

Unravelling the Silence: Exploring Tinnitus Pathophysiology and the Promise of Traditional Chinese Medicine

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Abstract: Tinnitus is a prevalent condition often associated with hearing loss. Tinnitus may persist throughout an individual's life and can result in a range of negative outcomes, including annoyance, anxiety, depression, insomnia, heightened auditory sensitivity, difficulties with concentration, and, in severe cases, suicidal ideation. Although not all individuals experiencing tinnitus require medical intervention, approximately 20% of them pursue clinical assistance. In addition to lidocaine, no pharmacological agents have demonstrated sustained efficacy in the management of tinnitus. Traditional Chinese Medicine (TCM) has shown promise for alleviating tinnitus. Consequently, this review aimed to synthesize the latest findings from both animal and clinical studies, while also examining the potential for comprehensive treatment approaches for tinnitus using TCM based on the understanding of its pathophysiology and neuroimaging mechanisms.

Keywords: tinnitus, hearing loss, auditory system, antidepressants, TCM

Introduction

Tinnitus, defined as the perception of sound in the absence of an external auditory stimulus, is a prevalent and often distressing condition with significant implications for global health.¹ Although transient tinnitus may be harmless, a considerable proportion of individuals experience persistent and intrusive symptoms that adversely affect their physical, psychological, and social well-being.² Clinically, tinnitus is not recognized as a distinct disease entity, but rather as a heterogeneous symptom arising from various pathologies of the auditory system, including otitis media, Meniere's disease, and sensorineural hearing loss (SNHL).^{3,4} In certain cases, it may be the first manifestation of more serious disorders such as acoustic neuroma.⁵

The American Academy of Otolaryngology–Head and Neck Surgery (AAO–HNS) categorizes tinnitus into two types: primary tinnitus, which is idiopathic and may or may not be associated with SNHL, and secondary tinnitus, which is attributable to an identifiable underlying cause.⁶ Although this classification assists in clinical stratification, it does not resolve the major therapeutic challenge, namely the lack of a definitive cure for most patients.

Current treatment strategies differ between these two categories. In primary tinnitus, treatment typically aims to reduce the symptom burden, whereas in secondary tinnitus, the primary objective is to address the underlying pathology.⁶ Despite these distinctions, protocols for treatment, assessment, and referral remain poorly standardized.⁷ In many clinical settings, patients receive care that is inconsistent in scope and quality, with some undergoing excessive intervention and others receiving none.^{8,9} Such variability can lead to prolonged distress, deterioration in the quality of life, increased consumption of healthcare resources, and greater social and economic burdens.

Traditional Chinese Medicine (TCM), an established component of complementary and alternative medicine, has been used for centuries in the management of auditory disorders. TCM treatments for tinnitus include herbal formulations, acupuncture, auricular therapy, and integrative regimens that combine pharmacological and nonpharmacological



approaches.¹⁰ Clinical observations and small-scale studies have suggested potential benefits, including reduced tinnitus severity, alleviation of comorbid symptoms such as anxiety and insomnia, and improved overall quality of life.^{11,12} However, the evidence supporting TCM for tinnitus is limited by its substantial methodological shortcomings. Research in this field demonstrates marked heterogeneity in study design, ranging from uncontrolled case series to randomized controlled trials (RCTs) of variable quality.¹³ Patient selection criteria are often inconsistent, with some studies recruiting solely based on symptom duration and others including heterogeneous patient populations without stratification by tinnitus type or severity.¹⁴ Intervention protocols vary widely in herbal composition, acupuncture point selection, treatment frequency, and duration, making direct comparisons difficult.¹⁵ Additionally, outcome measures lack standardization; studies have employed a variety of tools such as the Tinnitus Handicap Inventory (THI),¹⁶ Visual Analog Scale (VAS),¹⁷ and non-validated symptom scores,¹⁸ further complicating data synthesis and meta-analysis.¹⁸

Systematic reviews and meta-analyses have consistently reported that the certainty of evidence for TCM interventions for tinnitus is low to very low.^{19,20} Common methodological limitations include inadequate blinding of participants and study personnel, which increases the risk of performance and detection bias; small sample sizes that limit statistical power and generalizability; high attrition rates without appropriate handling of missing data; poor reporting of randomization and allocation concealment, leading to selection bias; and short follow-up durations that are insufficient to assess long-term efficacy or relapse.²¹ Risk-of-bias assessments using established tools, such as the Cochrane risk-of-bias framework, frequently classify many domains as high or unclear.²² Moreover, the absence of prespecified study protocols and trial registration raises concerns regarding selective outcome reporting. Cultural and language barriers may also contribute to the under-reporting of negative or inconclusive results,²³ thereby increasing the likelihood of publication bias. These limitations hinder the reliability and applicability of pooled effect estimates and make it difficult to issue strong clinical recommendations for or against TCM use of TCM for tinnitus. While some meta-analyses suggest that TCM interventions may provide statistically significant benefits compared to conventional therapy or placebo,²⁴ the effect sizes are often modest, and wide confidence intervals reflect heterogeneity and imprecision. Importantly, sensitivity analyses that exclude high-risk-of-bias trials often attenuate or negate observed benefits.

To strengthen the evidence base, future research should adhere to rigorous methodological standards, including well-defined eligibility criteria, stratification of participants by tinnitus type and duration, standardized intervention protocols, use of validated outcome measures, adequate sample size calculation, and extended follow-up to evaluate sustained effects. Risk-of-bias reduction strategies such as robust randomization methods, allocation concealment, blinding of outcome assessors, and intention-to-treat analysis should be incorporated to improve internal validity and reproducibility. Transparent reporting in accordance with CONSORT guidelines and mandatory trial registration would further enhance the credibility of the findings.²⁵

In this regard, the present review synthesizes the current knowledge on the pathophysiology of tinnitus, incorporating recent advances in neuroimaging research, and critically evaluates the evidence for TCM and acupuncture as therapeutic options. Special emphasis was placed on identifying methodological gaps, highlighting inconsistencies in trial design and the need for well-powered, high-quality RCTs capable of providing definitive evidence on efficacy and safety. By addressing both the biological rationale and methodological limitations of existing studies, this review provides insight that could be used as a reference to inform clinical decision-making and support the development of robust, evidence-based guidelines for tinnitus management.

Epidemiology

Epidemiological research on tinnitus is complicated by substantial methodological challenges, including inconsistent definitions of the condition and a tendency for studies to focus on specific age groups or occupational cohorts, which have contributed to wide-ranging prevalence estimates.²⁶ Nevertheless, most population-based studies suggest a conservative prevalence of tinnitus among adults of up to 19%.^{27,28} Approximately one-third of the elderly population is likely to experience persistent auditory perceptions consistent with tinnitus, which has been most frequently associated with hearing loss, prolonged exposure to loud noise, advancing age, and stress,²⁹ whereas links with otologic, neurological, infectious, drug-induced, and other comorbid conditions have been less commonly reported.³⁰

Hoffman et al reported one of the most comprehensive epidemiological investigations conducted prior to 2000.³¹ Their analysis has identified several notable epidemiological patterns. They found that the presence and severity of tinnitus were closely associated with the degree of hearing loss, exposure to high levels of occupational and non-occupational noise, and overall health status. Additional factors linked to an increased risk of tinnitus include cardiovascular and cerebrovascular disease, medication use, ear infections and other inflammatory disorders, head and neck trauma (including brain injury), thyroid dysfunction, Meniere's disease, otosclerosis, sudden SNHL, and vestibular schwannoma. The authors also suggested a potential genetic predisposition for tinnitus. Importantly, after adjusting for hearing loss, age alone did not appear to be a major determinant of the prevalence. They estimated that chronic tinnitus affects approximately 10–15% of the adult population and highlighted that military veterans have a substantially higher risk of developing chronic tinnitus than the general population.

Baguley et al³² conducted a comprehensive review of tinnitus epidemiology covering studies published between 1987 and 2012 and reported findings consistent with those of Hoffman et al,³¹ indicating that the prevalence of tinnitus among adults generally ranges between 10% and 15%. Hearing loss emerged as the primary risk factor; however, the authors noted that individuals reporting hearing loss may not necessarily acknowledge tinnitus, whereas some patients with bothersome tinnitus may demonstrate normal auditory thresholds within the standard frequency ranges. Occupational and recreational noise exposure have been identified as major risk factors. Additional risk factors include the use of various prescription and over-the-counter medications, otosclerosis, Meniere's disease, vestibular schwannoma, head trauma, smoking, alcohol consumption, arthritis, obesity, and hypertension.

In addition to the risk factors, Baguley et al³² highlighted several comorbidities frequently associated with tinnitus, such as depression, anxiety, temporomandibular joint disorders, and hearing impairments. Studies examining tinnitus localization revealed that approximately half of the affected individuals perceived the sound centrally in the head or bilaterally, while the remainder most often reported left-sided tinnitus,³³ and a minority of patients believed that the tinnitus originated from an external source. The review also identified a scarcity of longitudinal incidence data, with only one relevant study reporting a baseline incidence of approximately 8% among individuals aged 48–92 years.³⁴ The same study estimated the incidence of new tinnitus cases over five and ten years to be approximately 6% and 13%, respectively.

McCormack et al³⁵ later performed a systematic review of 39 studies that reported the prevalence of tinnitus in adults between 1980 and 2015. Approximately 60% of these studies were conducted in Europe and nearly half were published after 2010. The reported prevalence varied widely from 5% to 43%, reflecting substantial heterogeneity in the study methodology. Only 12 studies employed a consistent definition of tinnitus, yielding prevalence estimates ranging from 12% to 30%. In contrast, eight studies used differing definitions, with roughly one-third defining tinnitus as “lasting more than five minutes at a time.” This inconsistency in case definition likely contributed to the broad variability in prevalence estimates and underscores the need for standardized diagnostic criteria in future epidemiological research.

Sex-based differences in tinnitus prevalence have been consistently observed, with most evidence indicating a higher incidence in men than in women.²⁸ In a large-scale survey conducted in Norway, 21.3% of male participants and 16.2% of female participants reported experiencing tinnitus.³⁶ Among those affected, 9.6% of men and 9.3% of women described their tinnitus as low intensity, 7.3% of men and 4.8% of women reported moderate intensity, and 4.4% of men and 2.1% of women experienced high-intensity tinnitus.³⁷ These findings reinforce the observation that men are more likely to experience tinnitus than women. A similarly large population-based study from New Zealand involving 69,976 individuals aged ≥ 14 years reported an overall tinnitus prevalence of 6.0%, with a higher prevalence in men (6.5%) than in women (5.5%). In addition, the incidence increases with advancing age, peaking at 13.5% among individuals aged ≥ 65 years.³⁸

Epidemiological data also suggest that the prevalence of tinnitus in adolescents is comparable to that in adults. In a survey of 3,892 Belgian high school students, the prevalence of temporary tinnitus attributable to noise exposure was 74.9%, while permanent tinnitus was reported by 18.3% of the students. The occurrence of transient tinnitus appears to increase with age in an adolescent cohort.³⁹ Similarly, a United States study of individuals aged 12–19 years found that 7.5% reported tinnitus lasting at least five minutes within the preceding year, with 4.7% meeting the criteria for chronic tinnitus, corresponding to approximately 1.6 million adolescents nationwide.⁴⁰ In Korea, a study of 3,047 adolescents in the same age range reported an overall prevalence of 17.7%, although only 0.3% experienced severe discomfort due to their condition.⁴¹

Tinnitus in children is likely underrecognized, making accurate prevalence estimates challenging. Nevertheless, available data indicate that its occurrence is comparable to that in adults. A large-scale study from Poland, including 15,199 students aged 7–12 years, reported that 6.0% had experienced tinnitus lasting at least five minutes. No significant sex-related differences in prevalence have been observed in the pediatric population.⁴²

Definition and Classification of Tinnitus

Tinnitus is a common auditory perception that can substantially impair quality of life, particularly when coexisting with other medical or psychological conditions, and its heterogeneous presentation necessitates a comprehensive clinical evaluation that considers the full spectrum of contributing factors.⁴³ As tinnitus often arises from complex interactions between peripheral and central auditory mechanisms, management strategies should be guided by a structured assessment aimed at identifying clinically significant cases and tailoring interventions accordingly.

Clinically, tinnitus is defined as the perception of sound without an external acoustic source. While patients most frequently describe it as ringing, buzzing, or tonal,⁴⁴ the perceived sounds may also be hissing, clicking, or roaring.⁴⁵ Multiple auditory perceptions may coexist in the same individual, with variations in the sound quality, intensity, and temporal patterns. Perception can be unilateral, bilateral, or localized to the head, and may be continuous or intermittent. Tinnitus is further classified as pulsatile or non-pulsatile, with either type potentially being subjective, audible only to the patient or objective, audible to both the patient and an examiner.

One classification framework parallels that used in hearing loss, distinguishing conductive tinnitus from sensorineural tinnitus. Conductive tinnitus is typically attributable to alterations in middle ear physiology, blood flow, and muscular activity.⁴⁶ Examples include tinnitus secondary to otitis media, tympanic membrane perforation, tensor tympani or stapedius muscle spasms,⁴⁷ and tension tympanum syndrome.⁴⁸ In contrast, sensorineural tinnitus arises from dysfunction of the sensory or neural components of the auditory system. Pathological changes may occur at the level of the cochlea, auditory nerve, brainstem, or auditory cortex and can involve injury to hair cells, cochlear synapses, spiral ganglion neurons, or the stria vascularis. Sensorineural tinnitus is the most prevalent form of tinnitus and frequently associated with SNHL.

Accurate classification also requires an understanding of the reference standard for normal-hearing thresholds. The concept of “audiometric zero” was established in large-scale measurements at the 1939 World’s Fair in New York and San Francisco, defining the mean hearing threshold of 19-year-olds at 1 kHz as the 0 dB hearing level (HL). This value represents the minimum sound pressure level detectable by an average young adult with normal hearing. Deviations from this baseline, even within the clinically “normal” range, may be clinically relevant, as small threshold shifts can precipitate tinnitus in susceptible individuals. A schematic summary of the tinnitus classification is presented in [Figure 1](#).

Diagnosis

The diagnosis of tinnitus requires a systematic and multidisciplinary approach that integrates patient history, physical examination, neuropsychological assessment, audiometric testing, and specialized tinnitus evaluations. As tinnitus is predominantly a subjective phenomenon, diagnosis primarily relies on the patient’s description of their symptoms. Objective tinnitus, which is far less common, can be perceived by an external observer and is often associated with vascular abnormalities or muscular activity. In such cases, targeted radiological imaging, such as magnetic resonance imaging (MRI)⁴⁹ or computed tomography (CT),⁵⁰ is essential to identify underlying structural or vascular causes.

A detailed medical history is fundamental and should encompass demographic characteristics (age, sex, and educational background), relevant occupational or environmental exposures, and any family history of tinnitus. Equally important is a thorough characterization of tinnitus itself, including its perceived location (unilateral, bilateral, or central), duration, pitch, loudness, and whether it exhibits rhythmic or pulsatile qualities. These descriptors not only guide differential diagnosis but also help determine the need for further investigations.

Evidence supports the role of routine screening in early detection of associated auditory deficits. In one study,⁵¹ hearing impairment was identified in 13 of the 42 participants, including one case of otosclerosis unrelated to noise exposure. Although definitive causality could not be confirmed in the remaining cases, the audiometric patterns suggest

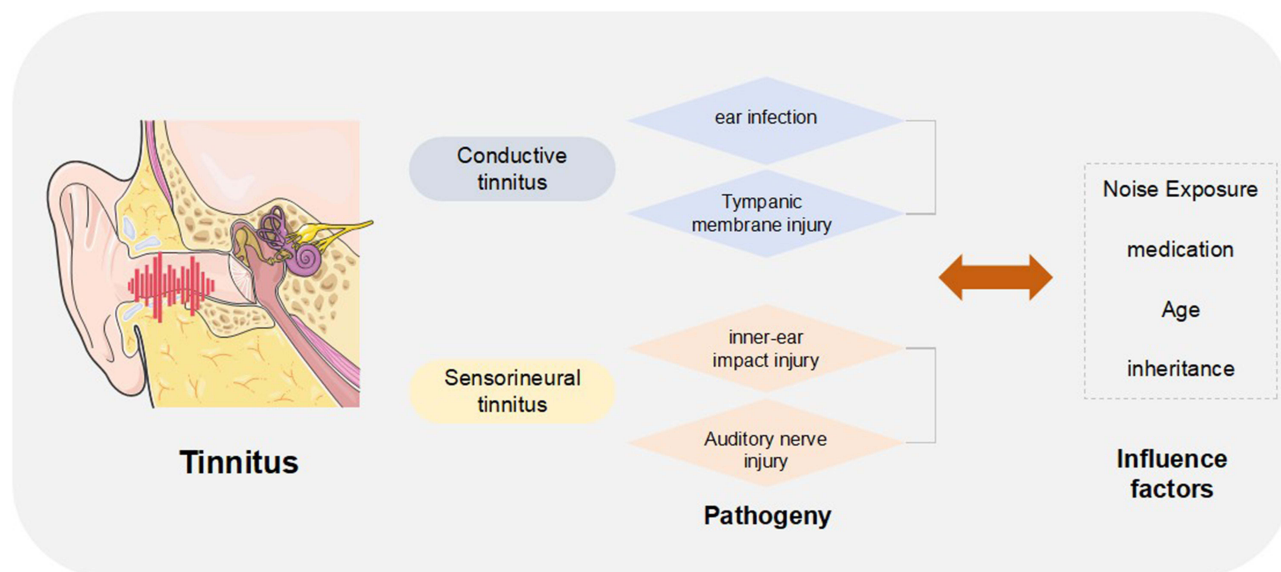


Figure 1 Classification, causes, and influencing factors of tinnitus. Illustration showing conductive and sensorineural tinnitus, their representative causes, and major influencing factors including noise exposure, medication, age, and inheritance.

noise-induced damage. While current screening tools have not yet been validated for widespread use, they may serve as valuable preliminary measures to identify at-risk individuals.

Distinguishing between acute and persistent tinnitus is of clinical relevance. Although definitions vary, chronic tinnitus is generally described as persisting for at least 3–12 months.^{52,53} For patients with tinnitus and hearing difficulties lasting more than six months, a comprehensive audiological evaluation is warranted to determine the presence, type, severity, and symmetry of hearing loss. Given the frequent coexistence of tinnitus and hearing impairment, hearing assessment is also recommended for new-onset tinnitus of less than six months' duration. The results will determine whether further audiological investigations or diagnostic imaging is indicated. Notably, certain tests that attempt to characterize tinnitus sound qualities have limited diagnostic value and do not influence clinical decision making.

Standardized and validated questionnaires are routinely used in both research and clinical settings to evaluate the impact of tinnitus on daily functioning and monitor treatment response. Widely adopted tools include the THI,⁵⁴ the Tinnitus Questionnaire (TQ),⁵⁵ and the Visual Analog Scale (VAS). The TQ, which consists of 52 items, assesses tinnitus-related psychological burden across five domains: cognitive and emotional distress, auditory perceptual difficulties, intrusiveness, sleep disturbances, and somatic complaints. It has demonstrated strong reliability across different languages.

The clinical features and diagnostic framework of tinnitus are summarized in Figure 2. Collectively, an accurate diagnosis of tinnitus requires an integrated evaluation strategy that combines detailed patient-reported information with targeted clinical, audiological, and imaging assessments, ensuring that management decisions are evidence-based and individualized.

Pathophysiology

Substantial progress has been made in recent decades to elucidate the mechanisms underlying tinnitus morbidities. Although no consensus exists, the prevailing view is that tinnitus often arises as a consequence of peripheral hearing loss.⁵⁶ This condition typically results from the disruption of auditory signal transmission from the cochlea to the auditory cortex, most commonly due to partial injury to the inner ear hair cells.⁵⁷

Much of the current understanding is derived from animal studies, which demonstrate that tinnitus is characterized by aberrant neural activity in the auditory system in the absence of measurable external sounds. This activity is perceived as an auditory signal, and may be accompanied by psychological distress. Hypotheses proposed to explain these abnormal discharges include increased spontaneous firing rates, enhanced synchrony of neuronal activity, and atypical excitatory patterns.⁵⁸ Cochlear pathology is frequently implicated, even when standard audiometry fails to detect deficits. For instance, moderate acoustic trauma may lead to detachment or degeneration of high-threshold cochlear fibers from their corresponding inner hair cells.^{59–61}

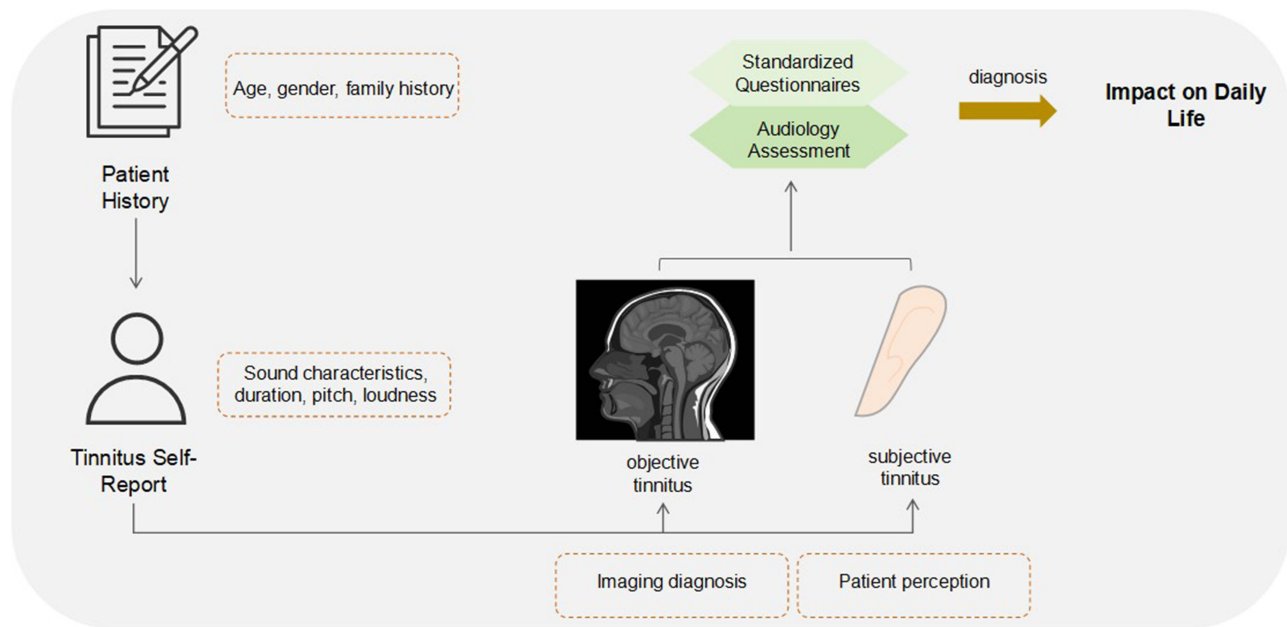


Figure 2 Diagnostic framework for tinnitus. Flowchart outlining the diagnostic process, incorporating patient history, tinnitus self-report, objective and subjective assessment, imaging, and standardized questionnaires to evaluate impact on daily life.

Tinnitus-related activity may originate from both the peripheral and central mechanisms. Peripheral and cochlear mechanisms include N-methyl-D-aspartate receptor activation,⁶² altered operating points of outer hair cells,⁶³ stereociliary detachment,⁶⁴ and elevated intracochlear potentials.⁶⁵ These changes often precede central reorganization, in which reduced inhibitory drive and increased excitatory input create a hyperactive state within the dorsal cochlear nucleus (DCN).⁶⁶ Central mechanisms may further involve cortical tonotopic remapping,⁶⁷ heightened somatosensory modulation of auditory neurons,⁶⁸ and noise-induced hyperactivity in the cochlear nucleus.⁶⁹

Clinical and experimental studies have demonstrated heterogeneity in the peripheral damage and central response among patients with tinnitus. For example, in noise-exposed cohorts, those with tinnitus may exhibit less overall hearing loss but steeper audiometric slopes and higher thresholds at specific frequencies than those without tinnitus.⁷⁰ Furthermore, pitch-matching experiments revealed a close correspondence between tinnitus pitch and audiogram edge frequency in tonal tinnitus, supporting the notion that cortical reorganization at the edge of hearing loss may influence perceptual characteristics.

Neurophysiological investigations in animal models have mapped the progression of tinnitus-related hyperactivity along the central auditory pathway, beginning with frequency-specific increases in spontaneous firing in the DCN and propagation via the inferior colliculus and auditory thalamus to the primary auditory cortex.⁷¹ Across these levels, enhanced neuronal synchrony, increased burst firing, and shifts in frequency tuning toward audiometric edge frequencies have been identified as consistent correlates of tinnitus.^{66,72,73} Central auditory hyperactivity is further amplified by decreased inhibitory neurotransmission, altered receptor expression, and increased excitatory drive, which may be reinforced by spike-timing-dependent plasticity.

Patients with moderate-to-severe noise-induced hearing loss resulting from prolonged occupational noise exposure have been shown to exhibit distinct patterns of audiometric changes, depending on the presence or absence of tinnitus. Individuals with tinnitus demonstrate less overall hearing loss,⁷⁴ a steeper maximum audiogram slope, and higher frequency thresholds than those without tinnitus. No significant differences were observed in these parameters between tonal- and noise-induced tinnitus groups. Another study⁷⁰ examined the relationship between tinnitus pitch and audiogram edge frequency (f_e) in cases of hearing impairment and tonal tinnitus. Among patients with mild-to-moderate sloping hearing loss, the pitch of tonal tinnitus closely matched f_e with targeted training to reduce octave errors in pitch matching, likely explaining why earlier studies failed to establish this association.

Over the past decade, advances in neuroimaging and electrophysiological methodologies in both animal models and human studies have significantly improved our understanding of tinnitus.⁷⁵ Evidence from experimental models has demonstrated that tinnitus is associated with elevated neuronal activity within multiple structures of the central auditory pathway. In animals exhibiting behavioral signs of tinnitus, an early, frequency-specific increase in the spontaneous firing rates of neurons in the DCN has been observed,⁷⁵ interpreted as a compensatory mechanism for reduced input from auditory nerve fibers originating in the cochlea. This hyperactivity subsequently propagates through the inferior colliculus to the auditory thalamus, and ultimately to the primary auditory cortex.⁷¹

Neural synchrony and burst firing patterns, which are regarded as key correlates of tinnitus, have been documented at several auditory processing levels. Within the DC network, synchrony occurs selectively at tinnitus-related frequencies;⁶⁶ in the inferior colliculus, tinnitus correlates with enhanced burstiness and transfiber synchrony;⁷² and in the auditory thalamus, changes in burst characteristics parallel tinnitus severity. Following high-frequency noise exposure in the auditory cortex, neurons corresponding to the region of hearing loss shift their preferred tuning toward edge frequencies, creating an over-representation of these frequencies in cortical maps.⁷⁶ Additional studies report that noise-induced trauma increases spontaneous firing, neuronal synchrony, and burst activity in the primary auditory cortex.^{72,73}

These electrophysiological changes reflect central plasticity mechanisms triggered by altered cochlear inputs. Partial reduction in auditory nerve activity after cochlear damage can reduce inhibitory neurotransmitter levels and alter receptor mRNA and protein expression in the ventral cochlear nucleus and DCN.⁷⁷ Increased excitatory neurotransmission,⁷⁸ enhanced non-auditory projections,⁷⁹ and changes in GABAergic transmission contribute to the excitatory-inhibitory imbalance.⁸⁰ NMDA receptor alterations and spike-timing-dependent plasticity, including stimulation-timing-dependent plasticity in the DCN,⁸¹ further support long-term central reorganization. Hyperactivity from the cochlear nucleus may be conveyed to the thalamus via downregulation of the accessory epiglottis, inducing hyperpolarization of medial geniculate body neurons and leading to thalamocortical dysrhythmia with altered low-frequency and gamma oscillations in the auditory cortex.⁸²

Spindle cells located within the cochlear nucleus are responsible for the integration of auditory and somatosensory afferent projections, employing mechanisms of long-term plasticity contingent on the timing of stimuli.⁸³ Clinically, approximately two-thirds of patients with tinnitus can modulate tinnitus loudness or pitch via somatosensory stimulation of the face or neck,⁸⁴ a phenomenon termed somatosensory tinnitus. This integration of auditory and somatosensory signals at the brainstem level has prompted the exploration of bimodal stimulation therapies that combine auditory and somatosensory input.⁸⁵

Tinnitus, often described as an auditory illusion, warrants detailed investigation of its underlying neural substrates within the auditory system. Although hearing loss, particularly cochlear or other forms of peripheral auditory damage, remains a major risk factor, it does not fully account for the persistence of the condition, as evidenced by its continuation following auditory nerve transection⁸⁶ and its occurrence in individuals without measurable hearing loss.⁵⁹ Such observations suggest that peripheral deafferentation may initiate tinnitus; however, it is a central neural plasticity that sustains its perception.

Animal model studies in which tinnitus was induced by peripheral deafferentation revealed pronounced alterations within the central auditory system (CAS), including tonotopic reorganization, heightened spontaneous activity, and enhanced neuronal synchrony.⁷⁵ Notably, in noise-induced deafness, neurons in cortical regions corresponding to hearing loss zones shift their tuning to preferentially respond to frequencies bordering the impaired range, leading to the overrepresentation of these edge frequencies.⁸⁷ If similar CAS reorganization occurs in humans, high-resolution neuroimaging should theoretically detect these effects. However, comparative studies using magnetoencephalography (MEG) and ultra-high field (up to 7 T) functional MRI (fMRI) have not consistently demonstrated frequency map alterations in tinnitus patients compared to controls, even at frequencies associated with hearing loss or at its audiometric edges.^{67,88-90} This discrepancy between robust animal data and inconsistent human findings highlights the need for advanced imaging paradigms and analysis methods capable of capturing subtle neuroplastic changes that may underlie tinnitus in clinical populations.

Patients with tinnitus exhibit distinct neurophysiological and neuroimaging signatures in both the auditory and non-auditory brain regions. Electrophysiological studies have demonstrated an increased spontaneous firing rate among

cortical auditory neurons, which is further amplified in the presence of external auditory stimuli.⁹¹ Resting-state FDG-PET analyses revealed marked hemispheric asymmetry in the metabolic activity of the primary auditory cortex, with tinnitus patients showing significantly greater left-sided resting activity than both the contralateral hemisphere and healthy controls.⁹²

Beyond the auditory system, convergent evidence from animal and human studies indicates that tinnitus is accompanied by structural and functional alterations in diverse brain regions, including the prefrontal, parietal, and cingulate cortices as well as the amygdala, hippocampus, nucleus accumbens, insula, thalamus, and cerebellum.^{93,94} Resting-state functional connectivity analyses further demonstrated reorganization within large-scale brain networks, interpreted as compensatory adaptations to reduced cochlear input. These adaptations involve the reactivation of regions responsible for auditory memory, salience detection, and emotional processing, which may arise from a mismatch between expected and actual auditory input following peripheral damage.^{95,96} Functional segregation within these networks appears to encode different aspects of tinnitus. Auditory cortex activation is linked to perceived loudness, whereas attentional engagement, salience, and associated distress are related to the co-activation of other resting-state networks.^{95,96} Both electroencephalography and resting-state fMRI data support the presence of increased functional coupling between the auditory cortex and the anterior frontal attention network,^{97–99} consistent with the necessity of long-range connectivity for conscious sound perception.¹⁰⁰ Moreover, tinnitus-related distress correlates with increased activity in neural circuits implicated in stress and emotion, alongside strengthened connectivity between the auditory and stress-responsive regions.¹⁰¹

Overall, these findings indicate that tinnitus emerges from a complex interplay of hyperactivity and maladaptive connectivity changes across the auditory and non-auditory neural systems. This distributed network involvement provides a mechanistic basis for the perceptual, attentional, and emotional dimensions of tinnitus (Figure 3).

Treatment

Currently, no pharmacological agents have been specifically approved for tinnitus treatment, although multiple medications indicated for other conditions have been repurposed to alleviate tinnitus-related symptoms. Among these, antidepressants are frequently considered given the high prevalence of comorbid depression in patients with tinnitus.¹⁰² In placebo-controlled trials, one single-blind¹⁰³ and one double-blind¹⁰⁴ trial, nortriptyline was found to significantly reduce depression severity, tinnitus-related disability, and loudness in patients with severe depressive symptoms. The improvement in tinnitus measures was correlated with reductions in depression scores, suggesting an enhanced benefit for patients with pronounced comorbid depression. Similarly, a six-week course of 100 mg amitriptyline significantly reduced tinnitus symptoms and loudness,¹⁰⁵ whereas trimipramine was not superior to placebo in a small double-blind crossover trial.¹⁰⁶ Evidence for selective serotonin reuptake inhibitors (SSRIs) is mixed, and an RCT reported that sertraline significantly reduced tinnitus loudness and severity,¹⁰⁷ whereas paroxetine, with or without the neurokinin-1 antagonist vestipitant, showed no benefit.¹⁰⁸ Tianeptine, a serotonin reuptake enhancer, improved both depression and tinnitus symptoms in an open-label study.¹⁰⁹ Overall, while the evidence remains limited,¹¹⁰ antidepressants may provide particular benefits for tinnitus patients with coexisting depression or anxiety.

Inhibitory neurotransmission is a recognized component of the pathophysiology of tinnitus,⁸⁰ and benzodiazepines (BZDs),¹¹¹ as positive allosteric modulators of GABAA receptors, have been evaluated for potential therapeutic benefits. Their anxiolytic and sedative properties also make them relevant for addressing common comorbidities, such as anxiety and insomnia, in patients with tinnitus. However, clinical findings remain mixed. In one small RCT, individualized alprazolam dosing reduced tinnitus loudness in 76% of participants after 12 weeks compared to 5% in controls.¹¹² Another RCT found that alprazolam (1.5 mg) significantly improved VAS scores, although no significant changes were observed in THI scores or loudness relative to the placebo.¹¹³ In contrast, a double-blind trial with 21 patients reported no effect of diazepam on tinnitus loudness,¹¹¹ while a prospective randomized single-blind study (10 patients per group) demonstrated that clonazepam significantly reduced VAS scores compared to placebo.¹¹⁴ Although these results suggest that BZDs may confer short-term symptomatic relief, overall evidence is insufficient to support their routine use in tinnitus management. Concerns about adverse effects, particularly the risk of dependence, and reports of tinnitus exacerbation upon discontinuation¹¹⁵ indicate the need for caution, and future research could clarify whether specific patient subgroups might benefit from targeted, short-duration BZD therapy under strict clinical supervision.

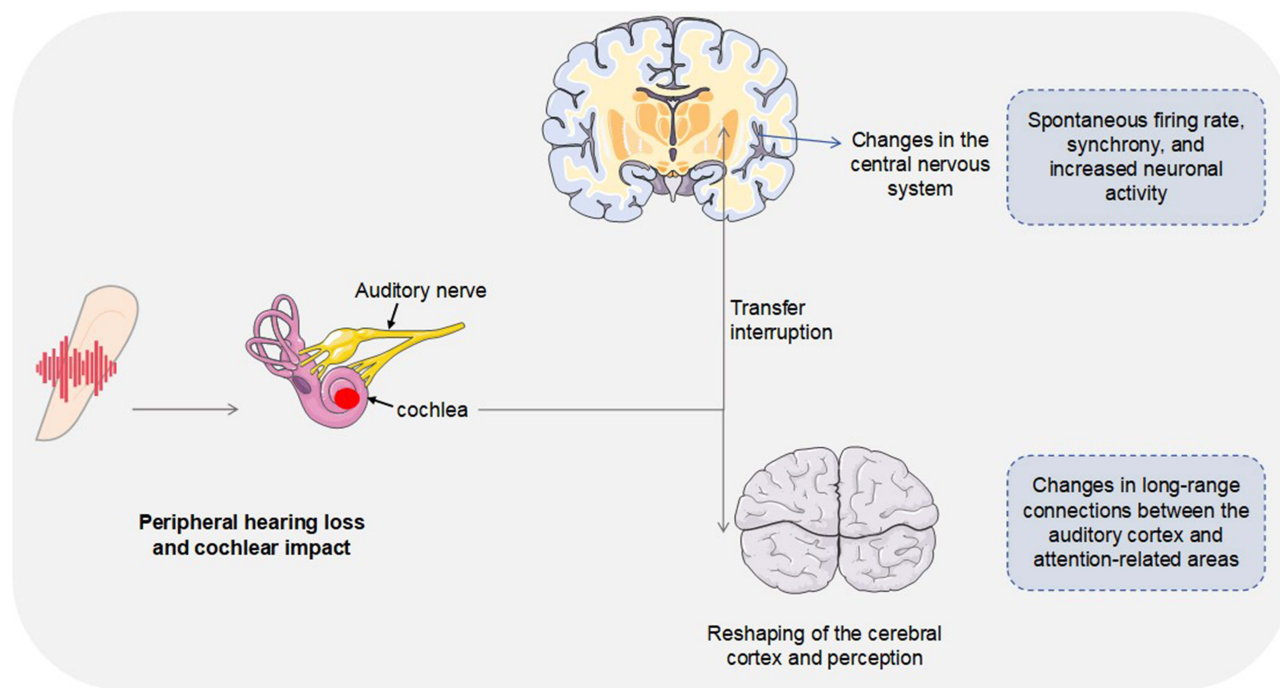


Figure 3 Neural mechanisms underlying tinnitus. Diagram illustrating how peripheral hearing loss and cochlear damage lead to altered auditory nerve signaling, central nervous system hyperactivity, cortical reorganization, and changes in connectivity with attention-related brain regions.

Gabapentin, an anticonvulsant that modulates voltage-gated calcium channels, has been assessed for tinnitus management, based on its established use in seizures, neuropathic pain, and migraine therapy.¹¹⁶ Preclinical studies have demonstrated that gabapentin reduces tinnitus in noise-exposed rats.¹¹⁷ In human trials targeting tinnitus secondary to acoustic trauma, gabapentin significantly decreased both perceived loudness and symptom-related annoyance.¹¹⁸ However, subsequent randomized controlled studies that did not stratify participants according to tinnitus etiology failed to replicate these effects, resulting in inconsistent outcomes.^{119,120} Similarly, potassium channel modulators, such as retigabine, have shown preventive effects on tinnitus onset in animal models;^{121,122} however, a meta-analysis of clinical anticonvulsant trials concluded that the observed benefits were modest, raising doubts regarding their clinical utility.¹²³

Glutamate receptor antagonists have been explored as a strategy to reduce excitatory neurotransmission implicated in tinnitus. Elevated glutamatergic activity is thought to contribute to both acute tinnitus originating in the cochlea and chronic tinnitus arising from maladaptive changes within the central auditory pathway. In this context, early intervention with glutamate receptor blockade after noise exposure has been hypothesized to prevent excitotoxic injury to afferent synapses of inner hair cells.¹²⁴ Carprofen, which inhibits both non-NMDA and NMDA receptors, has been tested via systemic and topical administration, although its therapeutic effects on tinnitus have been limited.¹²⁵ Acamprosate, a nonselective NMDA receptor antagonist originally approved for alcohol dependence, demonstrated favorable outcomes in two double-blind clinical studies.^{126,127} In contrast, memantine, another non-selective NMDA antagonist, failed to show greater efficacy than placebo in a 90-day prospective randomized double-blind crossover trial.¹²⁸ Neramexane, a memantine derivative with dual antagonistic activity against NMDA and $\alpha 9\alpha 10$ nicotinic cholinergic receptors, underwent Phase II evaluation.¹²⁹ While the primary endpoints were not met, an unexpected finding emerged four weeks after treatment cessation: patients receiving 50 mg/day of nivalexanil exhibited significantly higher THI scores than placebo recipients, raising concerns about possible rebound effects or symptom exacerbation after withdrawal.

Dopaminergic system modulation has been investigated as a therapeutic approach for tinnitus¹³⁰ based on evidence that the salience and emotional impact of tinnitus may be mediated by dopaminergic pathways in the mesolimbic and prefrontal regions. In a double-blind placebo-controlled trial, the dopamine antagonist sulpiride significantly reduced subjective tinnitus ratings, with a greater benefit observed when co-administered with hydroxyzine or melatonin.¹³¹ In

contrast, a double-blind placebo-controlled crossover study found no advantage of the dopamine agonist piribedil over placebo.¹³² However, the D2/D3 receptor agonist pramipexole demonstrated significant reductions in both THI scores and perceived tinnitus loudness in a four-week randomized, double-blind, placebo-controlled trial in presbycusis patients.¹³³

In addition to dopaminergic agents, intravenous lidocaine has been shown to transiently suppress tinnitus perception, although its effect is short-lived. Oral antiarrhythmic agents have been examined but yielded limited or inconsistent results.¹³⁴ Several other pharmacological compounds have been tested in small-scale or preliminary studies, including atorvastatin,^{135,136} betahistine,¹³⁷ triamcinolone,¹³⁸ Ginkgo biloba,¹³⁹ melatonin,¹⁴⁰ oxytocin,¹⁴¹ naltrexone,¹⁴² and ondansetron.¹⁴³ While some of these agents have demonstrated isolated positive findings, the overall evidence base remains insufficient, with most studies being limited by small sample sizes, methodological variability, or lack of replication.

In summary, although certain dopaminergic agents such as sulpiride and pramipexole show promise in specific patient subgroups and other pharmacological options have been explored, no intervention to date has demonstrated consistent, reproducible, and clinically meaningful efficacy across diverse tinnitus populations. Large, well-controlled, and mechanistically informed trials are warranted to identify agents capable of delivering sustained therapeutic benefits.

TCM for Tinnitus

Recent RCTs have explored the role of TCM in tinnitus management, often in combination with conventional interventions, with findings suggesting potential benefits across distinct patterns of TCM syndrome.

In a study that evaluated the efficacy of Bupi Shugan Decoction combined with sound therapy in 64 patients with chronic tinnitus attributed to liver depression and spleen deficiency who also presented with anxiety symptoms, compared with sound therapy alone, the combination treatment significantly improved THI, VAS, Self-Rating Anxiety Scale (SAS), and TCM syndrome scores, indicating symptomatic relief, anxiety reduction, and improved quality of life.¹⁴⁴

Tai et al¹⁴⁵ conducted an RCT to evaluate the clinical efficacy of a modified Zhengan Xifeng Decoction combined with cobamamide in patients with tinnitus attributed to liver yang hyperactivity. A total of 86 patients were randomly assigned to either the control group, which received cobamamide alone, or the experimental group, which received the combined treatment, with 43 participants in each group. Outcome measures included tinnitus loudness VAS score, tinnitus severity score, THI score, TCM syndrome integral, hemorheological parameters, and serum oxidative stress markers, specifically glutathione reductase (GR), superoxide dismutase (SOD), neutrophil-to-lymphocyte ratio (NLR), and platelet-to-lymphocyte ratio (PLR). The results demonstrated that the combined regimen significantly improved tinnitus-related scores and TCM syndrome integrals, enhanced hemorheological conditions, and reduced oxidative stress and inflammatory markers compared to cobamamide alone. These findings indicate that the integration of the modified Zhengan Xifeng Decoction with cobamamide may offer superior therapeutic benefits in tinnitus associated with hyperactivity of the liver yang by targeting both symptomatic relief and underlying biological mechanisms.

Yan et al¹⁴⁶ conducted an RCT to assess the efficacy of Erlong Zuoci Pill combined with sound therapy in patients with chronic tinnitus attributed to kidney essence deficiencies. Eighty eligible participants were randomly assigned to either the control group, which received sound therapy alone, or the observation group, which received Erlong Zuoci Pill in addition to sound therapy, with 40 patients in each arm. Both groups underwent three months of treatment. Clinical efficacy was determined by comparing the incidence of adverse events and evaluating changes in THI, tinnitus severity, Pittsburgh Sleep Quality Index (PSQI), and TCM syndrome scores before and after the intervention. The observation group demonstrated significantly greater improvement across all outcome measures than the control group, including enhanced symptom relief, improved sleep quality, and higher overall treatment efficacy, without an increase in adverse events.

These findings suggest that Erlong Zuoci Pill, when used alongside sound therapy, may offer superior benefits for chronic tinnitus associated with kidney essence deficiency, addressing not only symptom burden, but also sleep disturbances and overall functional well-being. The proposed mechanisms of action of TCM in tinnitus management are summarized in [Table 1](#).

Table 1 Reported Mechanisms of Traditional Chinese Medicine Interventions for Tinnitus

Treatment	Mechanism of Action	References
Bupi Shugan Decoction combined with sound therapy	Alleviates tinnitus symptoms, reduces anxiety, and enhances overall quality of life	[146]
Modified Zhengan Xifeng Decoction combined with cobamamide	Improves hemorheological parameters, reduces oxidative stress and systemic inflammation, alleviates tinnitus severity, and enhances overall clinical efficacy	[147]
Erlong Zuoci Pill combined with sound therapy	Improves clinical efficacy, alleviates tinnitus-related signs and symptoms, and enhances sleep quality	[148]

Acupuncture Treatment of Tinnitus

Sun Jin et al¹⁴⁷ conducted an RCT to assess the therapeutic efficacy of Tongdu Tiaoshen acupuncture combined with acupoint catgut embedding in patients with neurogenic tinnitus. One hundred participants were randomly allocated to an observation group (n = 50), receiving combined therapy, or a control group (n = 50), receiving Tongdu Tiaoshen acupuncture alone. Outcome measures included tinnitus severity, SAS scores, and Self-Rating Depression Scale (SDS) scores before and after treatment. The results showed that the combination therapy produced superior improvements in tinnitus severity and greater reductions in anxiety and depression symptoms than acupuncture alone, supporting its recommendation for clinical application.

Hongxia et al¹⁴⁸ performed an RCT of 104 patients with neurogenic tinnitus associated with liver qi stagnation. Participants were assigned to either a treatment group (n = 52), which received temporal three-needle acupuncture combined with a breathing technique, or a control group (n = 52), which received conventional oral medication. Clinical evaluation included the number of cases showing improvement and changes in THI scores pre- and posttreatment. Combined acupuncture and breathing therapy significantly reduced tinnitus severity, alleviated associated symptoms, and lowered tinnitus-related disability, demonstrating superior clinical benefits over medication alone. Xu et al¹⁴⁹ conducted an RCT to evaluate the effects of alternative acupoint electroacupuncture on tinnitus symptoms, microcirculatory function, and central neurotransmitter levels in 80 patients with neurogenic tinnitus. Participants were randomized to a control group (n = 40), receiving standard Western medical treatment, or an experimental group (n = 40), receiving electroacupuncture at selected alternative acupoints in addition to standard care. Compared to the control group, the experimental group achieved greater symptom relief, improved central neurotransmitter profiles, and better regulation of microcirculation.

Collectively, these findings indicate that acupuncture-based interventions, particularly when combined with targeted adjunctive techniques, such as catgut embedding, breathing regulation, or electroacupuncture at alternative acupoints, can produce meaningful clinical improvements in neurogenic tinnitus. The mechanisms of action, summarized in Table 2, are thought to involve the modulation of central and peripheral neural activity, regulation of neurotransmitter levels, enhancement of microcirculation, and reduction of tinnitus-associated emotional distress.

TCM Comprehensive Treatment of Tinnitus

Dong Yunhui et al¹⁵⁰ conducted an RCT to evaluate the efficacy of combining Tiaoshen Tongqiao acupuncture with Wuling capsules in patients with neurogenic tinnitus attributed to heart-blood deficiency. Sixty participants were randomly assigned to either a control group that received Wuling capsules alone or a treatment group that received Wuling capsules plus Tiaoshen Tongqiao acupuncture, with 30 patients in each group. Over a four-week treatment period, multiple outcomes were assessed, including overall clinical efficacy, tinnitus symptom improvement, TCM syndrome scores, THI scores, SAS scores, and PSQI scores. The results indicated that the combined therapy significantly alleviated tinnitus symptoms, reduced anxiety levels, improved sleep quality, and achieved greater overall efficacy than the Wuling capsule alone. Zhao et al¹⁵¹ investigated the clinical efficacy of a multimodal TCM regimen, Tongqiao Huoxue Decoction, Tongfeng Powder, and auricular point pressing pills, in combination with standard Western medical treatment for tinnitus of the qi stagnation and blood stasis types. Eighty-five patients were randomly allocated to a control group (n = 42), which received western treatment alone, or an observation group (n = 43), which received integrated

Table 2 Reported Mechanisms of Acupuncture-Based Interventions for Tinnitus

Treatment	Mechanism of Action	References
Tongdu Tiaoshen acupuncture combined with acupoint catgut embedding	Reduces tinnitus severity and alleviates associated depression and anxiety symptoms	[149]
Temporal three-needle acupuncture combined with pranayama	Provides significant relief of neurogenic tinnitus and related symptoms, and reduces tinnitus-related disability	[150]
Alternating acupoint electroacupuncture	Improves tinnitus-related signs and symptoms, modulates central neurotransmitter levels, and enhances systemic microcirculation	[151]

TCM and Western treatment. Evaluation parameters included TCM syndrome scores, pure tone threshold (PTA), tinnitus evaluation scale (TEQ) scores, anxiety and depression scales, quality of life assessments, clinical efficacy, and adverse reaction rates. The combination regimen significantly improved tinnitus symptoms, reduced anxiety and depression, and enhanced quality of life, with a favorable safety profile compared to Western therapy alone.

Hu et al¹⁵² evaluated acupuncture combined with TCM versus standard western pharmacotherapy in patients with tinnitus due to kidney essence deficiency. Sixty-four participants were randomized to an intervention group (n = 32) receiving acupuncture and a TCM herbal regimen or a control group (n = 32) treated with mecobalamin and flunarizine hydrochloride. Both groups underwent four treatment courses, each lasting one week. Outcomes included THI and VAS scores, as well as serum 5-hydroxytryptamine (5-HT) and γ -aminobutyric acid (GABA) levels before and after treatment. The combined acupuncture–TCM approach yielded greater reductions in tinnitus severity and intensity and more favorable modulation of 5-HT and GABA levels than the standard therapy.

Collectively, these studies indicate that comprehensive TCM-based approaches, particularly when integrating herbal medicine, acupuncture, and adjunctive modalities, can address both subjective symptoms and measurable physiological parameters of tinnitus. As summarized in Table 3, the proposed mechanisms include the regulation of organ system balance, improvement of microcirculation, modulation of neurotransmitter systems, and reduction of emotional distress. The overall treatment strategy for tinnitus is shown in Figure 4.

Challenges in Translational Research

Despite the substantial market potential of tinnitus therapeutics, no pharmacological agents have yet received formal regulatory approval, and industry-driven research remains limited.¹⁵³ Beyond lidocaine and other agents discovered serendipitously, the absence of systematically developed treatments reflects both the multifactorial nature of tinnitus and the persistent gaps in bridging preclinical discoveries to clinical success. The underlying heterogeneity of tinnitus, arising from diverse etiologies, variable symptom profiles, and differences in neural substrates, poses inherent difficulties in the development of universally effective agents. In addition, the neurobiological complexity of tinnitus, with contributions from both the auditory and non-auditory brain networks, challenges the identification of singular therapeutic targets. Leveraging empirical approaches along with advances in information technology, such as computational drug discovery and network-based pharmacology, may facilitate the identification of novel candidate compounds and accelerate preclinical-to-clinical translation.¹⁵⁴

Table 3 Reported Mechanisms of Comprehensive Traditional Chinese Medicine Approaches for Tinnitus

Treatment	Mechanism of Action	References
Tiaoshen Tongqiao acupuncture combined with Wuling capsule	Improves tinnitus symptoms, alleviates anxiety, and enhances sleep quality	[152]
Tongqiao Huoxue Decoction with Tongfeng Powder and auricular point pressing pill	Significantly reduces tinnitus symptoms and alleviates anxiety and depression	[153]
Acupuncture combined with Traditional Chinese Medicine herbal therapy	Reduces tinnitus severity and loudness, and modulates serum levels of 5-HT and GABA	[154]

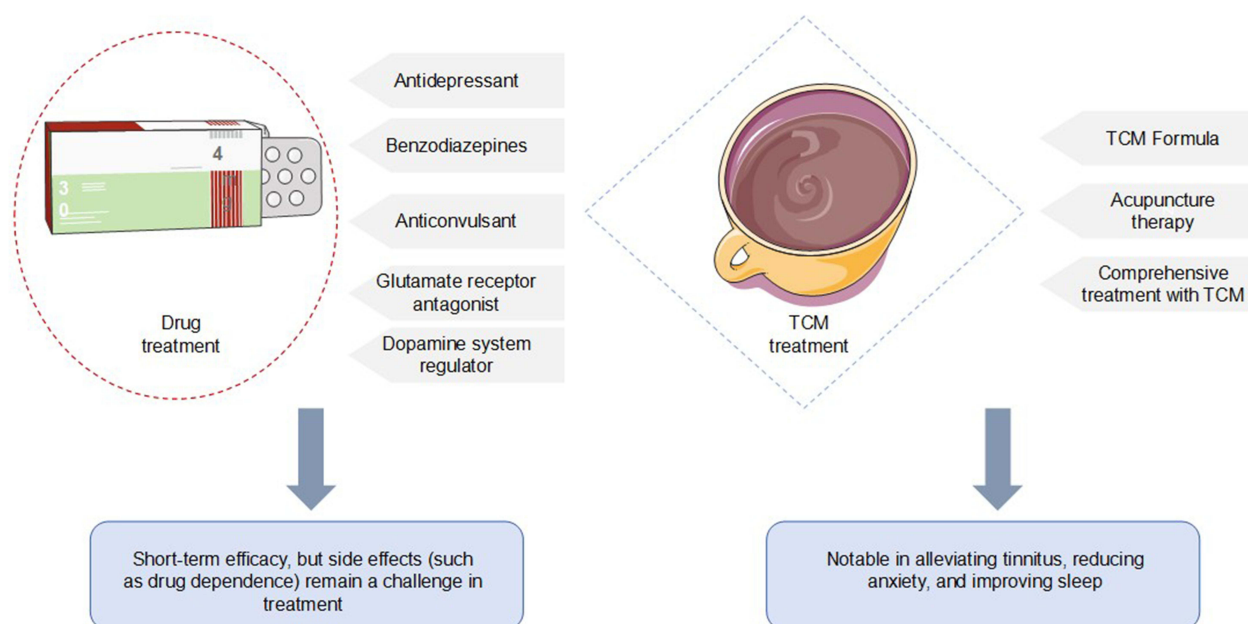


Figure 4 Comparative treatment approaches for tinnitus. Overview of pharmacological and Traditional Chinese Medicine (TCM) treatments, highlighting drug categories, associated challenges, and TCM modalities with reported benefits in symptom relief, anxiety reduction, and sleep improvement.

A major obstacle in this process lies in the limitations of animal models, which remain indispensable for mechanistic studies and early phase drug screening. Two primary challenges impede their optimization: reliable induction of tinnitus and accurate behavioral assessment. Current induction methods, such as systemic administration of ototoxic agents or high-intensity noise exposure, vary in their translational relevance, with the latter more closely simulating human noise-induced trauma. However, epidemiological data indicate that only approximately 17% of patients report tinnitus onset following noise trauma,¹⁵⁵ underscoring the difficulty of generalizing such models to a broader patient population. Moreover, although certain agents, such as carbamazepine¹⁵⁶ and *Eucalyptus bifida*,¹³⁹ have demonstrated efficacy in preclinical models, they have failed to translate into consistent clinical benefits. Similarly, interventions such as a stimulating acoustic environment have attenuated tinnitus behaviors in animal models⁷⁵ but have not yielded comparable effects in human trials.⁹⁹ These discrepancies reflect methodological limitations, including species-specific auditory processing differences, variations in outcome measurements, and the challenge of modeling subjective percepts in non-human systems, thereby cautioning against direct extrapolation from animal data to human clinical contexts.

Limitations in Clinical Assessment

The subjective and heterogeneous nature of tinnitus continues to hinder the development of objective diagnostic and evaluative tools, complicating both the clinical trial design and regulatory approval processes. For example, preliminary human testing of the Gap-Pulse Inhibition of Auditory Sensation (GPIAS), a method with promising animal data, revealed a high false-positive rate at non-tinnitus frequencies,¹⁵⁷ raising concerns about its specificity in human diagnostics. Moreover, tinnitus severity does not always correlate with its psychoacoustic parameters, necessitating a multidimensional assessment strategy that integrates psychoacoustic profiling, VAS scores, THI scoring, and validated impairment questionnaires.^{14,158} However, substantial heterogeneity in trial outcome measures persists,¹⁴ making meta-analysis and evidence synthesis difficult and highlighting the urgent need for consensus-driven standardized assessment protocols.^{9,159,160} This need is particularly pressing given the absence of unified regulatory criteria for the approval of tinnitus drugs.

TCM has gained recognition for its potential role in managing complex multifactorial disorders, such as tinnitus. Herbal agents, including *Ginkgo biloba* and *Astragalus membranaceus*, have been evaluated in clinical trials, yet findings remain inconsistent across meta-analyses.¹⁶¹ Although many traditional formulations are supported by *in vitro* and *in vivo* studies,¹⁶² the precise pharmacological effects of individual herbs on inner ear physiology are often incompletely

characterized. Furthermore, the translation of TCM approaches into mainstream practice is impeded by recurrent methodological limitations including small sample sizes, inadequate control arms, lack of blinding, and inconsistent outcome reporting. To validate both efficacy and safety, future investigations must employ robust disease models, elucidate molecular mechanisms, and conduct well-controlled, double-blind, randomized trials with standardized interventions and long-term follow-up.

Future Directions

Addressing these translational and clinical challenges requires a coordinated multidisciplinary research framework. First, animal model development should prioritize the physiological and behavioral relevance to human tinnitus, incorporating refined induction protocols, cross-species validation, and translational biomarkers measurable in both preclinical and clinical settings. The integration of advanced neuroimaging and electrophysiological techniques into model validation could improve the construct validity and facilitate mechanism-based therapeutic targeting.

Second, the creation of standardized and regulatory-endorsed assessment tools for tinnitus is essential. Consensus-driven core outcome sets encompassing psychoacoustic, functional, and quality-of-life domains would enhance comparability across trials and support regulatory decision-making. Emerging digital health technologies, including mobile-based symptom tracking and ecological momentary assessment, can complement traditional clinic-based measurements and provide richer longitudinal data.

Third, for TCM and other multimodal interventions, future studies should adopt hybrid trial designs that combine mechanistic endpoints with patient-centered outcomes. Rigorous pharmacological characterization of herbal formulations through chemical profiling, target validation, and network pharmacology will be crucial for linking traditional theory with modern biomedical mechanisms. Additionally, adaptive platform trials could enable simultaneous evaluation of multiple candidate interventions, accelerating the identification of the most promising regimens.

Finally, translational success depends on early and sustained collaboration among basic scientists, clinicians, biostatisticians, and regulatory authorities. Public–private partnerships, supported by targeted funding initiatives, could help bridge the resource gap that currently limits large-scale, high-quality tinnitus trials. By integrating these strategies, the field may move closer to delivering reliable, effective, and personalized therapies for tinnitus.

Conclusion

The urgent clinical demand for safe and effective pharmacotherapy of tinnitus remains unmet. Existing off-label drug use primarily targets comorbidities, such as depression, anxiety, and insomnia, with limited direct impact on tinnitus perception. Future progress will likely depend on targeted drug development, combination regimens tailored to tinnitus subtypes, integration of mechanistic insights from preclinical research, and the establishment of standardized clinical outcome measures. TCM has shown encouraging potential in alleviating tinnitus symptoms and improving the quality of life, with multiple clinical studies indicating benefits across different syndrome patterns. Nevertheless, the current evidence base is constrained by factors such as small sample size, methodological heterogeneity, and variable outcome measures. Conducting high-quality, multicenter RCTs with standardized protocols and extended follow-up will be essential to validate efficacy, clarify mechanisms, and promote wider, evidence-based integration of TCM into comprehensive tinnitus management strategies.

Abbreviations

ABR, auditory brainstem response; BDNF, brain-derived neurotrophic factor; BOLD, blood oxygen level-dependent; CNS, central nervous system; dB, decibel; EA, electroacupuncture; EEG, electroencephalogram; fMRI, functional magnetic resonance imaging; GABA, γ -aminobutyric acid; MGB, medial geniculate body; MRI, magnetic resonance imaging; PET, positron emission tomography; RCT, randomized controlled trial; rTMS, repetitive transcranial magnetic stimulation; SNHL, sensorineural hearing loss; TCM, traditional Chinese medicine; THI, Tinnitus Handicap Inventory; VAS, visual analog scale.

Disclosure

The authors declare that they have no affiliation with, or involvement in, any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

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