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Review

A Review of Recent Progress Regarding the Mechanisms and Effectiveness of Acupotomy for Treating Cervical Spondylosis

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Abstract

Cervical spondylosis (CS) is a prevalent age-related degenerative condition of the cervical spine that often leads to neck pain, radiculopathy, and functional impairment. Acupotomy, a minimally invasive therapy that combines acupuncture theory with small scalpel-based intervention, has attracted increasing attention in recent years. This review explores the latest mechanistic insights into acupotomy's therapeutic effects on CS, particularly focusing on neuromodulation, anti-inflammatory pathways, apoptosis regulation, and gut microbiota involvement. By integrating findings from both clinical trials and molecular studies, this paper aims to establish a comprehensive multidisciplinary understanding of acupotomy's value in managing CS. Furthermore, we emphasize its potential role as a bridge between traditional Chinese medicine and modern biomedical approaches. Our findings suggest that acupotomy holds significant promise as a safe, effective, and integrative modality for CS treatment, meriting inclusion in future clinical practice guidelines and translational research.

Keywords: acupotomy; cervical spondylosis; mechanisms; microcirculation; neuroimmune modulation

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Introduction

Cervical spondylosis (CS) is a progressive degenerative disorder of the cervical spine associated with intervertebral disc degeneration, osteophyte formation, and spinal canal narrowing. It is a leading cause of neck pain, radiculopathy, and myelopathy, significantly impairing patients' quality of life and functional capacity [1–3]. With increasing life expectancy and sedentary digital lifestyles on the incline, the incidence of CS is rising among both elderly and young populations [4]. Conventional therapies, including physical therapy, pharmacological interventions, and surgery, offer variable degrees of success and often fail to address the root causes of degeneration.

Acupotomy is a minimally invasive therapeutic modality rooted in Traditional Chinese Medicine (TCM) and refined through modern clinical techniques [5]. Acupotomy, also known as the needle knife technique, originates from the "Nine Classics of Needles" in the *Huangdi Neijing* (*The Yellow Emperor's Inner Classic*) and was developed in China in 1976 by Zhu Hanzhang [6] to release soft tissue adhesions, improve biomechanical alignment, and stimulate local and systemic healing responses. Its effectiveness has been reported for a variety of musculoskeletal conditions, including CS, through its mechanical, neurological, and inflammatory modulation effects [7,8].

Although the body of literature on acupotomy is growing, most reviews have focused on clinical efficacy without integrating underlying mechanisms, cellular effects, or emerging pathways such as the gut-brain-disc axis. A significant knowledge gap remains in understanding how acupotomy exerts multi-system effects, including neuroimmune regulation, apoptosis inhibition, and microbiota-mediated systemic balance.

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This review aims to synthesize current findings on the mechanisms and clinical effectiveness of acupotomy in the treatment of CS. It highlights its novel biological targets, systemic therapeutic potential, and its positioning as a bridge between traditional and modern medicine. Through this review, we aim to provide not only scientific evidence for the application of acupotomy to CS but also an outline of future directions for clinical and translational research.

Epidemiology

Cervical spondylosis is a non-infectious chronic degenerative disorder of the cervical spine that arises due to age-related wear and tear affecting the intervertebral discs, facet joints, and supporting ligaments [9,10]. This degenerative process leads to disc desiccation, osteophyte formation, and hypertrophy of the ligamentum flavum, which together contribute to a narrowing of the spinal canal and potential neural compression [10,11]. According to recent studies, the global prevalence of CS varies widely. The age-standardized global rates for the incidence and years lived with disability of neck pain per 100,000 population were 519 (95% uncertainty interval) and 242, respectively [12].

CS is one of the most common age-related degenerative diseases of the spine, with radiographic evidence appearing in over 50% of individuals older than 40 and in up to 90% of those older than 60. Although a considerable portion of these individuals remain asymptomatic, a growing number will develop chronic neck pain, radiculopathy, or myelopathy, especially as sedentary lifestyles and prolonged use of digital devices become more widespread.

Global epidemiological data indicate wide variability in the prevalence of CS-related symptoms. The one-year prevalence of neck pain is estimated at 25.8%, with higher rates observed in females, urban populations, and individuals in high-income countries. The C5-C6 and C6-C7 spinal levels are most commonly affected. A recent large-scale study suggested an inverted U-shaped age distribution, with peak symptomatic prevalence in the 45-60 age group [13,14]. Unhealthy lifestyles involving digital devices, smartphones, and laptops are contributing to a rising prevalence of cervical spine disorders (e.g., neck pain and degenerative disc disease) among young populations [15–18]. In line with the one-year prevalence data, epidemiological studies consistently indicate that neck pain is more common among women, among individuals in high-income countries compared to low- and middle-income nations, and in urban populations rather than rural ones [19,20].

Moreover, environmental and behavioral risk factors such as poor posture, repetitive cervical motion, and excessive screen time are increasingly associated with the onset of CS in younger adults. The 2015 Global Burden of Disease (GBD) study ranked neck pain as the fourth leading cause of disability-adjusted life years (DALYs) worldwide, underscoring the significant socioeconomic and public health impact of cervical spine degeneration [21,22]. CS is a highly prevalent degenerative condition that is often detected radiographically even in asymptomatic individuals, particularly older adults—a testament to its strong correlation with aging [23]. Clinically, it most frequently manifests as neck pain, which can severely impair function and quality of life, exacerbating the global disability burden [24]. Given the complex interplay between aging, radiographic findings, and symptomatic expression, further research is needed to refine diagnostic accuracy, optimize therapeutic strategies, and improve patient outcomes [25].

Pathophysiology

The pathogenesis of CS involves a cascade of degenerative changes, beginning with biochemical and structural alterations in the intervertebral disc. A reduction in proteoglycan content leads to disc dehydration, loss of disc height, and increased biomechanical stress on adjacent structures. This results in annular fissures, herniation of the nucleus pulposus, and progressive degeneration [26].

As disc height diminishes, ligamentous laxity and joint instability develop, contributing to osteophyte formation and hypertrophy of the facet joints and ligamentum flavum. These bony overgrowths and thickened soft tissues can narrow the spinal canal and intervertebral foramina,

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compressing nerve roots and the spinal cord. In response, normal cervical lordosis may be lost or even reversed into kyphosis, further exacerbating mechanical dysfunction [27–29].

This sequence of pathological events culminates in the reversal of physiological cervical lordosis and the development of kyphotic deformity [30]. With progression, detachment of annular and Sharpey's fibers from the vertebral endplates induces reactive osteogenesis, leading to osteophyte formation along the ventral and dorsal vertebral margins [31]. These osteophytes may encroach upon the spinal canal and intervertebral foramina, contributing to neural element compression [32]. Additionally, disruption of the normal load-sharing mechanisms places excessive stress on the uncovertebral and facet joints, promoting joint hypertrophy and accelerated osteophyte formation within the neural foramina [33]. Collectively, these degenerative processes result in progressive loss of cervical lordosis, restricted segmental mobility, and reduced spinal canal diameter, ultimately leading to neural compromise and clinical symptoms [28,29].

These mechanical alterations are closely tied to inflammatory processes, including upregulation of cytokines (e.g., Tumor Necrosis Factor Alpha (TNF-α), and Interleukin 1 Beta (IL-1β)) and Matrix Metalloproteinases (MMPs), which accelerate cartilage and extracellular matrix degradation. Consequently, patients often experience pain, stiffness, and neurological deficits, reflecting both local and systemic aspects of the degenerative process.

Clinical Manifestations

The clinical presentation of CS varies depending on the location and severity of the degenerative changes. The most common symptom is chronic neck pain, often accompanied by stiffness, a restricted range of motion, and muscle tightness. These symptoms are typically exacerbated by prolonged static posture or repetitive cervical motion [34]. In advanced cases, radicular pain, neurological deficits, and myelopathy may develop due to nerve root or spinal cord compression [35,36]. Symptom severity depends on cervical posture, physical activity, and the degree of neural involvement [14]. Cervical radiculopathy, characterized by radiating pain, numbness, or weakness in the upper extremities, arises from nerve root compression. Myelopathy, caused by spinal cord compression, may manifest as gait disturbances, hand clumsiness, and, in severe cases, bowel or bladder dysfunction [37–39].

Neck stiffness, frequently aggravated by prolonged static postures or sudden movements, results from irritation of the facet joint and soft tissues [40,41]. Occipital headaches, linked to upper cervical nerve irritation, occur in up to 70% of cases and correlate with the severity of neural compression [42].

CS is a degenerative disorder of the cervical spine associated with neurological and musculoskeletal symptoms. Although not immediately disabling, its chronic progression can lead to significant functional impairment. Degeneration of intervertebral discs, facet joints, and surrounding structures contributes to neck pain, stiffness, and potential nerve root or spinal cord compression [43]. Additional symptoms may include occipital headaches (due to upper cervical nerve irritation), dizziness, and shoulder or scapular pain. Symptom severity correlates with the extent of disc degeneration, neural involvement, and spinal misalignment. While not life-threatening, untreated CS can substantially impair daily function, reduce sleep quality, and lead to long-term disability.

Histopathology

Histopathological studies of CS reveal degenerative changes in the intervertebral disc, vertebral endplates, and adjacent ligaments, often overlapping with findings seen in cervical disc herniation. A hallmark feature is the loss of proteoglycans in the nucleus pulposus and annulus fibrosus, leading to decreased hydration and elasticity [44,45].

Inflammatory infiltration by macrophages, especially CD68-positive cells, has been observed in degenerated discs, along with the upregulation of pro-inflammatory mediators such as TNF-α and MMP-3. These molecules contribute to matrix degradation and tissue remodeling.

Comparatively, discs affected by herniation show more acute inflammatory responses, whereas spondylotic discs exhibit more chronic and diffuse degeneration with thickened endplates and irregular collagen deposition. This distinction is clinically relevant, as it guides therapeutic strategies—acute inflammation may benefit from anti-inflammatory intervention, whereas chronic degeneration often requires mechanical and structural correction [46,47].

Furthermore, altered expression of apoptotic markers, such as the Apoptosis Regulator (BAX) and B-Cell Lymphoma 2 (Bcl-2), has been noted in disc tissues, suggesting a role for cell death regulation in the pathophysiology of CS. These findings underscore the importance of targeting both inflammatory and biomechanical pathways in the treatment of CS.

Clinical Evidence of Acupotomy for CS

Overview of Randomized Controlled Trials (RCTs)

Clinical studies, including Randomized Controlled Trials (RCTs) and meta-analyses, have demonstrated the efficacy of acupotomy in managing CS, particularly in alleviating pain, restoring cervical mobility, and improving quality of life. Evidence suggests that acupotomy yields comparable or superior outcomes to acupuncture, physical therapy, or pharmacological interventions.

A study by Yao Zhi-Yuan [48] evaluated ultrasound-guided acupotomy as a minimally invasive adjunct to Percutaneous Cervical Disc Nucleoplasty (PCDN) in patients with Cervical Spondylotic Radiculopathy (CSR). In this study, 70 patients with CSR were randomly divided into an experimental group and a control group, with 35 patients in each group. The control group received PCDN alone, while the treatment group received additional ultrasound-guided acupotomy, which was administered once every five to seven days for a total of four to six sessions based on individual patient conditions. Clinical outcomes were assessed using the Visual Analog Scale (VAS), Neck Disability Index (NDI), and Japanese Orthopedic Association (JOA) cervical spine scores, and the Tanaka Yasuhisa 20-point scale, at baseline, one day, one month, three months, and six months post-procedure. Both groups showed significant improvements compared to the baseline ($p<0.05$), with reductions in VAS and NDI scores and increases in JOA and Tanaka Yasuhisa scores. Notably, the treatment group demonstrated significantly greater improvements than the control group at all follow-up points ($p<0.05$). The effective and excellent rates in the treatment group were also higher at one, three, and six months post-treatment ($p<0.05$). The treatment group also reported higher effective and excellent rates at one, three, and six months, with no adverse events observed during the one-year follow-up. These results indicate that acupotomy enhances the durability and efficacy of PCDN without increasing complications.

Findings from Systematic Reviews and Meta-Analyses

Systematic reviews and meta-analyses provide robust evidence by synthesizing data from multiple studies. Wenkang Dai [49] conducted a systematic review and meta-analysis to evaluate the clinical efficacy of acupotomy combined with massage in the treatment of CSR. Two reviewers independently searched multiple electronic databases from their inception to September 2019 to identify eligible studies. Following Cochrane methodological standards, a broad set of search terms was used, including "cervical spondylosis," "cervical spondylotic radiculopathy," "nerve root cervical spondylotic," "neck pain," "acupotomy," "needle knife," "scalpel needle," "chiropractic therapy," and related terms. Different strategies were applied based on the language and database, with no restrictions on language or article type.

In clinical practice, acupotomy is often used in combination with other modalities, such as manual therapy, rehabilitation exercises, or moxibustion, thereby enhancing synergistic effects. A multicenter trial from China demonstrated that acupotomy not only improved clinical outcomes but also reduced nonsteroidal anti-inflammatory drug (NSAID) consumption and hospital stay duration, indicating its cost-effectiveness.

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Importantly, acupotomy has a favorable safety profile when performed by trained practitioners. Most adverse events are minor and transient, including mild bleeding or soreness at the insertion site. The low complication rate, combined with significant functional gains, supports the inclusion of acupotomy in evidence-based guidelines for the management of cervical spondylosis.

Clinical Efficacy of Acupotomy in Improving CS Symptoms

In recent years, studies have increasingly demonstrated the clinical efficacy of acupotomy in alleviating symptoms of CS. Chan-Young Kwon [50] analyzed 69 RCTs using a blade-needle device with a flat scalpel tip. Studies focused on musculoskeletal disorders, including CS, frozen shoulder, and lumbar stenosis, reported significantly higher levels of effectiveness and cure rates with acupotomy versus active controls. Despite promising results, the review emphasized the need for higher-quality trials to strengthen clinical recommendations.

Mechanisms of Acupotomy in the Treatment of CS

Acupotomy exerts multifaceted therapeutic effects in CS through mechanical, neurological, immunological, and molecular pathways. The technique involves inserting a flat-blade needle into adhered soft tissues or pathological anatomical structures, which releases contractures, improves circulation, and alleviates nerve compression. The mechanism extends beyond local mechanical disruption to involve complex systemic responses.

Acupotomy integrates the dual benefits of acupuncture stimulation and minimally invasive surgical intervention. It elicits acupuncture-like analgesic effects by activating afferent nerve fibers (Aβ, Aδ, and c-fos) [51], triggering the release of neurotransmitters and endogenous opioid peptides (e.g., endorphins and enkephalins) that modulate central and peripheral pain pathways [52]. Simultaneously, it mechanically disrupts soft tissue adhesions, reduces myofascial tension and muscular spasms, enhances microcirculation, and restores cervical biomechanical alignment [53]. This dual-action approach uniquely addresses both neuromodulatory and structural dysfunctions in musculoskeletal disorders.

At the cellular level, acupotomy modulates muscle cell apoptosis by downregulating pro-apoptotic factors (BAX and Caspase-3) in the posterior cervical extensor muscles [54,55] and potentially upregulating anti-apoptotic Bcl expression [56,57]. This balance preserves muscle tissue integrity, prevents degenerative changes, and promotes tissue repair.

The biomechanical effects of acupotomy restore mechanical balance by releasing fascial restrictions and adhesions, improving blood flow, and reducing localized inflammation [58,59]. It interrupts the pathophysiological cascade of CS, addressing muscle spasms, adhesion formation, and nerve compression—thereby normalizing cervical biomechanics and preventing further degeneration [60].

Clinical studies have consistently demonstrated the therapeutic efficacy of acu-potomy in managing CS. A randomized controlled trial by Zhang Zhiwen [61] demonstrated that combining acupotomy with Guizhi-Gegen decoction significantly improved VAS scores, NDI scores, and TCM syndrome scores compared to traction/far-infrared therapy alone ($p<0.05$). Animal studies further revealed that acupotomy mitigated intervertebral disc degeneration in CS models, preserving disc cell density and tissue organization.

Research indicates that acupotomy downregulates pro-inflammatory cytokines (e.g., TNF-α, and IL-1β) in paraspinal tissues and modulates the Phosphoinositide 3-Kinase/protein kinase B/Mechanistic Target of Rapamycin (PI3K/Akt/mTOR) pathway, which regulates cell survival, autophagy, and oxidative stress in intervertebral disc tissues [62,63]. Enhancing cervical microcirculation facilitates the delivery of nutrients, the removal of waste, and tissue repair, thereby preventing the recurrence of adhesions.

In addition, acupotomy's systemic anti-inflammatory effects and modulation of the hypothalamic–pituitary–adrenal (HPA) axis may help restore gut microbiota (GM) balance, offering a novel "gut–disc axis" therapeutic approach [64,65]. Emerging research also suggests that acupotomy may influence the gut–brain axis and alter the composition of GM.

Preliminary Mendelian randomization (MR) analyses have identified GM taxa associated with cervical spondylosis (12 potentially pathogenic and 15 potentially protective) [66]. For instance, Ruminococcus abundance has been correlated with increased bone resorption and intestinal inflammation but inversely associated with bone formation markers [67].

Dysbiosis of the gut microbiota has been implicated in a wide range of conditions, including cardiovascular disease [68,69], Parkinson's disease [70], and disorders of bone metabolism via immune-mediated mechanisms [71].

Clinical Application of Acupotomy in the Treatment of CS

Acupotomy has emerged as an effective, minimally invasive therapy for CS, offering both immediate symptomatic relief and long-term functional improvement. Its clinical application combines precise mechanical intervention with neuromodulatory effects, making it particularly suitable for patients with cervical radiculopathy, myofascial pain syndrome, and cervical disc degeneration.

Technique and Procedure

Patient Assessment

First, a thorough examination of the patient's medical history, a physical examination, and imaging studies, such as X-rays or Magnetic Resonance Imaging (MRI), are carried out to locate the exact sites of pathology.

Needle Insertion

After applying local anesthetic when necessary, the practitioner inserts the acupotomy needle at sites corresponding to both symptomatic and strategic anatomical locations, typically around the cervical spinous processes and adjacent soft tissues.

Manual Manipulation

The practitioner manipulates the needle to engage target tissues, facilitating the release of fascial lesions and muscular adhesions.

Post-Treatment Care

Following treatment, patients may be advised on rehabilitation exercises and lifestyle modifications to enhance treatment benefits and prevent recurrence. The acupotomy technique emphasizes precision in needle placement and manipulation, which calls for trained practitioners adept in both the anatomical and mechanical aspects of the cervical spine [66].

Safety and Complications

While acupotomy is generally considered safe, potential adverse effects should be acknowledged. Complications may include localized pain, bleeding, or infection at the needle insertion sites [7]. Proper training and adherence to sterilization protocols are crucial in minimizing risks. Patient selection is also vital; those with severe underlying pathologies or psychological conditions may require more comprehensive evaluations before proceeding with acupotomy.

Comparative Effectiveness

The effectiveness of acupotomy should be considered alongside conventional treatment modalities such as physical therapy, medication, and surgery. Compared to surgical interventions

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like anterior cervical discectomy and fusion, acupotomy offers a non-invasive alternative that carries fewer risks and accelerates recovery time [72]. Traditional pharmacological treatments often present risks of side effects; hence, acupotomy provides a therapeutic avenue that synergizes well with other conservative strategies.

Future Directions and Research Implications

To advance the clinical integration and global recognition of acupotomy, several key research areas should be prioritized. First, its mechanistic elucidation requires a more in-depth investigation of intracellular signaling pathways such as the PI3K/Akt/mTOR axis, the mitogen-activated protein kinase (MAPK) cascade, and gut-disc-immune interactions to uncover the precise biological effects and potential therapeutic targets of acupotomy. In parallel, microbiome studies are increasingly important, as emerging evidence suggests that spinal degeneration may be linked to the gut microbiota; thus, future research should evaluate how acupotomy influences systemic inflammation and neural regulation through the gut–brain–disc axis. Additionally, standardization of clinical protocols is crucial, given the current variability in acupotomy techniques. Establishing evidence-based guidelines for needling parameters, treatment frequency, and anatomical targets will enhance both reproducibility and patient safety. To ensure scientific rigor and build international credibility, large-scale, multicenter RCTs across diverse populations and healthcare systems are essential. Furthermore, interdisciplinary integration combining acupotomy with rehabilitation science, neuroscience, and biomechanical modeling can foster translational strategies that align traditional therapeutic methods with modern precision medicine. Ultimately, the future success of acupotomy will depend on its scientific validation, collaborative, multidisciplinary research, and responsiveness to the global demand for safe, effective, and holistic approaches to musculoskeletal care.

Conclusion

This study reviews the multifactorial mechanisms and clinical efficacy of acupotomy in the treatment of CS. Acupotomy has emerged as a promising, minimally invasive intervention for cervical spondylosis, offering a unique blend of traditional Chinese medical principles and modern surgical techniques. Its therapeutic effects are mediated not only through mechanical decompression and myofascial release but also via complex neuroimmune, anti-apoptotic, and molecular signaling mechanisms.

This review highlights the multifactorial pathophysiology of CS and presents evidence that acupotomy targets key pathological processes, including inflammation, neural compression, and disc degeneration. By integrating findings from molecular biology, histopathology, and clinical studies, we establish acupotomy as a multidimensional therapeutic modality with growing scientific support.

Given its favorable safety profile, cost-effectiveness, and patient-centered outcomes, acupotomy should be considered a viable treatment option for CS. It holds strong potential to complement mainstream biomedical therapies and bridge gaps between traditional and modern medicine. Further efforts are needed to standardize treatment protocols and validate efficacy through large-scale, multicenter trials.

Author Contributions: Khaliunaa Tumurbaatar designed the study, collected data, and analyzed the results for the manuscript. Fushui Liu conducted the investigation and supervised the study. Ting Fang contributed to the literature screening and assisted in manuscript preparation and editing.

Data Sharing Statement: The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare that they have no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CS	Cervical Spondylosis
DALYs	disability-adjusted life years
TCM	Traditional Chinese Medicine
MMP-3	Matrix Metalloproteinases
TNF-α	Tumor Necrosis Factor Alpha
RCTs	Randomized Controlled Trials
PCDN	Percutaneous Cervical Disc Nucleoplasty
CSR	Cervical Spondylotic Radiculopathy
VAS	Visual Analog Scale
NDI	Neck Disability Index
NSAID	nonsteroidal anti-inflammatory drug
JOA	Japanese Orthopaedic Association
BAX	Apoptosis Regulator BAX
Bcl-2	B-Cell Lymphoma 2
IL-1β	Interleukin 1 Beta
PI3K	Phosphoinositide 3-Kinases
mTOR	Mechanistic Target Of Rapamycin
MAPK	mitogen-activated protein kinase
FAK	Focal Adhesion Kinase
MR	Mendelian Randomization
GBD	Global Burden of Disease
GM	Gut Microbiota
MRI	Magnetic Resonance Imaging

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