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REVIEW

Efficacy and Safety of Ultrasound-Guided Acupotomy for Chronic Spinal Musculoskeletal Pain: A Systematic Review and Meta-Analysis of Randomised Controlled Trials

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Purpose: Chronic spinal musculoskeletal pain (CSP) is a prevalent and disabling condition affecting hundreds of millions worldwide. Ultrasound-guided acupotomy (UGA) has emerged as a minimally invasive intervention for CSP. This study aimed to systematically evaluate the efficacy and safety of UGA for CSP through a meta-analysis of randomised controlled trials (RCTs).

Patients and Methods: The study protocol was prospectively registered with PROSPERO (CRD420251156718). A systematic search was conducted in PubMed, EMBASE, Cochrane Library, Web of Science, China National Knowledge Infrastructure, Wanfang Database, and VIP Database from inception to August 2025 for RCTs. Primary outcomes included pain intensity assessed by the Visual Analogue Scale (VAS), functional disability assessed by the Neck Disability Index/Oswestry Disability Index (NDI/ODI) and the Japanese Orthopaedic Association (JOA) score, and overall clinical response rate. Secondary outcomes included recurrence rate and incidence of adverse events. Methodological quality was assessed using the modified Jadad scale, Cochrane risk of bias tool, and GRADE system. Meta-analysis, subgroup analysis, sensitivity analysis, and publication bias assessment were performed.

Results: A total of 32 RCTs involving 2669 participants were included, all conducted in China and published between 2014 and 2025, covering spinal conditions including cervical spondylosis, lumbar disc herniation, cervicogenic headache, ankylosing spondylitis, and related disorders. UGA showed significant advantages over control groups in reducing pain intensity (VAS: SMD = −0.80, 95% CI: −0.97 to −0.64) and improving functional outcomes (NDI/ODI: SMD = −0.99, 95% CI: −1.36 to −0.63; JOA score: SMD = 0.77, 95% CI: 0.43 to 1.12), along with a higher overall response rate (RR = 1.15, 95% CI: 1.12–1.19). A trend toward reduced recurrence was observed (RR = 0.63, 95% CI: 0.27–1.43), though this did not reach statistical significance. Adverse events in the UGA group were mild and less frequent (0%–13.8%) than controls (0%–51.7%). Subgroup analysis revealed that add-on UGA therapy yielded optimal outcomes with low heterogeneity. Evidence quality was moderate for pain and response rate, and low for other outcomes. It should be noted that all 32 included RCTs were conducted in China, which may limit the generalisability of these findings to other geographic and clinical contexts.

Conclusion: UGA appears to be an effective and safe intervention for CSP, with particular benefit observed when used as an add-on therapy. However, given the moderate to low certainty evidence, high heterogeneity, and predominant risk of bias due to lack of blinding, these results should be interpreted with caution. Further high-quality multicentre RCTs with standardised protocols are warranted to confirm these findings.

Plain Language Summary: Chronic spinal pain affects millions of people worldwide and significantly impacts quality of life. While various treatments exist, they each have limitations. This study examined ultrasound-guided acupotomy (UGA), a minimally invasive technique that uses real-time imaging to precisely target affected tissues in patients with chronic spinal conditions. A total of 32 studies involving 2669 patients with chronic spinal conditions were analysed. Results showed that UGA significantly reduced pain and improved function compared to other treatments, with fewer side effects. The treatment appears particularly effective when combined with other therapies. However, more high-quality research is needed to confirm these findings and establish standardized treatment protocols.

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Introduction

Chronic musculoskeletal pain (CMP) is a prevalent type of pain encountered in clinical practice. Chronic spinal musculoskeletal pain (CSP) constitutes a significant subtype of CMP, referring to persistent pain arising from spinal and paraspinal musculoskeletal structures, with clinical manifestations spanning cervical, thoracic, and lumbosacral regions. CSP profoundly impacts patients' emotional well-being, daily functioning, and social engagement. In 2018, the World Health Organization (WHO) formally recognised chronic pain as an independent disease entity in the International Classification of Diseases, 11th Revision (ICD-11). Secondary CMP (MG30.3) is explicitly defined as persistent pain involving bones, muscles, tendons, and associated soft tissues affected by related diseases.[1] According to the Global Burden of Disease study, CMP affects approximately 1.3 billion people worldwide. CSP accounts for about 55.2% of CMP cases, impacting roughly 720 million individuals. With accelerating global population ageing and shifts in modern lifestyles, the prevalence of CSP continues to rise. Projections indicate a further expansion of the affected population worldwide by 2050.[2,3] This substantial patient population makes CSP a major global public health challenge, highlighting the need for effective treatment strategies. The therapeutic objectives for CMP encompass pain relief, functional improvement, and prevention of disease progression. Current CSP management primarily relies on conventional approaches, including pharmacological interventions,[4,5] physiotherapy,[6] and surgical procedures.[7] Pharmacological treatments, such as non-steroidal anti-inflammatory drugs and analgesics, provide symptomatic relief but are associated with risks of gastrointestinal, cardiovascular, and renal adverse effects with prolonged use.[8] Physiotherapy, including exercise therapy and manual therapy, improves function and reduces pain, but effects are often modest and progress is relatively slow.[9] Surgical interventions, whilst effective for selected structural pathologies, carry inherent procedural risks including persistent post-surgical pain in a non-negligible proportion of patients, and are subject to strict clinical indications.[10]

In recent years, ultrasound-guided acupotomy (UGA) has emerged as a promising minimally invasive treatment for CSP. UGA is particularly suitable for patients who have failed conservative treatment but have not yet reached surgical indications.[11] Acupotomy is a minimally invasive technique derived from traditional Chinese medicine, in which a needle-knife instrument is used to mechanically cut and release pathological soft tissues. The primary anatomical targets include fascial adhesions, contracted ligaments, thickened joint capsules, and myofascial trigger points—structures that undergo progressive fibrotic changes under sustained mechanical loading or chronic inflammatory conditions. The therapeutic rationale lies in the restoration of normal tissue mechanics: targeted release of these pathological structures reduces localised stress concentrations, alleviates compression of adjacent neurovascular elements, and interrupts the self-perpetuating cycle of tissue ischaemia, neurogenic inflammation, and central sensitisation that underlies chronic spinal pain.[12] UGA integrates real-time ultrasound imaging with acupotomy treatment, enabling precise guidance to accurately reach therapeutic targets and achieve favourable outcomes.[11] According to the Chinese Pain Expert Consensus (2025),[13] UGA is indicated for various CSP-related conditions, including cervicogenic headache, cervical spondylosis, lumbar disc herniation, and facet joint syndrome, among others. The pathological basis of CSP primarily involves deep soft tissues such as intervertebral discs, facet joints, ligaments, and fascia, which exhibit adhesions, contractures, and chronic inflammatory responses.[14,15] Other conservative treatments often struggle to directly target these deep pathological tissues. UGA therapy, however, enables precise, targeted intervention at the lesion site. The spinal region contains numerous critical structures such as spinal nerve roots and vertebral arteries, which are anatomically close to the affected soft tissues. Real-time ultrasound imaging provides accurate navigation for acupotomy manipulation, ensuring precise placement at the lesion site while avoiding critical structures, thereby significantly enhancing treatment safety and efficacy. However, research in this field remains limited, with studies showing considerable variation in design and quality, resulting in scarce and controversial evidence regarding UGA efficacy for CSP. While meta-analyses have explored this area,[16,17] they have included few studies of relatively low quality. More comprehensive and updated meta-analyses are required to address these limitations.

This study aimed to comprehensively evaluate the efficacy and safety of UGA in treating CSP through a systematic review and meta-analysis of RCTs, with the objective of clarifying the clinical value of UGA for CSP and providing recommendations for future research.

Material and Methods

This systematic review and meta-analysis was conducted in accordance with the PRISMA 2020 guidelines. The study protocol was prospectively registered with PROSPERO (CRD420251156718) prior to the commencement of data collection. All outcomes were pre-specified in the registered protocol before any study data were accessed; no outcomes were added, removed, or re-prioritised following data collection, and no amendments to the registered protocol were made at any stage.

Search Strategy

Literature searches were conducted in the following databases: PubMed, EMBASE, Cochrane Library, Web of Science, China National Knowledge Infrastructure (CNKI), Wanfang Database (Wanfang), and VIP Database (VIP). The search timeframe spanned from indexing inception to 1 August 2025. The following MeSH terms and keywords were employed for retrieval. Disease-related terms included: "cervicogenic headache", "cervical spondylosis", "lumbar disc herniation", "spinal stenosis", "vertebral compression fracture", "facet joint dysfunction syndrome", "ankylosing spondylitis", and "L3 transverse process syndrome". Intervention-related terms comprised: "ultrasound", "acupotomy", "small needle knife" and "visualized acupotomy". Study design terms included randomised controlled trials (RCTs), and search strategies were tailored to each database's characteristics. The retrieval process and results are detailed in Supplementary Material 1.

Inclusion and Exclusion Criteria

Inclusion criteria were based on the Participant, Intervention, Comparison, Outcome, and Study (PICOS) framework: (1) P: Adults diagnosed with CSP-related conditions—including cervical spondylosis, cervical spondylotic radiculopathy, cervicogenic headache, lumbar disc herniation, lumbar facet joint dysfunction, ankylosing spondylitis, or third lumbar transverse process syndrome—according to established clinical or imaging-based diagnostic criteria, with symptom duration of at least three months, and voluntarily consenting to UGA treatment; (2) I: The experimental group receiving UGA therapy alone or in combination with other conservative treatments (when additional therapies are included, the control group must receive identical adjunctive interventions); (3) C: The control group receiving one or more of the following: conventional acupotomy without ultrasound guidance, ultrasound-guided nerve block, manual acupuncture, pharmacological therapy, or sham procedures, provided that UGA was excluded from the control arm; (4) Outcomes: Primary outcomes included pain intensity assessed by the Visual Analogue Scale (VAS), an internationally validated and guideline-recommended instrument for pain measurement with established reliability and responsiveness; functional disability assessed by the Neck Disability Index (NDI) and Oswestry Disability Index (ODI), both internationally validated condition-specific instruments widely used in cervical and lumbar disorder research with well-established reliability and content validity; and spinal function assessed by the Japanese Orthopaedic Association (JOA) score, a validated and widely adopted clinician-administered scale for evaluating neurological and functional status in spinal conditions. Secondary outcomes included overall clinical response rate, recurrence rate, and incidence of adverse events.

Exclusion criteria: (1) Studies where both experimental and control groups received UGA treatment; (2) Composite intervention studies where the UGA treatment effect could not be isolated; (3) Studies with insufficient data or inadequate trial design; (4) Non-RCTs, meta-analyses, reviews, or other study types; (5) Animal studies.

Study Selection

Two researchers independently screened all retrieved literature using EndNote X9 software. First, after removing duplicates, they excluded irrelevant articles based on titles and abstracts. Full-text reviews were then conducted to determine final inclusion, with non-compliant literature excluded and reasons for exclusion documented. Any

discrepancies arising during screening were resolved through consultation with a third researcher to ensure literature selection aligned with the study objectives.

Data Extraction

Following literature screening, both researchers independently extracted characteristics and data from the included studies (Cohen's kappa = 0.88, indicating strong inter-rater agreement). Extracted data included study characteristics (authors, publication year, disease type), participant demographics (sample size, gender distribution, age, disease duration), interventions, and outcome measures (efficacy assessments, short-term and long-term efficacy).

Methodological Quality Assessment

The quality of included studies was assessed using a modified Jadad scale.[18] This scale evaluates study quality across four domains: (1) random sequence generation (0–2 points); (2) allocation concealment (0–2 points); (3) blinding implementation (0–2 points); and (4) description of loss to follow-up and withdrawal (0–1 point). The total score ranged from 0 to 7 points. Studies scoring ≥4 points were classified as high quality, while those scoring <4 points were deemed low quality. Additionally, the Cochrane Risk of Bias tool (RoB 1.0) was employed to assess the risk of bias in the included RCTs.[19] This tool evaluates bias risk across seven components: (1) generation of random sequences; (2) allocation concealment; (3) blinding of participants and personnel; (4) blinding of outcome assessors; (5) completeness of outcome data; (6) selective reporting; (7) other sources of bias. Each item was assessed as "low risk", "high risk", or "unclear" based on information in the study reports. Two researchers independently conducted the quality assessments. Disagreements during the assessment process were resolved through discussion. Where necessary, a third researcher was consulted.

Two researchers independently assessed the quality of evidence for outcomes using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) system. Certainty of evidence was categorised into four levels: High (very confident that the true effect is close to the estimated effect), Moderate (moderately confident in the effect estimate), Low (limited confidence in the effect estimate), Very Low (very little confidence in the effect estimate). Quality ratings were based on five domains: risk of bias, inconsistency, indirectness, imprecision, and publication bias. Evidence from RCTs was initially considered high quality. Evidence could be downgraded for lack of allocation concealment or blinding, outcome heterogeneity, small sample size, wide confidence intervals, or publication bias.

Data Synthesis and Analysis

Statistical analyses were performed using Stata 18.0 and R 4.5.0 software. The R software utilised the metafor and forestplot packages. For continuous outcomes, mean difference (MD) with 95% CI was calculated when studies used identical measurement tools, and SMD with 95% CI when studies employed different tools. Where trials did not report the SD of change scores, SDs were imputed using $SD_{\text{change}=}\sqrt{SD^2_{\text{baseline}} + SD^2_{\text{follow-up}} - \left(2 \times r \times SD_{\text{baseline}} \times SD_{\text{follow-up}}\right)}$, with r = 0.5 applied as a conservative default per Cochrane Handbook recommendations. For dichotomous outcome measures, the Relative Risk (RR) and its 95% CI were calculated as the effect measure. The incidence of adverse events was not subjected to meta-analytic pooling on pre-specified methodological grounds: adverse events were clinically heterogeneous in type, severity, and underlying mechanism, with no uniform definition or grading system applied consistently across trials, thereby precluding valid quantitative synthesis; this outcome was therefore analysed descriptively. All pre-specified outcomes are reported in full irrespective of the direction or statistical significance of findings. Negative VAS and NDI/ODI values indicated favourable UGA outcomes, while positive JOA scores and clinical response rates indicated favourable outcomes. The Cochrane Q test and I^2 statistic were employed to assess heterogeneity between studies. Degrees of heterogeneity were categorised as follows: $I^2 \leq 25\%$ indicated low heterogeneity, $25\% < I^2 < 50\%$ moderate heterogeneity, $50\% < I^2 < 75\%$ high heterogeneity, and $I^2 \geq 75\%$ very high heterogeneity. These thresholds, along with the criteria for model selection, were pre-specified in the registered study protocol (PROSPERO: CRD420251156718). When $I^2 < 50\%$ and $p > 0.10$, a fixed-effect model was employed for meta-analysis; otherwise, a random-effects model was used. When significant heterogeneity was present, subgroup analyses were conducted to explore its sources. Sensitivity analyses used the leave-one-out method, sequentially excluding individual studies to assess result robustness. If excluding any study substantially altered the direction or statistical significance of the pooled effect size, that study was deemed to have a critical

influence on the overall result. Small-study effects and publication bias were assessed using visual inspection of funnel plots and Egger's linear regression test, with a p-value < 0.05 considered indicative of significant asymmetry. When publication bias was detected, the trim-and-fill method was employed to estimate the number of potentially missing studies and to recalculate adjusted pooled effect sizes. This method recalculates adjusted pooled effect sizes after interpolating studies. The trim-and-fill approach utilised an auto-detection strategy for directionality. When necessary, both left- and right-sided interpolation were tested to determine the optimal outcome. All statistical tests were two-sided. A p-value < 0.05 was considered indicative of statistical significance. To contextualise the clinical relevance of pooled effect sizes, the following pre-specified MCID thresholds were applied: 1.5 points for VAS (0–10 points);[20,21] 15 percentage points for NDI and 10 percentage points for ODI (normalised 0–100% disability scale);[21–23] and 2 points for JOA (0–29 points).[24]

Results

Search Result

An initial search retrieved 395 articles across seven databases: PubMed (n = 9), EMBASE (n = 6), Cochrane Library (n = 4), Web of Science (n = 13), CNKI (n = 150), Wanfang (n = 144), and VIP (n = 69). After removing 87 duplicate records, 308 titles and abstracts were screened, excluding 201 irrelevant studies. After excluding six unavailable reports, 101 full texts were assessed, with 32 studies meeting inclusion criteria. The screening flowchart is shown in Figure 1.

Study Characteristics

This systematic review ultimately included 32 RCTs,[16,25–55] published between 2014 and 2025. These studies comprised 33 comparisons involving 2669 patients with chronic spinal disorders. Acupotomy therapy constitutes a minimally invasive treatment technique integrating traditional Chinese medicine with modern medical approaches. While this technique enjoys extensive clinical application within China, its utilisation remains relatively limited in other countries and regions. Consequently, all studies included in this review were conducted within China. The disease subtypes addressed by the included studies comprised: cervicogenic headache (4 studies[25–28]), cervical spondylosis (15 studies[16,29–41]), lumbar disc herniation (9 studies[42–50]), lumbar facet joint dysfunction (1 study[51]), ankylosing spondylitis (1 study[52]), and third lumbar transverse process syndrome (3 studies[53–55]). All 32 included trials were RCTs conducted in hospital-based settings in China. Intervention durations ranged from a single session to 3 months, with most studies delivering 2–4 sessions over 1–4 weeks. Follow-up was reported in 23 of the 32 studies: 18 studies assessed outcomes at up to 3 months[25–29,31,32,38–41,44,45,47,49,50,53,55] and 5 studies at 6 months;[16,30,34,43,46] no study provided assessment beyond 6 months. Detailed information on study design, setting, intervention duration, and follow-up is provided in Supplementary Material 2. Study sample sizes ranged from 30 to 160 participants. The mean age of participants ranged from 31.28 to 55.85 years, with disease duration spanning 0.087 to 43.2 months. Based on comparison types, these studies fall into three categories: (1) direct comparison studies (22 studies total[16,26,27,29,30,32,33,35–37,39,41,43–49,54,55]): UGA versus other single therapies (conventional acupotomy, nerve block); (2) add-on therapy studies (6 studies[25,28,31,42,52,53]): UGA combined with adjunctive therapy versus the same adjunctive therapy alone; (3) parallel control studies (5 studies[34,38,40,50,51]): UGA combined with adjunctive therapy versus other therapies (eg., conventional acupotomy, nerve block) combined with the same adjunctive therapy. Regarding outcome measures, 27 studies employed VAS to assess UGA treatment efficacy.[16,25–29,31,32,34–39,41,42,44–47,49–53,55] 15 studies employed NDI/ODI.[16,25,26,34–36,42–47,50,51,55] 7 studies employed JOA.[29,45,47,49–51,53] 29 studies reported the clinical overall response rate.[16,26,27,30–53,55] 2 studies reported recurrence rate.[30,43] 21 studies assessed the incidence of adverse reactions.[16,25–30,32–34,36,38,40,42–47,54,55] The basic characteristics of the included literature are detailed in Table 1.

Study Quality and Risk of Bias Assessment

Table 2 presents the assessment results of the modified Jadad scale for 32 RCTs, with detailed scoring procedures outlined in Supplementary Material 3. Among these, 7 studies were rated as high quality,[16,26,27,34,41–43] while 25 studies were rated as low quality.[25,28–33,35–40,44–55] Regarding randomisation, 32 studies mentioned employing randomisation methods, with 25 studies detailing randomisation procedures deemed adequate.[16,25–27,29,30,32–34,36–39,41–47,49–53] Regarding allocation

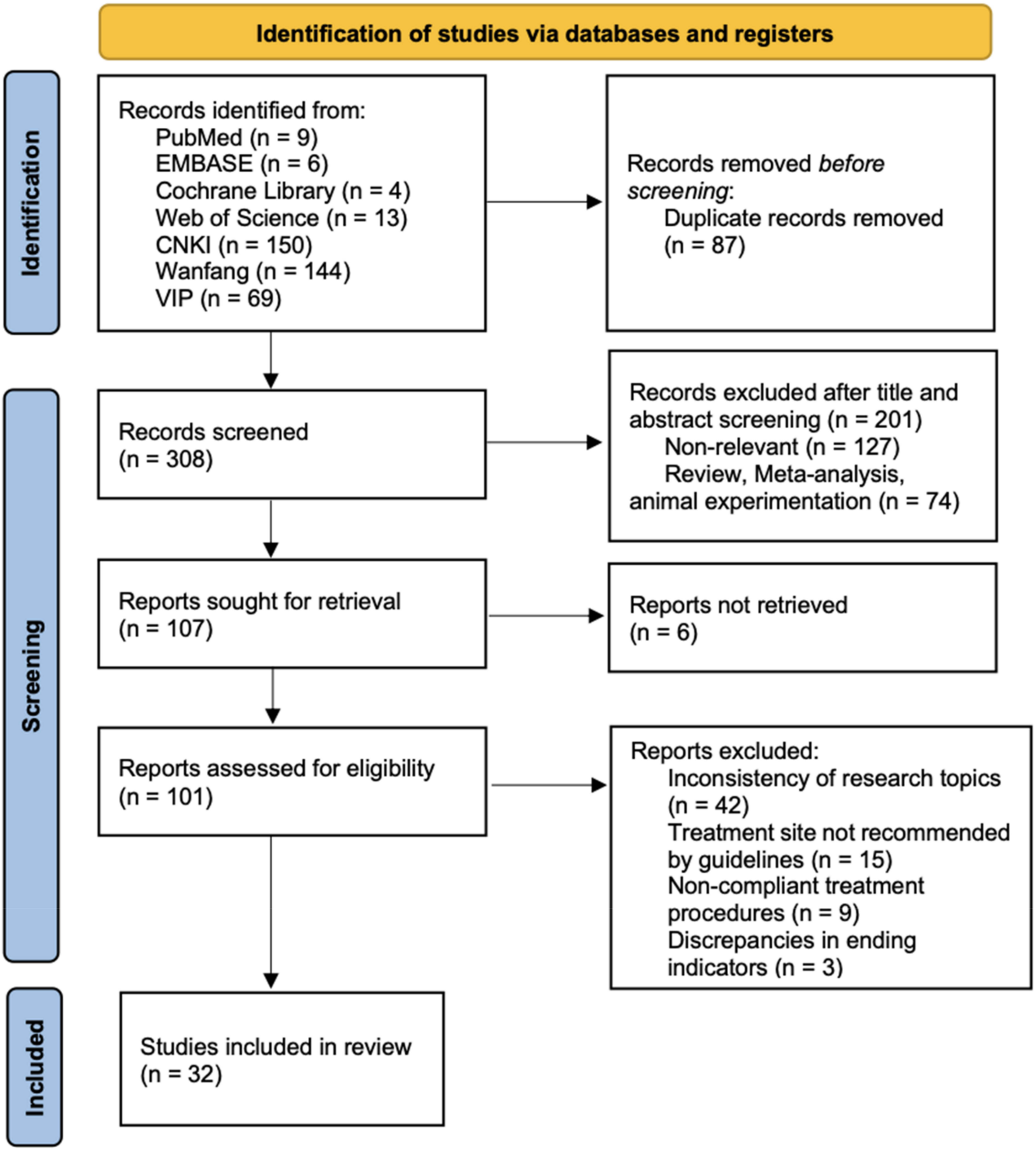

Figure 1 PRISMA flow diagram of study selection.

concealment, only 1 study mentioned and reasonably implemented it.[16] This may be attributed to UGA therapists requiring knowledge of specific needle insertion pathways, depths, and individualised protocols during allocation, making concealment difficult. Concerning blinding, 8 studies implemented and adequately described blinding.[16,26,27,34,41–43,54] This was primarily because patients could distinctly perceive the sensation of acupotomy puncture and cutting, making patient blinding impractical, while therapists must perform individualised procedures, rendering therapist blinding difficult. Regarding descriptions of loss to follow-up and withdrawal, 11 studies detailed the number and reasons for patients lost to follow-up

Table 1 Characteristics of Included Studies

First Author	Year	Disease Subtype	Sample Size		Mean Age (Years)		Disease Duration (Months)		Intervention		Outcomes
			Intervention Group (M/F)	Control Group (M/F)	Intervention Group	Control Group	Intervention Group	Control Group	Intervention Group	Control Group	
Yao[25]	2019	CGH	5/18	13/10	(42.7±10.6)	(41.8±11.0)	1.2 ± 0.9	1.4 ± 0.9	UGA + UGNB	UGNB	1, 2, 6
Wang[26]	2021	CGH	16/14	15/15	(42±10)	(43±12)	4.5	4.3	UGA	CA	1, 2, 4, 6
Li[27]	2025	CGH	16/44		(43±11)		NA	NA	UGA + sham UGNB	UGNB + sham UGA	1, 4, 6
Wang[28]	2019	CGH	34/34	38/30	M: (43.35±3.56) F: (44.66±3.34)		(18.23±6.56)		UGA + UGNB	UGNB	1, 6
Liu[29]	2021	CS	42/58	39/61	37.30 ± 7.95	35.19 ± 9.61	12.61 ± 5.68	13.05 ± 6.41	UGA	CA	1, 3, 6
Gao[30]	2021	CSR	28/32	30/30	46.08 ± 11.55	47.35 ± 10.81	7.20 ± 4.68	7.09 ± 4.35	UGA	CA	4, 5, 6
Cai[31]	2019	CSR	21/19	22/18	49.3	48.9	14.2	13.5	UGA + UGNB	UGNB	1, 4
Wang[32]	2014	CSR	15/15	15/15	42 ± 10	43 ± 12	18		UGA	CA	1, 4, 6
Zhong[33]	2019	CSA	12/17	11/18	42.8 ± 5.1	43.2 ± 4.6	43.2 ± 14.4	40.8 ± 21.6	UGA	UGNB	4, 6
Du[34]	2023	CSR	19/18	18/14	46.4±10.2	48.9±9.8	22.8±4.8	22.7±4.7	UGA + UGNB	CA	1, 2, 4, 6
Huang[35]	2023	CS	21/19	23/17	55.25±7.86	54.76±7.69	NA	NA	UGA	CA	1, 2, 4
Quan[36]	2024	CSR	18/28	16/30	47.23±5.11	46.59±4.37	20.21±3.05	19.75±2.55	UGA	CA	1, 2, 4, 6
Liu[37]	2018	CS	23/27	24/26	43.53±10.59	41.22±10.39	4.81±1.79	4.45±2.19	UGA	CA	1, 2, 4
Deng[38]	2016	CSR	13/17	10/20	52±16	51±18	5.5±2.2	5.2±2.4	UGA + UGNB	CA + UGNB	1, 4, 6
Wang[39]	2017	CSR	23/17	26/14	51.2±6.5	49.5±11.5	3.6±1.6	3.9±1.8	UGA	CA	1, 4
Yuan[40]	2021	CSR	17/13	16/14	55.85±1.42	54.75±1.16	NA	NA	UGA + Chinese herbal granules (Jingfang)	CA + Chinese herbal granules (Jingfang)	4, 6
Ruan[41] (1)	2018	CSR	14/16	15/15	45±13	43±14	0.41±0.14	0.44±0.11	UGA	Ultrasound-guided PRF	1, 4
Ruan[41] (2)	2018	CSR	14/16	17/13	45±13	44±15	0.41±0.14	0.47±0.17	UGA	UGNB	1, 4
Pu[16]	2023	CSR	42/38	41/39	55.6±10.5	52.5±11.5	0.25±1	0.25±1.25	UGA	UGNB	1, 2, 4, 6
Zhu[42]	2023	LDH	16/23	19/21	51.31±6.97	51.30±7.75	27	24	UGA + fire acupuncture	Fire acupuncture	1, 2, 4, 6
Li[43]	2025	LDH	25/35		53±12		16		UGA + sham UGNB	UGNB + sham UGA	2, 4, 6
Deng[44]	2019	LDH	30	30	36.42 ± 9.91	35.65 ± 12.06	10.69 ± 11.21	0.25±1.25	Ultrasound-guided hydro-acupotomy	hydro-acupotomy	1, 2, 4, 5, 6
Chen[45]	2022	LDH	28/15	28/15	46.55±5.08	46.49±5.02	16.17±3.05	16.19±3.08	Ultrasound-guided hydro-acupotomy	hydro-acupotomy	1, 2, 3, 4, 6

(*Continued*)

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Table 1 (Continued).

First Author	Year	Disease Subtype	Sample Size		Mean Age (Years)		Disease Duration (Months)		Intervention		Outcomes
			Intervention Group (M/F)	Control Group (M/F)	Intervention Group	Control Group	Intervention Group	Control Group	Intervention Group	Control Group	
Liu[46]	2017	LDH	20	20	40.83±11.47	39.17±10.06	11.33±9.20	12.67±10.43	Ultrasound-guided hydro-acupotomy	hydro-acupotomy	1, 2, 4, 6
Wang[47]	2022	LDH	25/21	22/24	46.71±8.23	47.13±8.49	16.39±4.08	5.89±4.24	UGA +MA	CA + MA	1, 2, 3, 4, 6
Xu[48]	2020	LDH	18/12	17/13	42.8±9.6	44.4±7.8	NA	NA	UGA	CA	4
Deng[49]	2025	LDH	17/13	16/14	43.64±10.22	43.96±10.42	18.17±10.00	15.79±10.50	UGA	CA	1, 3, 4
Yuan[50]	2022	LDH	16/14	15/15	39.5±1.31	38.7±1.32	NA	NA	UGA + Chinese herbal granules (Yaofang)	CA + Chinese herbal granules (Yaofang)	1, 2, 3, 4
Yan[51]	2024	LFJD	19/15	18/16	38.68±10.71	36.35±10.27	0.087±0.042	0.077±0.038	UGA + medical ozone (O_3)	CA + medical ozone (O_3)	1, 2, 3, 4
Li[52]	2025	AS	64/6	57/12	31.28±3.15	32.05±3.21	10.92±2.48	11.13±2.39	UGA +UGNB	UGNB	1, 4
Chen[53]	2022	TLTPS	23/19	27/15	45.12±6.25	43.72±6.31	15.21±3.16	14.34±3.21	UGA + local injection	Local injection	1, 3, 4
Liu[54]	2024	TLTPS	20/20	18/22	48.5±5.7	48.2±6.0	NA	NA	UGA	CA	6
Xu[55]	2025	TLTPS	15/15	16/14	46.20±9.83	42.60±11.32	6	2	UGA	MA	1, 2, 4, 6

Notes: Sham procedures involve mimicking the actual intervention without delivering therapeutic effect; M/F indicates male/female ratio; NA indicates data not available; Disease duration is standardized in months (original data in days converted accordingly); Vas: 1; ODI/NDI: 2; JOA: 3; Overall clinical response rate: 4; Recurrence rate: 5; Incidence of adverse reactions: 6.

Abbreviations: CGH, Cervicogenic Headache; CS, Cervical Spondylosis; CSR, Cervical Spondylotic Radiculopathy; CSA, Cervical Spondylotic Arteriopathy; LDH, Lumbar Disc Herniation; LFJD, Lumbar Facet Joint Disorder; AS, Ankylosing Spondylitis; TLTPS, Third Lumbar Transverse Process Syndrome; UGA, ultrasound-guided acupotomy; UGNB, ultrasound-guided nerve block; PRF, pulsed radiofrequency; CA, conventional acupotomy (needle-knife technique involving cutting and releasing of soft tissues); MA, manual acupuncture (traditional needle insertion for therapeutic purposes).

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Table 2 Methodological Quality Assessment of Included Studies (Modified Jadad Scale)

Study	Randomization Grouping (0–2)	Allocation Concealment (0–2)	Blinding (0–2)	Withdrawals and Dropouts (0–1)	Total Score (0–7)	Quality Level
Yao, 2019[25]	2	0	0	0	2	Low quality
Wang, 2021[26]	2	0	2	0	4	High quality
Li, 2025[27]	2	0	2	0	4	High quality
Wang, 2019[28]	1	0	0	0	1	Low quality
Liu, 2021[29]	2	0	0	0	2	Low quality
Gao, 2021[30]	2	0	0	0	2	Low quality
Cai, 2019[31]	1	0	0	0	1	Low quality
Wang, 2014[32]	2	0	0	0	2	Low quality
Zhong, 2019[33]	2	0	0	1	3	Low quality
Du, 2023[34]	2	0	2	0	4	High quality
Huang, 2023[35]	1	0	0	0	1	Low quality
Quan, 2024[36]	2	0	0	0	2	Low quality
Liu, 2018[37]	2	0	0	1	3	Low quality
Deng, 2016[38]	2	0	0	1	3	Low quality
Wang, 2017[39]	2	0	0	1	3	Low quality
Yuan, 2021[40]	1	0	0	0	1	Low quality
Ruan, 2018[41]	2	0	2	0	4	High quality
Pu, 2023[16]	2	2	2	1	7	High quality
Zhu, 2023[42]	2	0	2	1	5	High quality
Li, 2025[43]	2	0	2	1	5	High quality
Deng, 2019[44]	2	0	0	0	2	Low quality
Chen, 2022[45]	2	0	0	0	2	Low quality
Liu, 2017[46]	2	0	0	0	2	Low quality
Wang, 2022[47]	2	0	0	0	2	Low quality
Xu, 2020[48]	1	0	0	0	1	Low quality
Deng, 2025[49]	2	0	0	1	3	Low quality
Yuan, 2021[50]	2	0	0	1	3	Low quality
Yan, 2024[51]	2	0	0	0	2	Low quality
Li, 2025[52]	2	0	0	1	3	Low quality
Chen, 2022[53]	2	0	0	1	3	Low quality
Liu, 2024[54]	1	0	2	0	3	Low quality
Xu, 2025[55]	1	0	0	0	1	Low quality

or who withdrew.[16,33,37–39,42,43,49,50,52,53] The Cochrane risk of bias assessment results are detailed in Supplementary Material 4. Most studies demonstrated low or some concerns risk for randomisation (D1: low 15.6%, some concerns 81.2%) and selective reporting (D5: low 78.1%). Completeness of outcome data (D3) was adequate in the majority of studies (low 75.0%). The most prominent methodological concern was bias in outcome measurement (D4: high 71.9%), followed by deviations from intended interventions (D2: high 25.0%), both attributable to the inherent difficulty of implementing blinding in procedural acupotomy trials. Overall, 62.5% of studies were judged at high risk of bias, primarily reflecting these blinding-related limitations rather than flaws in randomisation or reporting. In summary, the unique operational characteristics of UGA pose significant challenges to allocation concealment and blinding designs, constituting the primary methodological limitations affecting the included studies.

Analysis of Results

VAS Scores

27 studies involving 2234 participants assessed differences in VAS pain scores before and after treatment. As shown in Figure 2, a random-effects model was employed due to high heterogeneity (I^2 = 69.7%, p<0.00001). Meta-analysis results demonstrated a significant advantage for UGA treatment over control groups in pain

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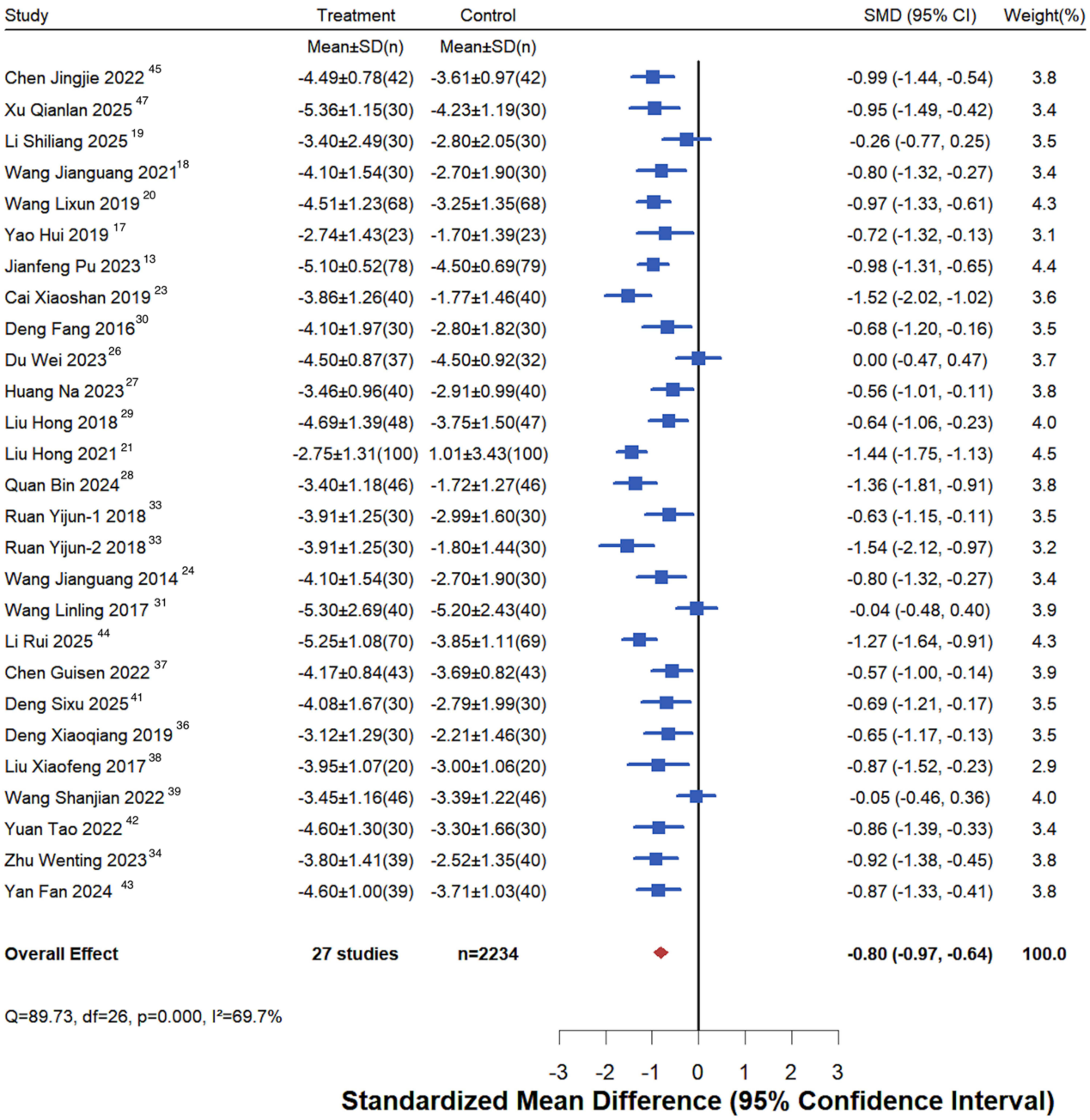

Figure 2 Forest plot of meta-analysis for VAS pain scores. Blue square: point estimate (SMD) for each individual study, with size proportional to its weight; horizontal line: 95% confidence interval; red diamond: pooled overall effect estimate, with width representing the 95% confidence interval; solid vertical line: line of no effect (SMD = 0). **Abbreviations**: SMD, standardized mean difference; CI, confidence interval; SD, standard deviation; Q, Cochrane's heterogeneity statistic; df, degrees of freedom; I^2, inconsistency index.

reduction (SMD = −0.80, 95% CI: −0.97 to −0.64, $p < 0.00001$), with a large effect size. Back-transforming to the original VAS scale (0–10 points; SD reference = 2.0 points), this corresponds to an estimated mean reduction of −1.6 points (95% CI: −1.94 to −1.28), which exceeds the established MCID of 1.5 points. Despite some variation between studies (weighted ranges 2.9%–4.5%), all included studies demonstrated a trend favouring the ultrasound-guided group. Liu Hong 2021 reported the largest effect size (SMD = −1.44), while Li Shiliang 2025 showed the smallest yet clinically meaningful improvement (SMD = −0.26).

NDI/ODI Scores

Differences in cervical or lumbar dysfunction indices before and after treatment were assessed across 15 studies involving 1155 participants. As shown in Figure 3, meta-analysis revealed extremely high inter-study heterogeneity (I^2 = 88.5%, p<0.00001), necessitating the random-effects model for analysis. Results indicated that the UGA treatment group demonstrated significantly greater functional improvement than the control group (SMD = −0.99, 95% CI: −1.36 to −0.63, p < 0.00001), with this effect size falling within the large effect range. NDI and ODI were normalised to a uniform 0–100% disability scale (NDI raw score ÷ 50×100) to permit pooled interpretation. Back-transforming the pooled SMD (SD reference = 17.0%) yields an estimated mean reduction of −16.8 percentage points (95% CI: −23.1 to −10.7), exceeding the MCIDs for both NDI (15 percentage points) and ODI (10 percentage points). The effect sizes varied considerably across studies, ranging from a slight improvement in Du Wei 2023 (SMD = −0.08) to a marked improvement in Quan Bin 2024 (SMD = −2.87), suggesting treatment efficacy may be influenced by multiple factors. The majority of findings supported the efficacy of UGA therapy.

JOA Scores

7 studies involving 661 participants assessed spinal function using the JOA. As shown in Figure 4, despite substantial heterogeneity (I^2=77.3%, p<0.00001), random-effects model analysis indicated that UGA treatment significantly improved JOA scores (SMD=0.77, 95% CI: 0.43 to 1.12, p<0.00001), suggesting moderate to large improvements in

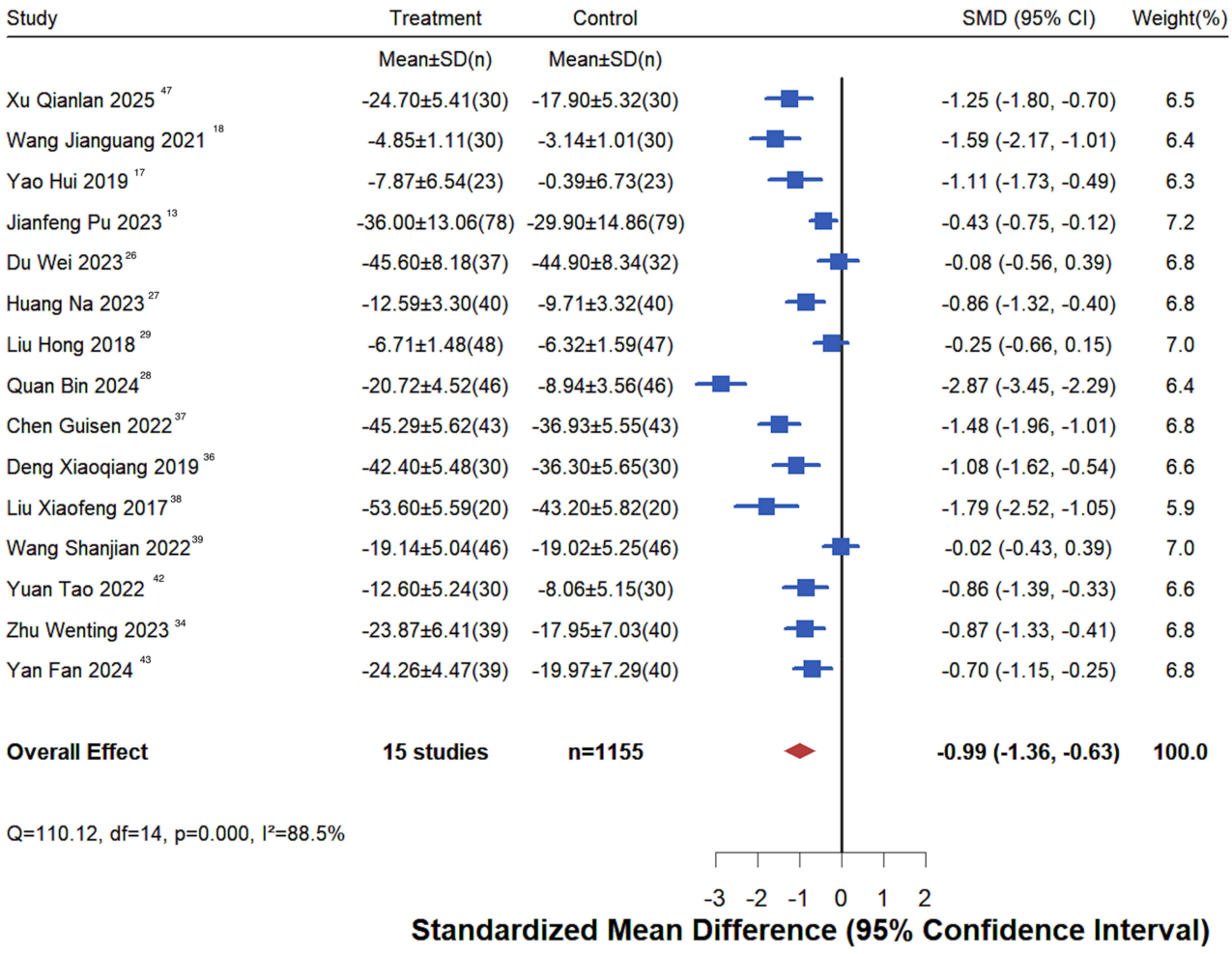

Figure 3 Forest plot of meta-analysis for NDI/ODI functional disability indices. Blue square: point estimate (SMD) for each individual study, with size proportional to its weight; horizontal line: 95% confidence interval; red diamond: pooled overall effect estimate, with width representing the 95% confidence interval; solid vertical line: line of no effect (SMD = 0).

Abbreviations: SMD, standardized mean difference; CI, confidence interval; SD, standard deviation; Q, Cochrane's heterogeneity statistic; df, degrees of freedom; I^2, inconsistency index.

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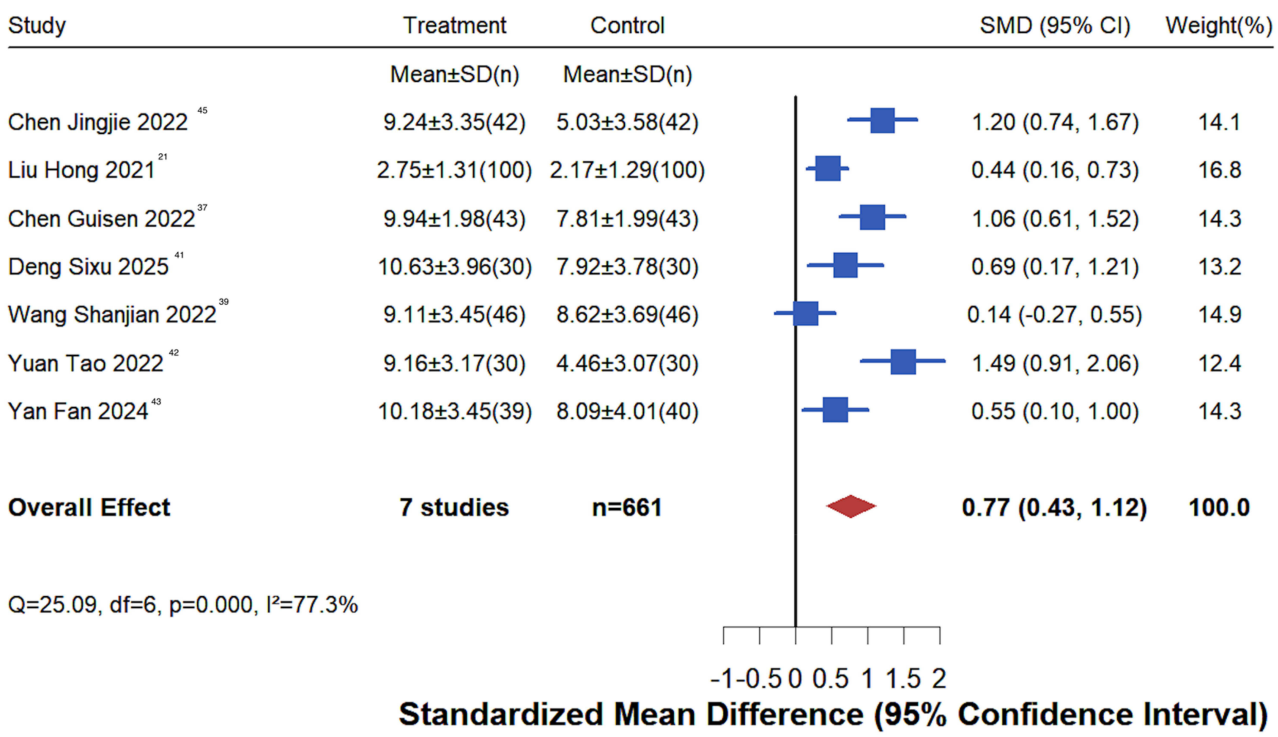

Figure 4 Forest plot of meta-analysis for JOA scores. Blue square: point estimate (SMD) for each individual study, with size proportional to its weight; horizontal line: 95% confidence interval; red diamond: pooled overall effect estimate, with width representing the 95% confidence interval; solid vertical line: line of no effect (SMD = 0).
Abbreviations: SMD, standardized mean difference; CI, confidence interval; SD, standard deviation; Q, Cochrane's heterogeneity statistic; df, degrees of freedom; I^2, inconsistency index.

spinal function. Back-transforming to the original JOA scale (SD reference = 4.5 points), this corresponds to an estimated mean improvement of +3.5 points (95% CI: +1.9 to +5.0), exceeding the established MCID of 2 points. Yuan Tao 2022 reported the largest effect size (SMD=1.49), while Wang Shanjian 2022 showed a smaller effect size (SMD=0.14), but all studies demonstrated positive improvement trends.

Clinical Overall Response Rate

28 studies (29 comparisons) reported overall efficacy rates, involving 1,097 patients in ultrasound-guided groups and 1,090 in control groups. As shown in Figure 5, analysis employed a fixed-effect model due to low inter-study heterogeneity (I^2 = 5.9%, p = 0.461). UGA treatment demonstrated a significant overall therapeutic effect (RR=1.15, 95% CI: 1.12–1.19, p<0.00001). Study weights were relatively evenly distributed (range 0.7%–10.1%), with no single study exerting a dominant influence on the overall effect. The forest plot showed most studies' effect estimates and confidence intervals fell to the right of the line of no effect, supporting UGA superiority.

Recurrence Rate

Only 2 studies reported recurrence rate metrics, involving 85 patients in the ultrasound-guided group and 83 in the control group. As shown in Figure 6, a fixed-effect model was employed due to the absence of heterogeneity between studies (I^2=0%, p=0.414). Analysis indicated a trend towards reduced recurrence rate with UGA treatment (RR=0.63, 95% CI: 0.27–1.43, p=0.27), though the difference failed to reach statistical significance. Given the limited number of included studies, this finding should be interpreted with caution.

In summary, UGA therapy demonstrated statistically and clinically significant improvements in pain relief, functional recovery, and overall clinical response rates, with effect sizes ranging from moderate to large. Although considerable heterogeneity existed in certain outcomes, the consistent direction of treatment effects supports the therapeutic value of UGA in managing chronic spinal disorders.

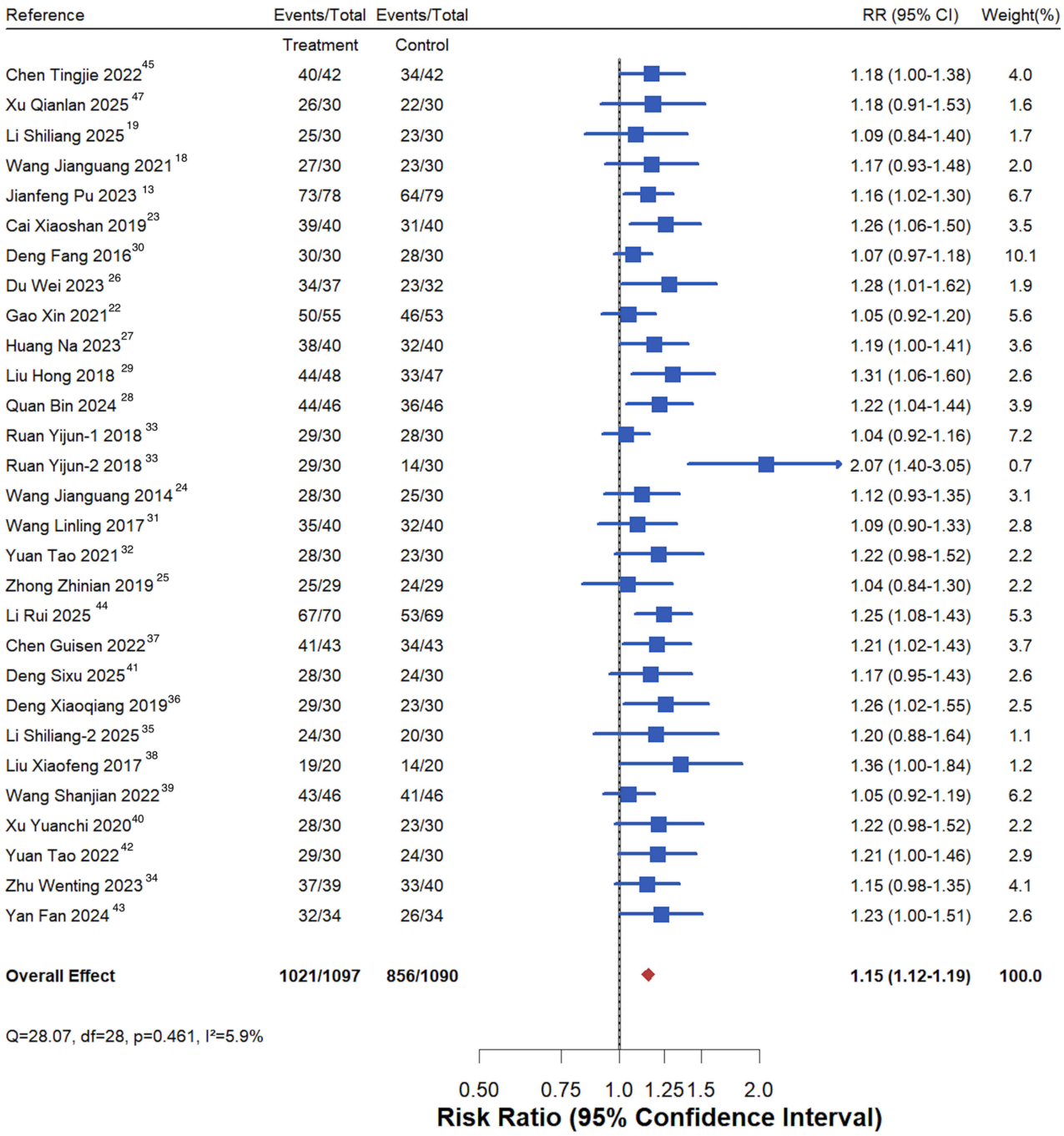

Figure 5 Forest plot of meta-analysis for clinical total effective rate. Blue square: point estimate (RR) for each individual study, with size proportional to its weight; horizontal line: 95% confidence interval; red diamond: pooled overall effect estimate, with width representing the 95% confidence interval; dashed vertical line: line of no effect (RR = 1).

Abbreviations: RR, risk ratio; CI, confidence interval; Q, Cochrane's heterogeneity statistic; df, degrees of freedom; I^2, inconsistency index.

Safety and Incidence of Adverse Events

A total of 21 studies investigated the safety and incidence of adverse events associated with UGA therapy. Among these, 10 studies reported adverse events occurring in the UGA treatment group, while 15 studies documented adverse events in the control group. The incidence of adverse events in the control group ranged from 0% to 51.7%, higher than the 0% to 13.8% observed in the UGA treatment group. Common adverse events associated with UGA included local haematoma, needle syncope, puncture site pain and swelling. These adverse reactions were generally mild and resolved

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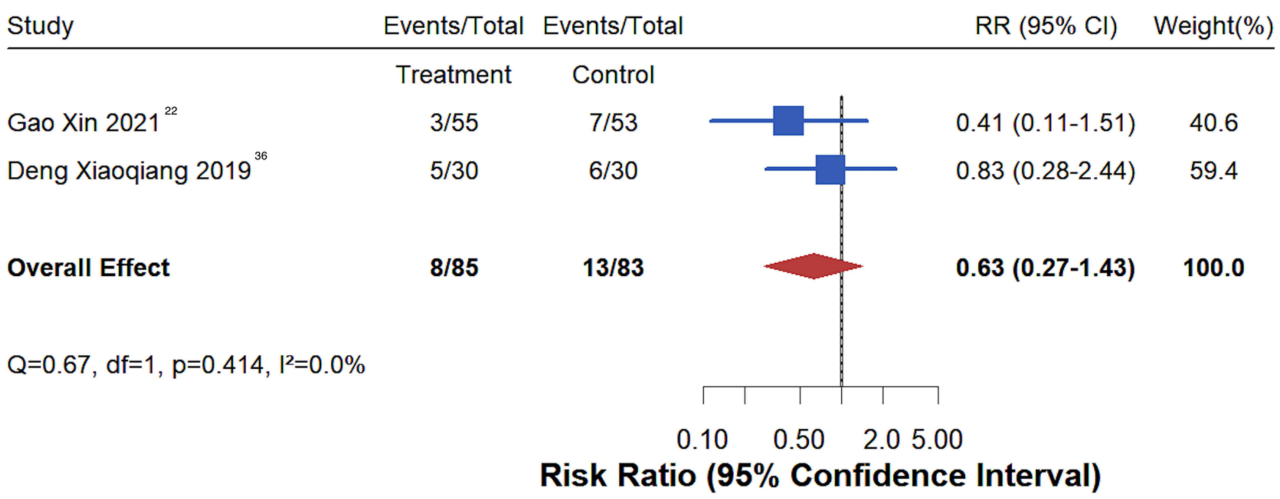

Figure 6 Forest plot of meta-analysis for recurrence rate. Blue square: point estimate (RR) for each individual study, with size proportional to its weight; horizontal line: 95% confidence interval; red diamond: pooled overall effect estimate, with width representing the 95% confidence interval; dashed vertical line: line of no effect (RR = 1).
Abbreviations: RR, risk ratio; CI, confidence interval; Q, Cochrane's heterogeneity statistic; df, degrees of freedom; I^2, inconsistency index.

spontaneously. Compared with traditional acupotomy therapy and its combination therapies, UGA treatment demonstrated superior safety characteristics, as detailed in Table 3. Using real-time imaging for precise visualisation, UGA treatment effectively avoids critical vascular and neural structures, ensuring accurate needle placement at therapeutic targets. This significantly enhances treatment safety and reduces the incidence of adverse events.

Table 3 Comparison of Adverse Events Between UGA and Control Groups

First Author	Year	Intervention Group and Adverse Reactions	Intervention Group Adverse Event Rate	Control Group and Adverse Reactions	Control Group Adverse Event Rate
Yao[25]	2019	UGA + UGNB—23 cases—no adverse reactions	0%	UGNB—23 cases—no adverse reactions	0%
Wang[26]	2021	UGA—30 cases—no adverse reactions	0%	CA—30 cases—3 cases of local soft tissue swelling, 2 cases of local bleeding	16.7%
Li[27]	2025	UGA + sham UGNB—30 cases—no adverse reactions	0%	UGNB + sham UGA—30 cases—no adverse reactions	0%
Wang[28]	2019	UGA + UGNB—68 cases—no adverse reactions	0%	UGNB—68 cases—no adverse reactions	0%
Liu[29]	2021	UGA—100 cases—no adverse reactions	0%	CA—100 cases—no adverse reactions	0%
Gao[30]	2021	UGA—55 cases—1 case of subcutaneous hematoma	1.8%	CA—53 cases—6 cases of subcutaneous hematoma	11.3%
Wang[32]	2014	UGA—30 cases—no adverse reactions	0%	0%CA—30 cases—3 patients with local swelling at treatment site	10%
Zhong[33]	2019	UGA—29 cases—2 cases of significant discomfort during treatment, 1 case of puncture site pain, 1 case of local hematoma	13.8%	UGNB—29 cases—6 cases of significant discomfort during treatment, 5 cases of puncture site pain, 4 cases of local hematoma	51.7%
Du[34]	2023	UGA + UGNB—37 cases—1 patient experienced sweating and pallor during treatment (vasovagal reaction)	2.7%	CA + UGNB—32 cases—2 cases of hoarseness, 1 case of transient upper limb pain and numbness (nerve stimulation symptoms), all symptoms resolved within 12 hours	9.4%
Quan[36]	2024	UGA—46 cases—1 case of hematoma	2.2%	CA—46 cases—3 cases of severe pain, 4 cases of hematoma, 1 case of nerve injury	17.4%

(*Continued*)

Table 3 (Continued).

First Author	Year	Intervention Group and Adverse Reactions	Intervention Group Adverse Event Rate	Control Group and Adverse Reactions	Control Group Adverse Event Rate
Deng[38]	2016	UGA + UGNB—30 cases—no adverse reactions	0%	CA + UGNB—30 cases—no adverse reactions	0%
Yuan[40]	2021	UGA + Chinese herbal granules (Jingfang)—30 cases—1 case of local hematoma	3.3%	CA + Chinese herbal granules (Jingfang)—30 cases—1 case of local hematoma, 2 cases of nerve injury	10%
Pu[16]	2023	UGA—80 cases—2 subjects experienced vasovagal reaction during treatment	2.5%	UGNB—80 cases—1 subject experienced vasovagal reaction	1.3%
Zhu[42]	2023	UGA + fire acupuncture—39 cases—5 patients had local skin bruising less than 2 cm×2 cm	12.8%	Fire acupuncture—40 cases—1 patient had local skin bruising less than 2 cm×2 cm	2.6%
Li[43]	2025	UGA + sham UGNB—30 cases—1 patient experienced needle site pain after treatment, resolved within 72 hours	3.3%	UGNB + sham UGA—30 cases—1 patient experienced needle site pain after treatment, resolved within 72 hours	3.3%
Deng[44]	2019	Ultrasound-guided hydro-acupotomy—30 cases—no obvious adverse reactions	0%	Hydro-acupotomy—30 cases—3 patients developed small local hematoma	10%
Chen[45]	2022	Ultrasound-guided hydro-acupotomy—43 cases—no adverse reactions	0%	Hydro-acupotomy—43 cases—5 patients developed small local hematoma	11.6%
Liu[46]	2017	Ultrasound-guided hydro-acupotomy—20 cases—no obvious adverse reactions	0%	Hydro-acupotomy—20 cases—2 patients developed small local hematoma	10%
Wang[47]	2022	UGA + MA—46 cases—no adverse reactions	0%	CA + MA—46 cases—2 cases of nerve root injury	4.3%
Liu[54]	2024	UGA—40 cases—no adverse reactions	0%	CA—40 cases—no adverse reactions	0%
Xu[55]	2025	UGA + local injection—30 cases—1 case of swelling at treatment site	3.3%	MA—30 cases—2 cases of swelling at treatment site, 2 cases of severe pain, 2 cases of muscle weakness, 1 case of ecchymosis, 1 case of bruising	26.7%

Sensitivity Analysis

Given the high heterogeneity in this study, a leave-one-out sensitivity analysis was conducted on the four primary outcome measures to assess the robustness of the overall effect (Supplementary Material 5 and Figure S1). For the total efficacy rate, excluding any single study did not substantially alter the magnitude of the overall effect, which remained centred around 1.152. The 95% confidence intervals for all iterations overlapped with the original pooled estimate, indicating relatively stable results. For VAS, the pooled SMD also proved robust across studies; excluding any individual study did not lead to substantial changes in the pooled estimate, which consistently remained close to 0.805, confirming result stability. For NDI/ODI outcomes, the pooled estimate exhibited greater dispersion, ranging around −0.994. For JOA, the pooled estimate remained near 0.771. Across iterations, the direction and magnitude of the effect remained stable, supporting the robustness of the findings despite the use of different measurement tools.

Evaluation of Publication Bias

Publication bias among the included RCTs was assessed by constructing funnel plots and conducting Egger's tests (Supplementary Material 5 and Figure S2). Funnel plots for the overall response rate and NDI/ODI exhibited asymmetry, with Egger's tests revealing significantly non-zero regression slopes ($p = 0.0002$ for overall response rate; $p = 0.0049$ for NDI/ODI), indicating publication bias. This may be due to unpublished small-sample trials with negative results, or the limited number of trials in the present review that were predominantly published in Chinese. Although funnel plots for

VAS and JOA also showed asymmetry, the Egger tests (VAS p = 0.2303; JOA p = 0.1260) did not support the presence of publication bias. Trim-and-fill analysis further supported these findings (Supplementary Material 5 and Figure S3). The overall efficacy rate detected 11 missing studies, VAS detected 7 missing studies, NDI/ODI detected 2 missing studies, while JOA detected no missing studies. These results largely concurred with the Egger test findings, suggesting a possible degree of publication bias in the overall efficacy rate and NDI/ODI.

GRADE Evidence Grading Assessment

In the included studies, the quality of evidence for VAS scores and clinical overall response rates was moderate, while that for NDI/ODI scores, JOA scores, and recurrence rate was low. Primary reasons for downgrading included substantial heterogeneity between studies and potential publication bias for certain outcomes. It should be noted that due to the procedural specificity of UGA therapy, double-blind designs are difficult to implement in clinical practice. This represents an inherent limitation of the treatment modality rather than a methodological flaw. Despite these limitations in evidence quality, the substantial number of included studies (32 RCTs) and adequate sample size (2669 participants), coupled with statistically and clinically significant improvements across all primary outcomes, provide valuable evidence-based support for the efficacy of UGA in treating CSP. Detailed findings are presented in Table 4.

Subgroup Analysis

Subgroup analysis results are presented in Table 5 and Supplementary Material 5 (Figures S4–S21). Subgroup analyses were conducted based on participants' disease type, comparison type, age, sample size, Jadad score, and publication year to explore the clinical significance and potential sources of heterogeneity for VAS, NDI/ODI, and JOA outcomes. Meta-analysis was performed only when each subgroup contained at least two studies; otherwise, narrative synthesis was employed.

In subgroup analyses based on disease type, results demonstrated that UGA therapy produced comparable therapeutic effects across different spinal anatomical regions. Regarding pain relief, the cervical spine group demonstrated significant improvement in VAS scores (SMD = −0.81, 95% CI: −1.05 to −0.58; p < 0.001), with the lumbosacral spine group also showing significant improvement (SMD = −0.79, 95% CI: −1.00 to −0.58; p < 0.001). Subgroup interaction tests revealed no significant difference in efficacy between groups (p=0.89), confirming consistent therapeutic effects across anatomical regions. Regarding functional improvement, the cervical spine group demonstrated significant reduction in NDI/ODI scores (SMD=−1.01, 95% CI: −1.72 to −0.30; p=0.01), while the lumbosacral group also demonstrated significant improvement (SMD=−0.97, 95% CI: −1.35 to −0.60; p<0.001). Interaction analysis (p=0.93) further supported the absence of statistical differences between groups. In JOA score analysis, the lumbosacral spine disease group showed significant improvement (SMD=0.84, 95% CI: 0.45 to 1.23; p<0.001), whilst only one study reported for the cervical spine disease group (SMD=0.44, 95% CI: 0.16 to 0.72; p<0.001). Despite the limited sample size in the cervical spine group, interaction tests (p=0.11) suggested a potentially similar trend of improvement between groups. Regarding heterogeneity assessment, this subgroup analysis did not significantly reduce inter-study heterogeneity. I^2 values were 77.77% for VAS analysis and 93.91% for NDI/ODI analysis in the cervical spine group; I^2 = 54.17% for VAS analysis in the lumbosacral spine disease group, I^2 = 77.06% for NDI/ODI analysis, and I^2 = 76.26% for JOA analysis. These findings indicate that disease location along the spinal anatomy was not the primary source of heterogeneity in this study.

In subgroup analyses based on comparison type, the type of comparison employed exerted a certain influence on both the efficacy of UGA treatment and the observed heterogeneity. Subgroup interaction analyses revealed significant differences in VAS pain scores across different comparison designs (p = 0.03), but no significant differences for NDI/ODI functional scores (p = 0.21) or JOA scores (p = 0.10). Specifically, the direct comparison group demonstrated significant improvements in both VAS scores (SMD = −0.75, 95% CI: −0.97 to −0.54; p < 0.001) and NDI/ODI scores (SMD = −1.14, 95% CI: −1.66 to −0.62; p < 0.001), though with high heterogeneity (I^2 = 72.43% and 91.72%). JOA scores also showed significant improvement (SMD = 0.57, 95% CI: 0.19 to 0.94; p < 0.001), with 71.64% heterogeneity. The add-on therapy group demonstrated a larger effect size for VAS scores (SMD = −1.08, 95% CI: −1.28 to −0.89; p < 0.001) and lower heterogeneity (I^2 = 15.41%). NDI/ODI scores also showed significant improvement (SMD = −0.96, 95% CI: −1.32 to −0.59; p < 0.001) with no heterogeneity (I^2 = 0.00%). JOA scores showed the greatest improvement (SMD = 1.20, 95% CI: 0.74 to 1.66; p < 0.001), with no heterogeneity. Treatment effects in the parallel-controlled group

Table 4 GRADE Evidence Quality Assessment for Outcome Measures

Outcome	Number of Studies (Participants)	Quality Assessment					Relative Effect (95% CI)	Certainty of Evidence
		Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias		
VAS scores	27 RCTs (2234 participants)	Serious [a]	Serious [b]	Not serious	Not serious	Not serious [c]	SMD = −0.80 (−0.97, −0.64)	⊕⊕⊕⊖ **MODERATE**
NDI/ODI scores	15 RCTs (1155 participants)	Serious [a]	Serious [d]	Not serious	Not serious	Serious [e]	SMD = −0.99 (−1.36, −0.63)	⊕⊕⊖⊖ **LOW**
JOA scores	7 RCTs (661 participants)	Serious [a]	Serious [f]	Not serious	Not serious	Not serious [g]	SMD = 0.77 (0.43, 1.12)	⊕⊕⊖⊖ **LOW**
Clinical total effective rate	28 RCTs (2187 participants)	Serious [a]	Not serious [h]	Not serious	Not serious	Not serious [i]	RR = 1.15 (1.12, 1.19)	⊕⊕⊕⊖ **MODERATE**
Recurrence rate	2 RCTs (168 participants)	Serious [a]	Not serious [h]	Not serious	Serious [j]	Cannot be assessed [k]	RR = 0.63 (0.27, 1.43)	⊕⊕⊖⊖ **LOW**

Notes: a: Most studies lacked allocation concealment and blinding; b: High heterogeneity present (I^2 = 69.7%); c: Egger's test p = 0.2303, no significant publication bias; d: Very high heterogeneity present (I^2 = 88.5%); e: Egger's test p = 0.0049, significant publication bias detected; f: High heterogeneity present (I^2 = 77.3%); g: Egger's test p = 0.1260, no significant publication bias; h: Acceptable between-study heterogeneity (I^2 < 10%); i: Although Egger's test was significant, the large number of included studies and good effect consistency limited the impact of publication bias; j: Only 2 studies with small sample size, wide 95% CI including null effect; k: Insufficient number of studies. ⊕⊕⊕⊖: moderate certainty evidence; ⊕⊕⊖⊖: low certainty evidence. Each ⊕ symbol represents one level of certainty; ⊖ represents a downgraded level. Text in blue indicates moderate certainty; text in orange indicates low certainty.

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Table 5 Subgroup Analysis Results for VAS, NDI/ODI, and JOA Scores

Subgroups	Outcomes	No. of Studies	SMD (95% CI)	P-Value for Overall Effect	I^2 for Heterogeneity	P-Value forHeterogeneity
Disease Type						
Cervical spine disease	VAS	16	−0.81[−1.05,-0.58]	P=0.00	77.77%	P=0.00
	NDI/ODI	7	−1.01[−1.72,-0.30]	P=0.01	93.91%	P=0.00
	JOA	1	0.44[0.16, 0.72]	P=0.00	NA	NA
Lumbosacral disease	VAS	11	−0.79[−1.00,-0.58]	P=0.00	54.17%	P=0.01
	NDI/ODI	8	−0.97[−1.35,-0.60]	P=0.0	77.06%	P=0.00
	JOA	6	0.84[0.45, 1.23]	P=0.00	76.26%	P=0.00
Comparison Type						
Direct comparison	VAS	17	−0.75[−0.97,-0.54]	P=0.00	72.43%	P=0.00
	NDI/ODI	10	−1.14[−1.66,-0.62]	P=0.00	91.72%	P=0.00
	JOA	4	0.57[0.19, 0.94]	P=0.00	71.64%	P=0.02
Add-on therapy	VAS	6	−1.08[−1.28,-0.89]	P=0.00	15.41%	P=0.26
	NDI/ODI	2	−0.96[−1.32,-0.59]	P=0.00	0.00%	P=0.54
	JOA	1	1.20[0.74, 1.66]	P=0.00	NA	NA
Parallel control	VAS	4	−0.60[−1.01,-0.18]	P=0.00	64.70%	P=0.03
	NDI/ODI	3	−0.54[−1.01,-0.07]	P=0.02	64.84%	P=0.06
	JOA	2	1.00[0.09, 1.92]	P=0.03	84.53%	P=0.01
Age						
≥45 years	VAS	12	−0.71[−1.00,-0.43]	P=0.00	79.51%	P=0.00
	NDI/ODI	8	−0.97[−1.60,-0.34]	P=0.00	93.65%	P=0.00
	JOA	3	0.79[0.13, 1.46]	P=0.02	85.45%	P=0.00
<45 years	VAS	15	−0.89[−1.07,-0.71]	P=0.00	53.97%	P=0.00
	NDI/ODI	7	−1.01[−1.40,-0.62]	P=0.00	73.12%	P=0.00
	JOA	4	0.75[0.32, 1.19]	P=0.00	74.72%	P=0.01
Sample Size						
n>60	VAS	15	−0.82[−1.07,-0.57]	P=0.00	82.32%	P=0.00
	NDI/ODI	9	−0.83[−1.39,-0.26]	P=0.00	93.47%	P=0.00
	JOA	5	0.66[0.28, 1.05]	P=0.00	78.16%	P=0.00
n≤60	VAS	12	−0.77[−0.94,-0.61]	P=0.00	9.76%	P=0.33
	NDI/ODI	6	−1.24[−1.49,-0.98]	P=0.00	14.59%	P=0.29
	JOA	2	1.08[0.30, 1.86]	P=0.01	75.95%	P=0.04
Jadad Score						
≥4 (High quality)	VAS	7	−0.73[−1.09,-0.37]	P=0.00	76.00%	P=0.00
	NDI/ODI	4	−0.72[−1.34,-0.11]	P=0.02	87.06%	P=0.00
	JOA	0	NA	NA	NA	NA
<4 (Low quality)	VAS	20	−0.83[−1.01,-0.65]	P=0.00	68.98%	P=0.00
	NDI/ODI	11	−0.81[−1.05,-0.58]	P=0.00	88.86%	P=0.00
	JOA	7	0.77[0.43, 1.12]	P=0.00	77.72%	P=0.00
Publication Year						
Recent studies (≥2021)	VAS	16	−0.80[−1.01,-0.58]	P=0.00	74.11%	P=0.00
	NDI/ODI	11	−0.99[−1.45,-0.52]	P=0.00	91.02%	P=0.00
	JOA	7	0.77[0.43, 1.12]	P=0.00	77.72%	P=0.00
Earlier studies (<2021)	VAS	11	−0.81[−1.07,-0.56]	P=0.00	65.51%	P=0.00
	NDI/ODI	4	−1.01[−1.63,-0.39]	P=0.00	80.30%	P=0.00
	JOA	0	NA	NA	NA	NA

Abbreviation: NA, not applicable.

were relatively modest, with moderate improvement in VAS scores (SMD = −0.60, 95% CI: −1.01 to −0.18; p < 0.001), and a smaller improvement in NDI/ODI scores (SMD = −0.54, 95% CI: −1.01 to −0.07; p = 0.02), with heterogeneity rates of 64.70% and 64.84% respectively. Although JOA scores showed a significant increase (SMD = 1.00, 95% CI: 0.09 to 1.92; p = 0.03), heterogeneity was high (I^2 = 84.53%). In summary, the add-on therapy group demonstrated superior efficacy in pain relief compared to other comparison types, exhibiting the largest effect size and lowest heterogeneity. Heterogeneity analysis indicated that study design type was one potential factor influencing heterogeneity, though it could not be considered the primary source of study heterogeneity.

In age-based subgroup analyses, UGA therapy demonstrated significant efficacy across all age groups, though the influence of age on effect size and heterogeneity varied depending on the outcome measure. Subgroup interaction analysis revealed no statistically significant differences between age groups in VAS scores (p = 0.30), NDI/ODI scores (p = 0.91), or JOA scores (p = 0.92). The <45 years group exhibited numerically superior effect sizes for VAS scores (SMD = −0.89, 95% CI: −1.07 to −0.71; p < 0.001) and lower heterogeneity (I^2 = 53.97%). NDI/ODI scores also improved significantly in this group (SMD = −1.01, 95% CI: −1.40 to −0.62; p < 0.001), with 73.12% heterogeneity. JOA scores similarly showed significant elevation (SMD = 0.75, 95% CI: 0.32 to 1.19; p < 0.001), with 74.72% heterogeneity. The ≥45 years age group demonstrated significant improvement in VAS scores (SMD = −0.71, 95% CI: −1.00 to −0.43; p < 0.001), though with considerable heterogeneity (I^2 = 79.51%). NDI/ODI scores showed significant improvement (SMD = −0.97, 95% CI: −1.60 to −0.34; p < 0.001), with extremely high heterogeneity (I^2 = 93.65%). JOA scores demonstrated significant elevation (SMD = 0.79, 95% CI: 0.13 to 1.46; p = 0.02), with 85.45% heterogeneity. Results indicated that although the <45 years age group demonstrated numerically superior effect sizes and greater study consistency for pain relief, the between-group difference did not reach statistical significance. Age was also not a primary source of heterogeneity in this study.

Exploratory heterogeneity analyses were also conducted based on sample size (>60 vs ≤60), study quality (Jadad score ≥4 vs <4), and publication year (≥2021 vs <2021). No statistically significant differences in efficacy were observed across these subgroups (interaction test p-values all >0.05), with heterogeneity levels remaining moderate to high. Notably, studies with sample sizes ≤60 exhibited markedly reduced heterogeneity in VAS (I^2=9.76%) and NDI/ODI (I^2=14.59%) analyses. However, this reduction may stem from factors such as study design variations and thus cannot be considered the primary determinant of heterogeneity.

Comprehensive analysis of all subgroups revealed that disease type, comparison type, age, sample size, study quality, and publication year failed to effectively identify the primary sources of heterogeneity in this study. Although add-on therapy groups and small-sample studies exhibited lower heterogeneity in certain indicators, these grouping factors remain insufficient to fully account for the high level of inter-study heterogeneity. The persistent high heterogeneity likely results from multiple combined factors, including variations in acupotomy technique standardisation, operator skill differences, individualised treatment parameters, and patient condition complexity. Of note, acupotomy is an inherently operator-dependent procedure that requires substantial training in both musculoskeletal anatomy and ultrasound-guided manipulation. Differences in practitioner expertise—including experience in lesion identification, needle-knife angulation, and tissue release technique—may directly influence treatment efficacy and contribute to the inter-study variability observed. Furthermore, the absence of standardised competency requirements across the included trials limits the reproducibility of findings and should be considered when extrapolating these results to clinical settings where such specialised expertise may not be uniformly available.

Discussion

This study represents the first meta-analysis to systematically evaluate the efficacy and safety of UGA in treating CSP. Analysis of 32 RCTs involving 2669 patients demonstrated that UGA significantly outperformed control groups in both pain relief and functional improvement. It markedly increased the overall clinical response rate, showed a trend toward reduced recurrence rate, and exhibited superior safety. These findings provide evidence-based support for the application of UGA in CSP treatment, particularly for patients who have failed conservative therapies but do not yet meet surgical criteria.

Pain

Pain is the primary reason CSP patients seek medical assistance and serves as a core indicator for evaluating treatment efficacy. This study demonstrates that UGA therapy exhibits a substantial effect size advantage in pain relief (SMD = −0.80, 95% CI: −0.97 to −0.64). This finding aligns with previous acupotomy studies for musculoskeletal pain,[16,17,56] but ultrasound guidance further enhances treatment precision and efficacy. Subgroup analyses revealed significant insights into pain management. Firstly, the combined treatment modality (add-on therapy group) demonstrated optimal pain relief with the lowest inter-study heterogeneity, suggesting that UGA combined with other conservative treatments may represent an effective therapeutic strategy. This finding aligns with other studies.[57,58] Age may influence treatment outcomes, with patients under 45 years showing numerically greater pain relief effect sizes, though this difference was not statistically significant. This may relate to younger patients' superior tissue repair capacity and relatively less chronicity, providing important guidance for clinicians in patient selection and prognosis prediction. Thirdly, UGA demonstrated comparable pain-relieving effects across different spinal anatomical regions, with no significant therapeutic differences observed between cervical and lumbosacral conditions. This finding holds significant clinical importance, confirming the technique's broad therapeutic value. Furthermore, acupotomy primarily targets pathological ligaments, fascia, and other soft tissues regardless of treatment site, with relatively fixed therapeutic targets resulting in minimal efficacy variation.

UGA alleviates CSP through multiple mechanisms. It modulates central nervous system neurotransmitter levels, such as elevating spinal noradrenaline (NE) to activate descending inhibitory pathways,[59] regulating serotonin (5-HT) distribution,[60] and downregulating substance P (SP) release,[61] thereby blocking pain signal transmission. Concurrently, UGA significantly reduces levels of pro-inflammatory factors including TNF-α, IL-1β, IL-6, and prostaglandin E2 (PGE2),[62] effectively suppressing inflammatory responses. At the tissue repair level, UGA modulates the PI3K/Akt key signalling pathway, activates chondrocyte autophagy levels, regulates the Bcl-2/Bax ratio to inhibit intervertebral disc cell apoptosis, and delays the disc degeneration process.[63,64] The fascia, rich in Aδ and C sensory nerve fibres, participates in pain perception and neurogenic inflammatory processes.[65] UGA achieves effective analgesia by releasing fascial adhesions, restoring tissue flexibility, and blocking pain signal transmission.[12] These multi-layered mechanisms collectively form the theoretical basis for UGA treatment of CSP.

Functionality

Functional impairment is one of the core manifestations of CSP, significantly affecting patients' quality of daily life and work capacity. This study demonstrates that UGA therapy exhibits significant advantages in functional improvement, with NDI/ODI scores showing a large effect size (SMD = −0.99, 95% CI: −1.36 to −0.63). JOA scores also showed a significant increase (SMD = 0.77, 95% CI: 0.43 to 1.12). These findings indicate that UGA effectively enhances spinal function. Functional improvement is closely associated with, yet relatively independent of, pain relief. CSP frequently induces protective postures and avoidance behaviours, with prolonged altered movement patterns exacerbating muscle imbalances, restricted joint mobility, and diminished proprioceptive function.[66] UGA directly improves the local biomechanical environment by precisely releasing adhesions in affected soft tissues such as ligaments and fascia, redistributing mechanical loads and restoring tissue gliding to enhance spinal stability and mobility.[31,40,47,51] Fascia is richly innervated with mechanoreceptors and proprioceptive afferents; its pathological fibrosis impairs proprioceptive input and disrupts neuromuscular coordination patterns.[67,68] Acupotomy therapy restores mechanoreceptor function and normalises afferent proprioceptive signalling, thereby facilitating the recovery of deep stabilising muscle activation and motor control.[39,43,44] Furthermore, under chronic pain conditions, deep stabilising muscles surrounding the spine often become inhibited and atrophied, while superficial muscle groups exhibit excessive tension.[69] UGA therapy helps disrupt this abnormal muscle activation pattern by reducing pain signal input, thereby promoting the functional recovery of deep stabilising muscles. Research indicates that pain relief frequently accompanies functional enhancement, consistent with the significant improvements in both pain and functional measures observed in this study.[16,25,26,29,34–36,42,44–47,49–51,53,55] This suggests UGA can simultaneously address pain-related dysfunction, achieving comprehensive therapeutic outcomes.

Recurrence Rate and Long-Term Efficacy

The recurrence rate of CSP remains a key clinical concern. Only two studies[30,43] reported recurrence rate in this review, showing a trend towards reduced recurrence with UGA treatment (RR=0.63, 95% CI: 0.27–1.43), though the difference was not statistically significant (p=0.27). This finding warrants cautious interpretation. Regarding long-term efficacy, most included studies[27,34,38,43–47] found that CSP patients treated with UGA demonstrated superior pain and functional improvement at 2–6 months compared to short-term outcomes, suggesting a degree of therapeutic persistence. However, three studies[25,28,39] still reported superior short-term effects over long-term effects, indicating a tendency for disease rebound and reflecting inconsistent conclusions in this field. Due to limited studies reporting long-term follow-up data and inconsistent follow-up time points, meta-analysis to clarify UGA's long-term efficacy maintenance was not feasible. Therefore, future research should conduct standardised long-term follow-up studies, establish uniform efficacy evaluation time points and criteria, identify factors influencing efficacy maintenance, and provide evidence-based support for individualised treatment plans and relapse prevention strategies.

Safety

Safety serves as a crucial indicator for evaluating the clinical value of therapeutic approaches. This study demonstrates that the incidence of adverse events in the UGA group ranged from 0 to 13.8%, markedly lower than the 0 to 51.7% observed in the control group, indicating a significant safety advantage. Adverse events during UGA treatment primarily comprised local haematoma, needle syncope, and mild pain at the puncture site, all of which were relatively minor and resolved spontaneously, with no severe complications occurring. The safety advantage of UGA is primarily attributed to the application of real-time ultrasound imaging technology. This technology clearly visualises critical anatomical structures such as vessels and nerves along the acupotomy insertion path, enabling practitioners to precisely avoid risk areas and achieve visualised operations. This significantly reduces the risk of inadvertently damaging vital structures. Compared to conventional acupotomy, which relies on anatomical landmarks and tactile sensation, ultrasound guidance markedly enhances treatment precision and safety. Furthermore, compared to pharmacological treatments and surgical interventions, UGA avoids the systemic side effects associated with long-term medication and complications such as anaesthesia risks and infection associated with surgery. As a minimally invasive technique, it offers the advantages of reduced trauma and rapid recovery, providing a safe and effective treatment option for CSP patients.

Whilst the above findings consistently favour UGA across multiple outcome domains, several methodological considerations warrant caution in interpreting the magnitude of the observed effects. The predominant absence of participant and assessor blinding across the included trials may have introduced performance and detection bias, respectively. Expectation effects and operator allegiance, in which both patients and practitioners were aware of treatment allocation, could have further amplified perceived treatment differences. Additionally, the predominance of small single-centre trials, combined with evidence of publication bias for certain outcomes, suggests that studies reporting negative or null results may be underrepresented in the current evidence base. Collectively, these factors indicate that the true treatment effects of UGA may be more modest than the pooled SMDs suggest, and the findings should be interpreted with this caveat in mind.

Heterogeneity Analysis

In this study, VAS scores (I^2=69.7%), NDI/ODI functional disability indices (I^2=88.5%), and JOA scores (I^2=77.3%) all demonstrated moderate to high heterogeneity, reflecting the complexity of evaluating the effects of UGA interventions on CSP. Comparison type emerged as a significant factor influencing heterogeneity. The add-on therapy group exhibited a marked advantage in heterogeneity reduction, with VAS analysis showing substantially lower heterogeneity (I^2=15.41%) and NDI/ODI analysis demonstrating no heterogeneity (I^2=0.00%). In contrast, direct comparison group exhibited significantly higher heterogeneity (VAS: I^2=72.43%; NDI/ODI: I^2=91.72%), indicating that the combination pattern of interventions significantly influences study heterogeneity. Findings from other pre-specified subgroup analyses were relatively limited. Stratification by disease type, age, study quality, and publication year failed to effectively reduce heterogeneity, with I^2 values in each subgroup largely maintaining their original levels. Although studies with smaller sample sizes demonstrated significantly lower heterogeneity in VAS (I^2=9.76%) and NDI/ODI (I^2=14.59%) analyses,

while larger studies exhibited higher levels of heterogeneity, these findings may be influenced by confounding factors such as study design. While current subgroup analyses have identified some influencing factors, none fully explain the high inter-study heterogeneity. This persistent heterogeneity likely stems from multiple factors: the degree of acupotomy standardisation, variations in operator skill levels, individualised treatment parameters, differences in patient disease duration and severity, and patient compliance. Constrained by the reporting quality and quantity of existing studies, these potential factors remain challenging to explore through in-depth subgroup analyses. Future research requires establishing more refined stratified study designs based on standardised operating procedures. This approach will better control and elucidate sources of heterogeneity, thereby enhancing the reliability of evidence-based medical evidence.

Advantages and Limitations of UGA Therapy for CSP

CSP involves pathological alterations in multiple perispinal structures including intervertebral discs, facet joints, ligaments, muscles, and nerve roots. Conventional acupotomy relies on superficial anatomical landmarks and operator experience, making precise localisation challenging for complex deep lesions and resulting in insufficient targeted release. Indeed, the adoption of ultrasound-guided techniques has expanded substantially across medical specialties, including musculoskeletal medicine, pain management, and interventional procedures, driven by its capacity to improve targeting accuracy, reduce procedure-related complications, and enhance reproducibility across operators and clinical settings.[70] These advantages are particularly relevant in the context of UGA for CSP, where the spinal region's complex anatomy demands exceptional procedural precision. UGA, through real-time ultrasound imaging, clearly visualises structures along the needle-knife pathway such as fascia, muscles, ligaments, bone surfaces, and vascular nerves. Operators can guide the acupotomy under direct visualisation to precisely reach the pathological site for targeted release. Research by Liu et al[54] demonstrated that the positioning error rate for UGA treatment of Third Lumbar Transverse Process Syndrome was only 2.5%, significantly lower than the 20% observed in the conventional acupotomy group. Visualised operation also alleviates patients' psychological stress. Patients transition from passively receiving "blind" treatment to actively participating in a "visualized" precision procedure, diminishing fear and anxiety towards acupotomy therapy while enhancing treatment compliance.

UGA unifies "morphological assessment" with "structural-functional" dual intervention. Real-time ultrasound imaging provides the foundation for evaluating CSP lesion morphology, clearly delineating affected areas and severity. Structural intervention is achieved through guided acupotomy, while functional improvement is validated using metrics such as VAS, JOA, and ODI/NDI. UGA propels CSP diagnosis and treatment from traditional symptom-relief models towards an integrated "morphology, structure, function" approach, establishing novel pathways for developing individualised treatment plans based on imaging evidence.[71]

Despite these advantages, several limitations warrant acknowledgement. The current evidence base remains predominantly of low-to-moderate quality, and the absence of standardised treatment protocols across institutions limits the reproducibility of findings.[12] Additionally, as a minimally invasive procedure involving tissue cutting, UGA carries inherent procedural risks including local haematoma and vasovagal reactions, necessitating careful patient selection and informed consent. Furthermore, robust long-term follow-up data evaluating treatment durability and recurrence prevention remain scarce, which constrains definitive conclusions regarding the sustained efficacy of UGA in the management of chronic pain conditions.

Clinical Implications

The findings of this review carry practical implications for multiple stakeholders. For clinicians, the results support the consideration of UGA as a viable minimally invasive option for patients with CSP who have not responded adequately to conventional conservative treatments but have not yet reached surgical thresholds. The subgroup finding that add-on UGA therapy yields superior outcomes with lower heterogeneity further suggests that integrating UGA into existing treatment regimens, rather than replacing them, may represent an optimal clinical strategy. For researchers, the persistent methodological limitations identified in this review, including inadequate blinding, lack of allocation concealment, and absence of standardised protocols, highlight priority areas for future trial design. Multicentre RCTs with pre-registered protocols, standardised outcome measurement time points, and extended follow-up periods are urgently needed to

generate higher-certainty evidence. For patients, this review provides evidence-based support that UGA is associated with meaningful improvements in pain and function, with a favourable safety profile characterised by mild and self-limiting adverse events. However, patients should be informed that the current evidence is of moderate-to-low certainty, and that treatment outcomes may vary depending on practitioner expertise and individual clinical characteristics.

Limitations and Future Developments

Due to objective factors, this study presents several limitations. (1) The methodological quality of included studies varied considerably, with a scarcity of high-calibre literature. This primarily stems from the technical characteristics of UGA therapy, which render allocation concealment and blinding challenging to implement in practice. As practitioners must be aware of specific procedural protocols during the allocation phase, and patients can distinctly perceive the sensation of needle-knife puncture, standardised RCT designs face inherent difficulties; (2) Regional and linguistic biases may compromise the generalisability of findings. As UGA therapy constitutes an extension of traditional Chinese medicine, all 32 included studies were conducted in China. Differences in patient demographics, practitioner training, and healthcare contexts between China and other regions mean that these findings may not be directly transferable to non-Chinese clinical settings. Furthermore, the limited availability of trained UGA practitioners outside China may constrain the real-world applicability of these results internationally. Future multicentre studies across diverse geographic regions are warranted to establish broader generalisability. In addition, publication bias assessments indicated potential bias in overall efficacy rates and NDI/ODI scores, potentially linked to non-publication of small studies with negative results; (3) Heterogeneity existed between studies. Despite multiple pre-specified subgroup analyses, the sources of heterogeneity could not be fully explained. This heterogeneity may stem from factors including variations in the standardisation of acupotomy manipulation techniques, differences in practitioner experience levels, the degree of individualisation in treatment parameter settings, and stratification of patient disease severity. However, due to limitations in the detail provided by the original research reports, in-depth quantitative analysis of these factors was not feasible; (4) Evidence regarding long-term efficacy and recurrence rate remains relatively limited. Only two studies reported recurrence data, and the relatively short follow-up periods in most investigations constrained a comprehensive assessment of UGA therapy's long-term outcomes and safety; (5) For trials not reporting the SD of change scores, imputation was performed using a correlation coefficient of $r = 0.5$. A formal sensitivity analysis across alternative correlation values was not conducted, which represents a methodological limitation. Future meta-analyses in this field should consider reporting results across a plausible range of assumed correlation coefficients to enhance analytical transparency; (6) Several time-related limitations should be acknowledged. First, most included studies had short follow-up periods ($\leq$ 3 months), and only a few provided long-term outcomes ($\geq$ 6 months), limiting the assessment of sustained efficacy. Second, the intervention durations and follow-up time points varied considerably across studies, contributing to heterogeneity in the pooled estimates. Third, due to insufficient reporting of outcomes at multiple time points, time-course analysis could not be performed to evaluate the durability of treatment effects.

These limitations warrant caution in interpreting findings while also indicating directions for future research improvements. Future studies should prioritise multicentre RCTs conducted across geographically diverse settings to address the external validity concerns identified in this review. Standardised UGA treatment protocols encompassing operator competency criteria, needle-knife specifications, and session parameters should be established to reduce inter-study heterogeneity and enhance reproducibility. Extended follow-up periods of at least 12 months are recommended to evaluate long-term treatment durability and recurrence prevention. Additionally, sham-controlled trial designs with validated blinding procedures should be developed to minimise performance and detection bias inherent to procedural interventions.

Conclusion

Based on moderate-certainty evidence for pain intensity and overall response rate, and low-certainty evidence for functional outcomes, this meta-analysis indicates that UGA is an effective and safe intervention for CSP. Subgroup analyses suggest that add-on UGA therapy yields the most favourable outcomes with the lowest heterogeneity. These findings should be interpreted with caution given the restriction of all included trials to China, the predominance of high

risk of bias related to blinding, and the persistent inter-study heterogeneity. Further high-quality multicentre RCTs with standardised protocols and adequate follow-up are warranted to confirm these findings.

Generative AI Statement

The authors declare that no Generative AI was used in the creation of this manuscript.

Data Sharing Statement

All data generated or analyzed during this study are included in this published article.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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References

1. Raja SN, Carr DB, Cohen M, et al. The revised International Association for the Study of Pain definition of pain: concepts, challenges, and compromises. *Pain*. 2020;161(9):1976–1982. doi:10.1097/j.pain.0000000000001939
2. Safiri S, Kolahi AA, Cross M, et al. Prevalence, Deaths, and Disability-Adjusted Life Years Due to Musculoskeletal Disorders for 195 Countries and Territories 1990-2017. *Arthritis Rheumatol*. 2021;73(4):702–714. doi:10.1002/art.41571
3. Gill TK, Mittinty MM, March LM. Global, regional, and national burden of other musculoskeletal disorders, 1990-2020, and projections to 2050: a systematic analysis of the Global Burden of Disease Study 2021. *Lancet Rheumatol*. 2023;5(11):e670–e682. doi:10.1016/S2665-9913(23)00232-1
4. Cohen SP, Hooten WM. Advances in the diagnosis and management of neck pain. *BMJ*. 2017;358:j3221. doi:10.1136/bmj.j3221
5. Derry S, Conaghan P, Da Silva JA, Wiffen PJ, Moore RA. Topical NSAIDs for chronic musculoskeletal pain in adults. *Cochrane Database Syst Rev*. 2016;4(4):Cd007400. doi:10.1002/14651858.CD007400.pub3
6. Ezzatvar Y, Dueñas L, Balasch-Bernat M, Lluch-Girbés E, Rossettini G. Which Portion of Physiotherapy Treatments' Effect Is Not Attributable to the Specific Effects in People With Musculoskeletal Pain? A Meta-Analysis of Randomized Placebo-Controlled Trials. *J Orthop Sports Phys Ther*. 2024;54(6):391–399. doi:10.2519/jospt.2024.12126
7. Yang YD, Zhao H, Chai Y, et al. A comparison study between hybrid surgery and anterior cervical discectomy and fusion for the treatment of multilevel cervical spondylosis. *Bone Joint J*. 2020;102(8):981–996. doi:10.1302/0301-620X.102B8.BJJ-2019-1666.R1
8. Anderson DB, Shaheed CA. Medications for Treating Low Back Pain in Adults. Evidence for the Use of Paracetamol, Opioids, Nonsteroidal Anti-inflammatories, Muscle Relaxants, Antibiotics, and Antidepressants: an Overview for Musculoskeletal Clinicians. *J Orthop Sports Phys Ther*. 2022;52(7):425–431. doi:10.2519/jospt.2022.10788
9. Rasmussen-Barr E, Halvorsen M, Bohman T, et al. Summarizing the effects of different exercise types in chronic neck pain - a systematic review and meta-analysis of systematic reviews. *BMC Musculoskelet Disord*. 2023;24(1):806. doi:10.1186/s12891-023-06930-9
10. Alshammari HS, Alshammari AS, Alshammari SA, Ahamed SS. Prevalence of Chronic Pain After Spinal Surgery: a Systematic Review and Meta-Analysis. *Cureus*. 2023;15(7):e41841. doi:10.7759/cureus.41841
11. Qiu Z, Jia Y, Shen Y, et al. Acupotomy by an ultrasound-guided technique: a protocol for a systematic review. *Medicine*. 2019;98(42):e17398. doi:10.1097/MD.0000000000017398
12. Hu J, Tong H, Zhang J, Jiang L. Acupotomy for Musculoskeletal Pain: exploring Therapeutic Potential and Future Directions. *J Pain Res*. 2025;18:3027–3036. doi:10.2147/JPR.S518705
13. Expert Group for the Consensus on Acupotomy Therapy for Chronic Musculoskeletal Pain. Chinese pain expert consensus on acupotomy therapy for chronic musculoskeletal pain (2025 edition). *Chin J Pain Med*. 2025;21(2):168–177. doi:10.3760/cma.j.cn101658-20241126-00153.
14. Theodore N. Degenerative Cervical Spondylosis. *N Engl J Med*. 2020;383(2):159–168. doi:10.1056/NEJMra2003558
15. Kirnaz S, Capadona C, Wong T, et al. Fundamentals of Intervertebral Disc Degeneration. *World Neurosurg*. 2022;157:264–273. doi:10.1016/j.wneu.2021.09.066
16. Pu J, Cao W, Chen Y, Fan Y, Cao Y. Ultrasound-guided injection acupotomy as a minimally invasive intervention therapy for cervical spondylotic radiculopathy: a randomized control trial. *Ann Med*. 2023;55(1):2233556. doi:10.1080/07853890.2023.2233556

17. Liang YS, Chen LY, Cui YY, Du CX, Xu YX, Yin LH. Ultrasound-guided acupotomy for trigger finger: a systematic review and meta-analysis. *J Orthop Surg Res*. 2023;18(1):678. doi:10.1186/s13018-023-04127-3
18. Jadad AR, Moore RA, Carroll D, et al. Assessing the quality of reports of randomized clinical trials: is blinding necessary? *Control Clin Trials*. 1996;17(1):1–12. doi:10.1016/0197-2456(95)00134-4
19. Higgins JP, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ*. 2011;343:d5928. doi:10.1136/bmj.d5928
20. Ostelo RW, de Vet HC. Clinically important outcomes in low back pain. *Best Pract Res Clin Rheumatol*. 2005;19(4):593–607. doi:10.1016/j.berh.2005.03.003
21. Ostelo RW, Deyo RA, Stratford P, et al. Interpreting change scores for pain and functional status in low back pain: towards international consensus regarding minimal important change. *Spine*. 2008;33(1):90–94. doi:10.1097/BRS.0b013e31815e3a10
22. Pool JJ, Ostelo RW, Hoving JL, Bouter LM, de Vet HC. Minimal clinically important change of the Neck Disability Index and the Numerical Rating Scale for patients with neck pain. *Spine*. 2007;32(26):3047–3051. doi:10.1097/BRS.0b013e31815cf75b
23. Copay AG, Glassman SD, Subach BR, Berven S, Schuler TC, Carreon LY. Minimum clinically important difference in lumbar spine surgery patients: a choice of methods using the Oswestry Disability Index, Medical Outcomes Study questionnaire Short Form 36, and pain scales. *Spine J*. 2008;8(6):968–974. doi:10.1016/j.spinee.2007.11.006
24. Kato S, Oshima Y, Oka H, et al. Comparison of the Japanese Orthopaedic Association (JOA) score and modified JOA (mJOA) score for the assessment of cervical myelopathy: a multicenter observational study. *PLoS One*. 2015;10(4):e0123022. doi:10.1371/journal.pone.0123022
25. Yao H, Wang N, Zhu YQ, Wang ZY, Liu FH. Ultrasound-guided posterior acupotomy release of the atlantoaxial joint combined with joint blockade for cervicogenic headache. *Mod J Integr Tradit Chin West Med*. 2019;28(07):736–740.
26. Wang JG, Fu LJ, Cui YF, Li XM. Clinical Efficacy of Ultrasound-guided Acupotomy Target Release in Treatment of Cervicogenic Headache. *Shandong J Tradit Chin Med*. 2021;40(10):1095–1099. doi:10.16295/j.cnki.0257-358x.2021.10.012
27. Li SL, Jia Y, Qiu ZY, et al. Clinical study on the treatment of cervicogenic headache with ultrasound-guided acupotomy release of tissue in the cutaneous branch distribution area of cervical nerves. *Chin Res Hosp*. 2025;12(02):13–18. doi:10.19450/j.cnki.jcrh.2025.02.002
28. Wang LX, Ma JY, Zhu LX, Cai YH. Efficacy and safety of ultrasound-guided C2-3 zygapophyseal joint block combined with posterior acupotomy release of the atlantoaxial lateral joint for cervicogenic headache. *J Imaging Res Med Appl*. 2019;3(18):126–127.
29. Liu H, Zhang ZS, Zhang LZ, Gong YR, Yuan MW, Lin X. Effect on the ultrasound-guided acupotomy technique in the treatment of cervical spondylosis. *China Med Her*. 2021;18(15):180–183. doi:10.20047/j.issn1673-7210.2021.15.043
30. Gao X, Zhang SN. Clinical study of musculoskeletal ultrasound-guided knife-needle lysis for cervical spondylotic radiculopathy. *Hebei J Tradit Chin Med*. 2021;43(04):662–665.
31. Cai XS, Ruan YJ, Li XP, Lin ZL, Zhong XL. Clinical Observation on Ultrasound-guided Cervical Nerve Root Acupotomy in Treatment of Cervical Spondylotic Radiculopathy. *J Hubei Univ Chin Med*. 2019;21(05):101–104.
32. Wang JG, Xie SC, Zhu XJ, He CH, Chen Y, Liu HJ. Clinical Efficacy of Acupotome by Ultrasound-guided Technique on Cervical Spondylotic Radiculopathy. *Guid J Tradit Chin Med Pharm*. 2014;20(07):6–10. doi:10.13862/j.cnki.cn43-1446/r.2014.07.003
33. Zhong ZN, Gui H, Jin K, Deng SG, Lin XQ, Wang QF. Clinical observation of ultrasound-guided acupotomy stimulation of the stellate ganglion for vertebral-artery-type cervical spondylosis. *Guid J Tradit Chin Med Pharm*. 2019;25(10):82–114. doi:10.13862/j.cnki.cn43-1446/r.2019.10.021
34. Du W, Ding Y, Liu F, Zhao P, Jia Y, Zhang XT. Clinical observation of ultrasound-guided acupotomy combined with nerve root block for cervical spondylotic radiculopathy. *Chin J Pain Med*. 2023;29(12):948–952. doi:10.3969/j.issn.1006-9852.2023.12.010
35. Huang N, Liu ZP, Wang YW, Zhang ZT, Liu YF. Effect of ultrasound-guided acupotomy soft-tissue release on pain and cervical range of motion in cervical spondylosis. *Shenzhen J Integr Tradit Chin West Med*. 2023;33(13):25–28. doi:10.16458/j.cnki.1007-0893.2023.13.008
36. Quan B, Liu CX, Ma CL. Observation on Effect of Ultrasound-guided Needle Knife Release of Cervical Transverse Process in the Treatment of Cervical Spondylotic Radiculopathy. *Chin Foreign Med Res*. 2024;22(09):56–59. doi:10.14033/j.cnki.cfmr.2024.09.014
37. Liu H, Xiu ZB, Zhang LZ, Gong YR, Yuan MW, Lin X. Clinical observation of ultrasound-guided acupotomy release therapy for cervical-type cervical spondylosis. *Fujian J Tradit Chin Med*. 2018;49(03):8–10. doi:10.13260/j.cnki.jfjtcm.011617
38. Deng F, Li QH, Luo Y, Lei ZK, Yu L, Sun JL. Effect of acupotomy lysis under ultrasound guidance for treatment of cervical radiculopathy. *Zhejiang J Trauma Surg*. 2016;21(02):206–208.
39. Wang LL, Wang YA. Clinical observation of ultrasound-guided acupotomy for radicular cervical spondylosis. *Guid J Tradit Chin Med Pharm*. 2017;23(15):65–67. doi:10.13862/j.cnki.cn43-1446/r.2017.15.020
40. Yuan T, Yao MH, Zhang H. Ultrasound-guided Needle-Knife Loosening Combined with Neck Prescription Granules in the Treatment of Nerve Root Cervical Spondylopathy. *Liaoning J Tradit Chin Med*. 2021;48(04):99–221. doi:10.13192/j.issn.1000-1719.2021.04.029
41. Ruan YJ, Zeng ZM. Acupotomy release of cervical nerve roots for radicular cervical spondylosis. *Chin J Surg Integr Tradit West Med*. 2018;24(04):491–495.
42. Zhu WT, Guo CQ, Zhao L. Clinical Study of Ultrasound-visualized Acupotomy Combined with Fire Needling in the Treatment of Paracentric Lumbar Disc Herniation. *Chin J Tradit Chin Med Emerg*. 2023;32(12):2107–2111.
43. Li SL, Shi C, Wang HL, Deng QY, Zhang YS. Clinical study on ultrasound-guided acupotomy percutaneous release of the ligamentum flavum for the treatment of lumbar disc herniation. *Chin Res Hosp*. 2025;12(03):53–58. doi:10.19450/j.cnki.jcrh.2025.03.007
44. Deng XQ, Xiao ZH. Clinical Observation on Hydro-acupuncture and Acupotomy Guided by Ultrasound in Treating Prolapse of Lumbar Intervertebral Disc. *J Guangzhou Univ Tradit Chin Med*. 2019;36(12):1921–1925. doi:10.13359/j.cnki.gzxbtcm.2019.12.011
45. Chen GS, Chen WZ. Effect of the ultrasound-guided injection acupotomy treatment on pain relief and lumbar function recovery in patients with lumbar disc herniation. *Jilin J Tradit Chin Med*. 2022;42(09):1100–1103. doi:10.13463/j.cnki.jlzyy.2022.09.027
46. Liu XF, Wu YH, Wang HM, Guo JB, Deng XQ, Chen WZ. Clinical Study on Water Needle Knife Guided by Ultrasound in Treating Prolapse of Lumbar Intervertebral Disc. *J Shandong Univ Tradit Chin Med*. 2017;41(04):341–344. doi:10.16294/j.cnki.1007-659x.2017.04.014
47. Wang SJ, Chen XP. Clinical observation of ultrasound-guided acupotomy release at Jiaji points combined with deep needling of Ciliao (BL32) for lumbar disc herniation. *J Cervicodynia Lumbodynia*. 2022;43(05):700–702.
48. Xu YC, Mo HF, Mo PY. Clinical observation of ultrasound-guided miniscalpel-needle treatment for lumbar disc herniation. *J Imaging Res Med Appl*. 2020;4(19):228–230.

49. Deng SX, Qin FL, Sun C, Nie RR, Yu D. Ultrasound-guided press-through acupotomy using proximal-distal acupoint pairing for lumbar disc herniation. *Jilin Med J*. 2025;46(01):40–43.
50. Yuan T, Wei W, Gong YZ, Yao XS, Zhang H. Clinical study on ultrasound-guided needle-knife loosening combined with Yaofang granules in the treatment of lumbar intervertebral disc protrusion. *Pract Pharm Clin Rem*. 2021;24(04):330–333. doi:10.14053/j.cnki.ppcr.202104009
51. Yan F, Ren SJ, Zhao LN, Su K. Clinical Observation of Visualization Needle-Knife Combined with Medical Ozone on the Treatment of Acute Lumbar Facet Joint Disorder. *Chin J Tradit Med Traumatol Orthop*. 2024;32(12):38–42. doi:10.20085/j.cnki.issn1005-0205.241207
52. Li R, Wang RS, Huang XQ, Wei Z, Zhang HB, Tang RF. Efficacy of ultrasound-guided miniscalpel-needle combined with nerve block for lumbosacral pain in ankylosing spondylitis. *Shaanxi J Tradit Chin Med*. 2025;46(07):997–1001.
53. Chen JJ, Yang YG, Wang CJ, Du DF, Li YY, Meng XD. Curative effect of musculoskeletal ultrasound-guided needle-knife combined with local block treatment for third lumbar vertebrae transverse process syndrome. *Hebei J Tradit Chin Med*. 2022;44(04):622–631.
54. Liu Z, Wu F, Liu FF. Clinical value of musculoskeletal ultrasound-guided acupotomy for third lumbar transverse process syndrome. *J Med Imaging*. 2024;34(01):162–163.
55. Xu QL, Wang HY, Zhan JJ, Wu D, Du FF. The treatment of third lumbar transverse process syndrome by ultrasound visualization injection and acupotomy based on holistic mechanics. *Chin J Gen Pract*. 2025;23(01):131–134. doi:10.16766/j.cnki.issn.1674-4152.003851
56. Lee CJ, Luo WT, Tam KW, Huang TW. Comparison of the effects of acupotomy and acupuncture on knee osteoarthritis: a systematic review and meta-analysis. *Complement Ther Clin Pract*. 2023;50:101712. doi:10.1016/j.ctcp.2022.101712
57. Zhao G. Effect of ultrasound-guided cervical acupotomy release on cervical joint range of motion in elderly patients with radicular cervical spondylosis. *J Med Theory Pract*. 2023;36(14):2409–2411. doi:10.19381/j.issn.1001-7585.2023.14.024
58. Yu Q, Zheng E, Li X, Ding X. Greater occipital nerve acupotomy combined with ultrasound-guided stellate ganglion block in the treatment of a case of cervicogenic headache. *Minerva Med*. 2023. doi:10.23736/S0026-4806.23.08740-2
59. Ji B, Liu QG, Guo CQ, Zhu LP, Wang Y, Xu C. Effects of acupotome dissolution therapy and electro-acupuncture on central monoamine neurotransmitters in rabbits with knee osteoarthritis. *J Beijing Univ Tradit Chin Med*. 2009;32(09):598–602.
60. Ji B, Guo CQ, Jin Y, Zhong DW, Chen YN, Guo MW. Effects of acupotome and electro-acupuncture on pain threshold and monoamine-neurotransmitters of central nerves in rats with knee osteoarthritis. *Chin J Pathophysiol*. 2010;26(06):1091–1095.
61. Zhang LY, Chen XY. Water Needle Knife Combined with Tongbi Tincture and Hot Compress in Treatment of Periarthritis of Shoulder and The Effect of Plasma Beta-Endorphin and Substance P Content. *Chin Arch Tradit Chin Med*. 2018;36(08):1841–1843. doi:10.13193/j.issn.1673-7717.2018.08.012
62. Nie KQ, Zhang ZW, Luo G, Su AG. Miniscalpel-needle treatment for lumbar disc herniation and its effects on serum inflammatory factors and pain mediators. *J Cervicodynia Lumbodynia*. 2021;42(01):136–137.
63. Yan J, Hu JS, Hu X, Tang HT, Li J. Effect of acupotomology therapy on expression of apoptosis-regulating genes Bcl-2 and Bax in degenerative rabbit lumbar intervertebral disc. *J Hubei Univ Chin Med*. 2023;25(01):5–9.
64. Jia XF, Ran L, Ma XS, Li SL, An WZ, Hao YJ. Regulation of chondrocyte autophagy by acupotomy to promote chondrocyte homeostasis in osteoarthritis. *Chin J Tissue Eng Res*. 2024;28(34):5452–5457.
65. Machi A, Patel A, Ottestad E. Nerve stimulation and neuromodulation for painful nerves: a narrative review. *Int Orthop*. 2025;49(5):989–996. doi:10.1007/s00264-025-06498-0
66. Pope MH, Goh KL, Magnusson ML. Spine ergonomics. *Annu Rev Biomed Eng*. 2002;4(1):49–68. doi:10.1146/annurev.bioeng.4.092101.122107
67. Suarez-Rodriguez V, Fede C, Pirri C, et al. Fascial Innervation: a Systematic Review of the Literature. *Int J Mol Sci*. 2022;23(10):5674. doi:10.3390/ijms23105674
68. Langevin HM. Fascia Mobility, Proprioception, and Myofascial Pain. *Life*. 2021;11(7):668. doi:10.3390/life11070668
69. Kondrup F, Gaudreault N, Venne G. The deep fascia and its role in chronic pain and pathological conditions: a review. *Clin Anat*. 2022;35(5):649–659. doi:10.1002/ca.23882
70. Chiaramonte R, Bonfiglio M, Castorina EG, Antoci SAM. The primacy of ultrasound in the assessment of muscle architecture: precision, accuracy, reliability of ultrasonography. Physiatrist, radiologist, general internist, and family practitioner's experiences. *Rev Assoc Med Bras*. 2019;65(2):165–170. doi:10.1590/1806-9282.65.2.165
71. Kim DY, Lee JS, Lee SH, et al. Effectiveness and safety of ultrasound-guided needle-knife therapy for patients with spinal pain disorders: a systematic review and meta-analysis. *Front Med Lausanne*. 2025;12:1705669. doi:10.3389/fmed.2025.1705669