		
4-7.9	56 (53.85%)	55 (50%)		
≥8	20 (19.23%)	23 (20.91%)		
Physical exercise frequency (times/week)			0.608	0.436
≥3	55 (52.88%)	64 (58.18%)		
<3	49 (47.12%)	46 (41.82%)		
History of hypertension			0.136	0.713
Yes	19 (18.27%)	18 (16.36%)		
No	85 (81.73%)	92 (83.64%)		
History of diabetes			0.425	0.514
Yes	12 (11.54%)	16 (14.55%)		
No	92 (88.46%)	94 (85.45%)		
History of hyperlipidemia			0.515	0.473
Yes	23 (22.12%)	20 (18.18%)		
No	81 (77.88%)	90 (81.82%)		

Note: BMI, Body Mass Index.

compared to pre-treatment scores (P<0.05), with scores at 4 weeks being significantly lower than at 2 weeks (P<0.05). Detailed results are presented in **Tables 3**-**5**.

Table 2. Comparison of NDI scores between the two groups before and after treatment

Variable	Total Score	Observation Group (n=110)	Control Group (n=104)	Statistic	*P*-value
Pre-treatment NDI Score	45.91±14.99	45.11±14.96	46.76±15.04	0.804	0.422
2-week NDI Score	26.00 [18.00, 33.75]	20.50±10.57*	33.56±13.82*	7.734	<0.001
4-week NDI Score	14.00 [9.00, 20.00]	11.00±5.66*,#	19.25±9.80*,#	7.487	<0.001
F value		115.077	278.27		
P value		<0.001	<0.001		

Note: *P<0.05, compared with pre-treatment; #P<0.05, compared with 2 weeks post-treatment; NDI, Neck Disability Index.

Table 3. Comparison of VAS scores between the two groups before and after treatment

Variable	Total Score	Observation Group (n=110)	Control Group (n=104)	Statistic	*P*-value
Pre-treatment VAS	5.00 [5.00, 6.00]	5.00 [5.00, 6.00]	5.50 [4.00, 6.00]	0.014	0.989
2-week VAS	3.00 [2.00, 4.00]	3.00 [2.00, 3.00]*	4.00 [3.00, 4.00]*	6.311	<0.001
4-week VAS	2.00 [1.00, 2.00]	2.00 [1.00, 2.00]*,#	2.00 [1.00, 3.00]*,#	3.121	0.001
F value		217.76	333.192		
P value		<0.001	<0.001		

Note: *P<0.05, compared with pre-treatment; #P<0.05, compared with 2 weeks post-treatment; VAS, Visual Analog Scale.

Table 4. Comparison of PRI scores between the two groups before and after treatment

Variable	Total Score	Observation Group (n=110)	Control Group (n=104)	Statistic	*P*-value
Pre-treatment PRI Score	16.00 [14.00, 18.00]	16.08±3.07	16.11±3.02	0.058	0.954
2-week PRI Score	9.00 [7.00, 11.00]	8.00 [7.00, 10.00]*	10.05±3.54*	3.325	<0.001
4-week PRI Score	4.00 [3.00, 6.00]	4.00 [2.00, 5.00]*,#	5.25±2.37*,#	4.371	<0.001
F value		338.195	626.394		
P value		<0.001	<0.001		

Note: *P<0.05, compared with pre-treatment; #P<0.05, compared with 2 weeks post-treatment; PRI, Pain Rating Index.

Table 5. Comparison of PPI scores between the two groups before and after treatment

Variable	Total Score	Observation Group (n=110)	Control Group (n=104)	Statistic	*P*-value
Pre-treatment PPI	3.00 [2.00, 4.00]	3.00 [2.00, 4.00]	3.00 [2.00, 3.00]	-1.702	0.072
2-week PPI	2.00 [1.00, 2.00]	1.00 [1.00, 2.00]*	2.00 [2.00, 3.00]*	6.799	<0.001
4-week PPI	1.00 [1.00, 2.00]	1.00 [1.00, 2.00]*,#	1.00 [1.00, 2.00]*,#	2.18	0.016
F value		84.479	191.161		
P value		<0.001	<0.001		

Note: *P<0.05, compared with pre-treatment; #P<0.05, compared with 2 weeks post-treatment; PPI, Present Pain Intensity.

Clinical efficacy evaluation

Clinical efficacy evaluation showed differences in therapeutic outcomes between the two groups. The cure rate in the research group was 51.8%, significantly higher than 36.5% in the control group (P=0.035). However, there was no significant difference in the Significant Effect rate between the two groups (P=0.186), while the control group had significantly higher effective rate as well as ineffective rate than the research group (23.1% vs. 10.9%, P=0.028; 19.2% vs. 7.3%, P=0.017). Notably, the total effective rate in the research group (92.7%) was significantly higher than in the control group (80.8%) (P=0.017). Detailed outcomes are illustrated in **Figure 1**.

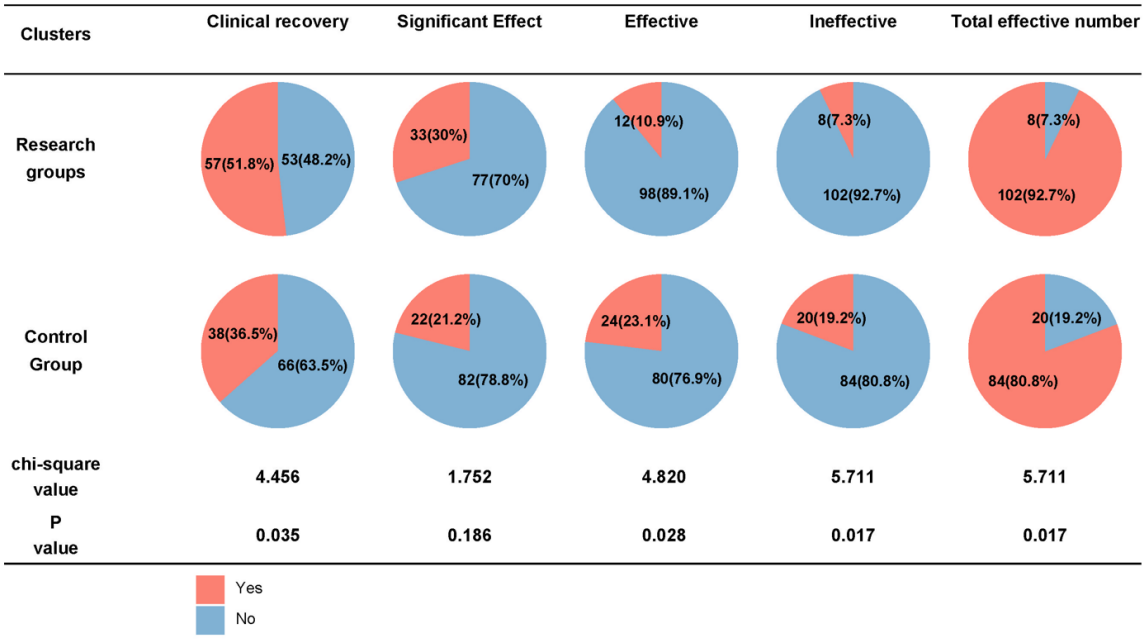

Figure 1. Clinical efficacy evaluation. This figure presents the clinical efficacy outcomes for the observation and control groups, including clinical cure, marked efficacy, effectiveness, non-effectiveness, and total effective rate.

Adverse reactions

The occurrence of adverse reactions, including skin irritation, dizziness, muscle soreness, and localized numbness, showed no statistically significant differences between the two groups (P>0.05). Specifically, skin irritation occurred in 8.2% of the observation group versus 2.9% of the control group; dizziness occurred in 9.1% versus 6.7%; muscle soreness occurred in 7.3% versus 4.8%; and localized numbness occurred in 3.6% versus 5.8%. Detailed information is shown in **Figure 2**.

Comparison of recurrence and risk factor analysis

Comparison of baseline data between the recurrence and non-recurrence groups revealed significant differences in treatment regimen, age, history of neck trauma, and pillow height. Specifically: (1) Treatment Regimen: The recurrence rate in the observation group was significantly lower than in the control group (7.3% vs. 20.2%, P=0.006). (2) Age: Patients aged ≥50 years had a significantly higher recurrence rate compared to those <50 years (19.2% vs. 6.4%, P=0.007). (3) Neck Trauma: Patients with a history of neck trauma had a higher recurrence rate than those without (23.1% vs. 9.4%, P=0.007). (4) Pillow Height: Patients using pillows ≥10 cm exhibited a markedly higher recurrence rate compared to those using lower pillows (41.5% vs. 0%-8.1%, P<0.001).

Other variables, including gender, BMI, disease duration, sleep duration, frequency of physical exercise, and underlying conditions (hypertension, diabetes, hyperlipidemia), showed no statistically significant differences between the two groups (P>0.05). Detailed results are presented in **Table 6**.

Logistic regression analysis identified treatment regimen, age, and pillow height as independent risk factors for recurrence: (1) Treatment Regimen: Patients in the observation group had a significantly lower recurrence risk than those in the control group (OR= 0.139, P=0.001, 95% CI: 0.042-0.404), indicating that combination therapy effectively reduces recurrence risk. (2) Age: Patients aged ≥50 years were at a significantly higher risk of recurrence compared to those <50 years (OR=0.300, P=0.038, 95% CI: 0.088-0.888), suggesting that age is a critical influencing factor. (3) Pillow Height: Patients using pillows ≥10 cm had a significantly higher recurrence risk compared to those using lower pillows (OR=11.084, P<0.001, 95% CI: 4.762-31.151), highlighting high pillows as a primary risk factor

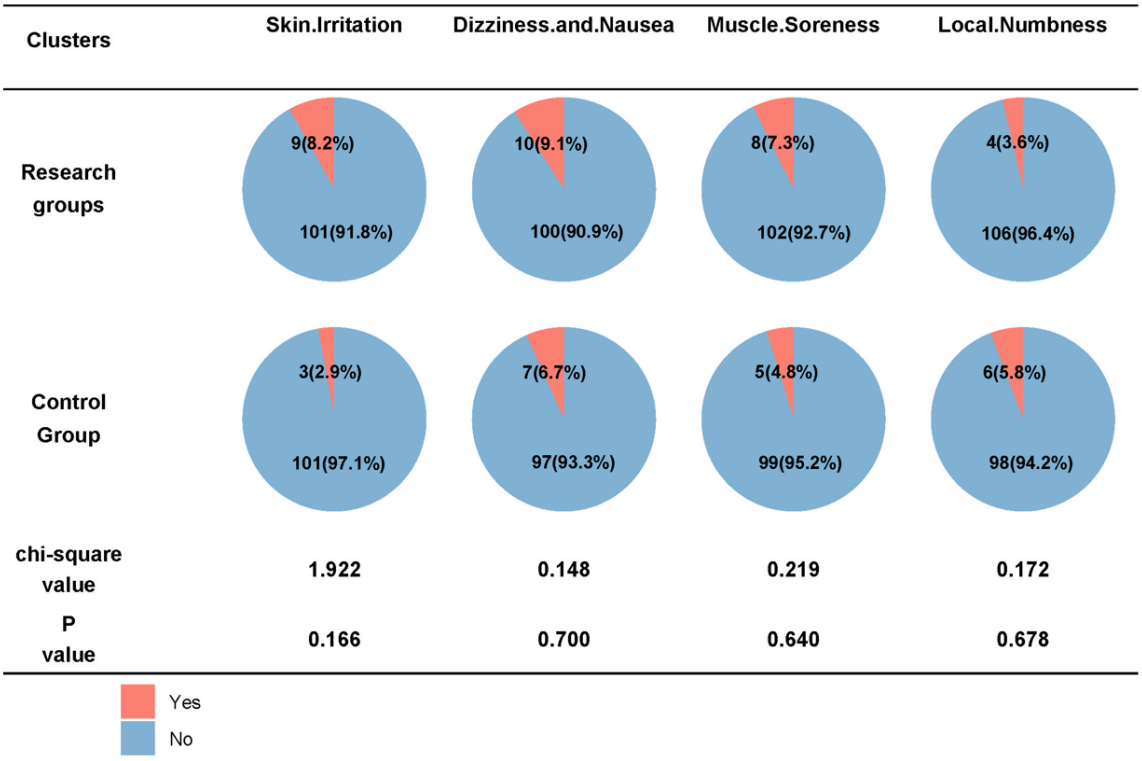

Figure 2. Adverse reactions statistics. This figure shows the incidence of adverse reactions in both groups, including skin irritation, dizziness and nausea, muscle soreness, and local numbness.

Table 6. Comparison of baseline data and pre-treatment function scores between recurrence and non-recurrence patients

Variable	Total	Non-recurrent (n=184)	Recurrent (n=30)	χ^2/t/Z value	*P*-value
Treatment regimen				7.617	0.006
Control Group	104 (48.6%)	83 (44.86%)	21 (72.41%)		
Observation Group	110 (51.4%)	102 (55.14%)	8 (27.59%)		
Age				7.353	0.007
≥50	120 (56.07%)	97 (52.43%)	23 (79.31%)		
<50	94 (43.93%)	88 (47.57%)	6 (20.69%)		
Gender				1.723	0.189
Male	94 (43.93%)	78 (42.16%)	16 (55.17%)		
Female	120 (56.07%)	107 (57.84%)	13 (44.83%)		
BMI				0.009	0.995
18-21.9	44 (20.56%)	38 (20.54%)	6 (20.69%)		
22-24.9	127 (59.35%)	110 (59.46%)	17 (58.62%)		
≥25	43 (20.09%)	37 (20%)	6 (20.69%)		
Disease duration				0.740	0.390
≥6 months	97 (45.33%)	86 (46.49%)	11 (37.93%)		
<6 months	117 (54.67%)	99 (53.51%)	18 (62.07%)		
Education level				0.853	0.653
≤ Junior high school	58 (27.1%)	49 (26.49%)	9 (31.03%)		
High school	120 (56.07%)	106 (57.3%)	14 (48.28%)		
≥ College	36 (16.82%)	30 (16.22%)	6 (20.69%)		

Neck trauma				7.231	0.007
Yes	65 (30.37%)	50 (27.03%)	15 (51.72%)		
No	149 (69.63%)	135 (72.97%)	14 (48.28%)		
Sleep duration				0.788	0.375
≥8 h	141 (65.89%)	124 (67.03%)	17 (58.62%)		
<8 h	73 (34.11%)	61 (32.97%)	12 (41.38%)		
Pillow height (cm)				49.27	<0.001
0-4.9	75 (35.05%)	75 (40.54%)	0 (0%)		
5-9.9	86 (40.19%)	79 (42.7%)	7 (24.14%)		
≥10	53 (24.77%)	31 (16.76%)	22 (75.86%)		
Desk work duration (h/day)				4.423	0.110
0-3.9	60 (28.04%)	54 (29.19%)	6 (20.69%)		
4-7.9	111 (51.87%)	98 (52.97%)	13 (44.83%)		
≥8	43 (20.09%)	33 (17.84%)	10 (34.48%)		
Physical exercise frequency (times/week)				0.123	0.725
≥3	119 (55.61%)	102 (55.14%)	17 (58.62%)		
<3	95 (44.39%)	83 (44.86%)	12 (41.38%)		
History of hypertension				1.1	0.294
Yes	37 (17.29%)	30 (16.22%)	7 (24.14%)		
No	177 (82.71%)	155 (83.78%)	22 (75.86%)		
History of diabetes				0.221	0.638
Yes	28 (13.08%)	25 (13.51%)	3 (10.34%)		
No	186 (86.92%)	160 (86.49%)	26 (89.66%)		
History of hyperlipidemia				0.007	0.931
Yes	43 (20.09%)	37 (20%)	6 (20.69%)		
No	171 (79.91%)	148 (80%)	23 (79.31%)		
Pre-treatment NDI	45.911±14.988	46.326±15.057	43.367±14.545	1.003	0.317
Pre-treatment VAS	5.00, 5.00, 6.00, 5.00, 6.00, 5.00, 6.00	5.00, 5.00, 6.00, 5.00, 6.00, 5.00, 6.00	5.00, 4.00, 7.00, 4.00, 7.00, 4.00, 7.00	0.762	0.446
Pre-treatment PRI	16.00, 14.00, 18.00, 14.00, 18.00, 14.00, 18.00	16.00, 14.00, 18.00, 14.00, 18.00, 14.00, 18.00	15.00, 13.00, 17.75, 13.00, 17.75, 13.00, 17.75	1.462	0.144
Pre-treatment PPI	3.00, 2.00, 4.00, 2.00, 4.00, 2.00, 4.00	3.00, 2.00, 4.00, 2.00, 4.00, 2.00, 4.00	3.00, 2.00, 3.00, 2.00, 3.00, 2.00, 3.00	0.823	0.411

Note: NDI, Neck Disability Index; VAS, Visual Analog Scale; PRI, Pain Rating Index; PPI, Present Pain Intensity.

Table 7. Logistic regression analysis of recurrence risk factors

Variable	Estimate	SE	*P* Value	OR Value	Lower	Upper
Treatment regimen	-1.971	0.575	0.001	0.139	0.042	0.404
Age	-1.205	0.581	0.038	0.300	0.088	0.888
Neck trauma	-0.904	0.528	0.087	0.405	0.140	1.130
Pillow height	2.406	0.475	<0.001	11.084	4.762	31.151
Intercept	-1.641	1.82	0.367	0.194	0.005	6.244

Note: SE, Standard Error; OR, Odds Ratio.

for recurrence. Detailed regression results are shown in **Table 7**.

Recurrence risk prediction and model validation

Based on logistic regression results, the recurrence risk scoring formula was constructed as: Risk =-1.971 × Treatment Protocol - 1.205 × Age + 2.406 × Pillow Height - 1.641.

The recurrence group had significantly higher risk scores than the non-recurrence group (P<0.001, **Figure 3A**). ROC curve analysis demonstrated that the recurrence risk scoring model had high predictive accuracy, with an

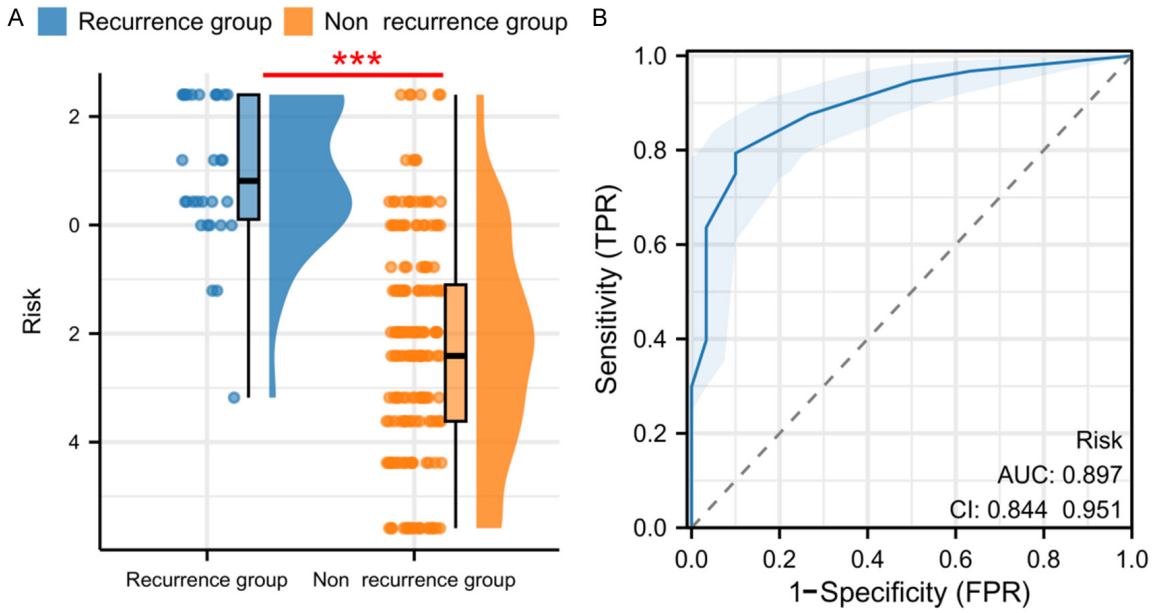

Figure 3. Expression and predictive value of recurrence scores. A. Comparison of recurrence risk scores between the two patient groups. B. ROC curve analysis for the predictive performance of the recurrence risk scoring model. Note: ROC, receiver operating characteristic curve, ***P<0.001.

AUC of 0.897 (95% CI: 0.844-0.951), indicating excellent discriminative ability (**Figure 3B**).

Discussion

This study offers valuable insights for optimizing conservative treatment strategies for CSR by retrospectively comparing the clinical efficacy and recurrence rates of interference electrotherapy combined with rotary traction manipulation versus rotary traction alone. The findings indicate that the combination therapy significantly enhances cervical function and alleviates pain symptoms in the short term, resulting in a higher total effective rate. However, long-term recurrence is influenced by multiple factors, including age, treatment approach, and pillow height. By developing and validating a recurrence risk model, this study provides clinicians with scientific evidence to support individualized treatment plans and preventive interventions.

CSR is one of the most prevalent types of cervical spondylosis, with rising incidence and disability rates linked to an aging population and lifestyle changes such as prolonged desk work and excessive use of electronic devices [21]. Conservative treatment remains the cornerstone of CSR management due to its low risk and cost-effectiveness, making it the first-line approach for most patients [5]. Manual traction and physical therapy are widely employed to improve cervical biomechanics, relieve nerve root compression, and alleviate clinical symptoms. However, single-modality therapies may have limited efficacy in enhancing function and reducing pain, and long-term outcomes, including recurrence [22]. This study explored the combined application of interference electrotherapy and rotary traction manipulation to enhance conservative treatment outcomes.

The study was designed as a retrospective analysis of CSR patients treated at a single hospital over two years. Although retrospective studies have inherent limitations in establishing causality and may introduce biases related to data completeness and selection, the use of rigorous inclusion and exclusion criteria, comprehensive medical records, and thorough follow-up data helped minimize these biases. Both groups had comparable baseline characteristics, ensuring a balanced foundation for evaluating treatment effects. Rotary traction, used in the control group, provided a robust baseline, while the observation group received additional interference electrotherapy, allowing for the specific assessment of the benefits of interference electrotherapy [12].

Evaluation metrics in this study included multidimensional tools such as the NDI, VAS, PRI, and PPI. These scales are highly sensitive and reliable for assessing cervical function and pain. NDI comprehensively reflects functional disability in daily activities, while VAS, PRI, and PPI quantify pain intensity, nature, and scope from different perspectives. Additionally, the modified Macnab criteria offered a comprehensive evaluation of clinical efficacy. Short-term follow-ups at 2 and 4 weeks captured immediate treatment effects, while the 1-year follow-up enabled the analysis of recurrence and long-term outcomes.

The results demonstrated that the combined treatment significantly outperformed rotary traction alone in improving cervical function and reducing pain in the short term. The observation group showed significantly greater improvements in NDI, VAS, PRI, and PPI scores at both 2 and 4 weeks after treatment, indicating that interference electrotherapy accelerates pain relief and functional recovery. This may be attributed to interference electrotherapy's ability to generate low-frequency modulated currents in tissues through medium-frequency currents, which help relax muscles, promote blood circulation, and reduce inflammatory factors, thereby alleviating pain and functional impairment caused by nerve root compression. Supporting this, Yan Li et al. [23] found that precise acupuncture targeting axillary nerves rapidly alleviated shoulder and neck dysfunction, suggesting that targeted interventions may enhance early pain relief and functional recovery. Similarly, Juan Yang et al. [24] emphasized that treatments enhancing local circulation, such as Huangqi-based acupuncture for elderly CSR patients, demonstrate effective mechanisms. These findings suggest that diversified and precise interventions could form an effective integrated treatment strategy for CSR.

Beyond confirming the short-term benefits of interference electrotherapy, this study identified key factors influencing mid-to-long-term recurrence, including age, treatment approach, and pillow height. Aging (≥50 years) is associated with accelerated degeneration of intervertebral discs and ligaments, bone loss, and muscle weakness, which reduce cervical spine stability and tolerance to rehabilitation or reinjury [25]. The treatment protocol, as a modifiable clinical factor, showed that multimodal interventions (e.g., interference electrotherapy combined with manual therapy) can stabilize local biomechanics, alleviate nerve root pressure, and reduce recurrence rates. In contrast, single or incomplete treatments may not sustain their therapeutic effects. Pillow height also plays a critical role; using pillows ≥10 cm can lead to prolonged poor cervical alignment during sleep, exacerbating soft tissue tension and nerve root irritation [26]. Therefore, targeted treatment strategies that consider age and emphasize lifestyle modifications, such as proper pillow height adjustment and comprehensive rehabilitation, are essential for minimizing CSR recurrence.

This study developed a recurrence risk prediction model based on identified risk factors and demonstrated its high predictive accuracy (AUC=0.897) through ROC analysis. This model provides clinicians with a quantitative tool to predict recurrence risk, enabling early targeted interventions for high-risk patients. Compared to Keyue Xie et al. [14], who identified disease duration, numbness, and numeric pain scores as independent predictors of post-surgical recurrence, this study's model, which focuses on different variables (treatment approach, age, and pillow height), also exhibited high predictive accuracy. Both studies highlight the complementary nature of identified risk factors, contributing to a more comprehensive and precise prediction model.

Despite its valuable contributions, this study has several limitations. First, as a single-center retrospective study, it lacks the higher level of evidence provided by prospective, randomized controlled trials. Second, although the sample size is substantial, larger multi-center studies are necessary for further validation. The study did not perform a stratified analysis of the impact of different parameters of interference electrotherapy or specific manual therapy details. Future research should explore the underlying mechanisms and optimize treatment parameters. Additionally, factors such as psychological state, socioeconomic status, and patient compliance were not analyzed. Future multidisciplinary studies incorporating biological, psychological, and social dimensions will enhance the model's applicability and precision [12, 27].

Conclusion

Interference electrotherapy combined with rotary traction manipulation significantly improves cervical function and alleviates pain in patients with cervical spondylotic radiculopathy, achieving a high total effective rate. However, the risk of recurrence is significantly influenced by the treatment approach, patient age, and pillow height.

Disclosure of conflict of interest

None.

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