

Tinnitus: Diagnosis and Treatment Options

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Introduction

Tinnitus derived from the Latin “tinnire” meaning “to ring” is a perceived ringing, buzzing, or hissing in the ear(s) or around the head which has multiple etiologies and is sometimes idiopathic. As of 2009 in the United States, approximately 50 million Americans were affected for six months or greater, while a United Kingdom study in 2000 reported 10% prevalence in the adult population [1]. Tinnitus may vary widely with regard to pitch, loudness, description of sound, special localization, and temporal pattern [2]. Most often, tinnitus is associated with other aural symptoms, such as hearing loss and hyperacusis [3]. Tinnitus may result in sleep disturbances, work impairments, and distress. The severity varies within this cohort of chronic sufferers, with some unable to fulfill daily activities. Though tinnitus is more likely to affect adults and the incidence increases with age, children can experience tinnitus as well [4]. Males are more likely to suffer as are individuals who smoke [5].

Tinnitus can be categorized as objective or subjective. Objective tinnitus can be divided into muscular, pulsatile, and spontaneous. The sound is perceived by other individuals, as well, and is thought to originate somewhere within the body, such as turbulent blood flow or contraction of a muscle (such as the stapedius within the inner ear). Objective tinnitus can give insight to an underlying pathology such as hypertension, dural arteriovenous shunts, or multiple sclerosis. In contrast, subjective tinnitus is only audible to the affected individual. There are several etiologies with the most common being noise-induced tinnitus. Pharmacotherapy including salicylates, non-steroidal anti-inflammatory medication, amino glycoside antibiotics, loop diuretics, and chemotherapy agents are not uncommon culprits.

Ototoxic medication use, history of hearing loss, vertigo, head trauma, bruxism, and triggers are among the questions that should be inquired about to help determine the etiology and to rule-out serious medical conditions [6]. Subjective tinnitus is very common. It can be sub-divided into peripheral and central tinnitus for classification [7]. Central tinnitus can also be divided into primary and secondary central tinnitus. Primary central tinnitus originates in the brain, while the perception of tinnitus, triggered peripherally but manifesting in the brain, can be classified as secondary central tinnitus [8]. Peripheral tinnitus is divided into conductive and sensor neural tinnitus [9]. The current state of knowledge

regarding the etiology and pathogenesis of tinnitus suggests that its etiology, whether symptomatic or idiopathic, is often based upon a primary pathophysiologic process in the ear. With simultaneous hearing loss, the tinnitus frequently appears within the range of the greatest hearing loss [10]. However, the inner ear damage does not need to be obvious in the tone threshold audiogram [11,12].

Somatosensory tinnitus can be evoked or modulated by inputs from the somatosensory and somatomotor systems [13]. Cervicogenic somatosensory tinnitus is a sub-group of patients with somatosensory tinnitus, in which the tinnitus is related to changes in anatomical structures and physiological functions of the cervical region [14]. Based upon a number of animal studies, the existence of neural connections between the auditory system and the cervical region is assumed. The underlying principle is based upon the convergence of auditory signals from the cochlea and somatosensory input from the face, and innervated structures in the cervical region (C1-C4) at the cochlear nucleus, part of the Trigeminal Nerve (V) and the external and middle ears via the common spinal tract of the facial (VII), gloss pharyngeal (IX) and vagus (X) cranial nerves [15,16].

The mechanisms leading to the development of chronic somatosensory tinnitus are similar to those occurring in chronic pain [17]. The common thread for chronic pain and chronic somatosensory tinnitus is sensitization of the peripheral and central nervous system, including the sympathetic nervous system. It is possible that under conditions of central sensitization, the sensitivity of sympathetic innervated cochlear hair cells is increased, and even in the absence of peripheral auditory signals, sound will be perceived and identified as noxious. Chronic somatosensory tinnitus can be linked within a group of conditions, such as chronic back pain, whiplash associated disorders, and chronic fatigue syndrome due to central sensitization [18]. Treatment strategies for tinnitus

Acupuncture: We have found no published studies showing the benefit or efficacy of acupuncture in the treatment of tinnitus [19].

Hyperbaric oxygen: We have found no published studies showing the benefit or efficacy of hyperbaric oxygen therapy in the treatment of tinnitus [20].

Tinnitus counseling: The goal of counseling is to educate the patient on the anatomy and physiology of the ear and tinnitus, and how to cope with tinnitus [21]. The effectiveness of tinnitus counseling has only been addressed in conjunction with other procedures such as cognitive behavioral therapy. There have been no studies of the effectiveness of counseling alone [22].

Acoustic therapy: Acoustic, or sound therapy is using external sounds to provide relief from tinnitus. The rationale is that the increase in the level of external sounds in the patient's environment will decrease the patient's perception of tinnitus. By increasing the level of background sound, we will decrease the tinnitus signal-to-noise ratio. Acoustic therapy is non-invasive, and has no side effects. Patients will often obtain immediate relief from the tinnitus. The patient can exert some control over the tinnitus, utilizing external sounds which can result in reduced anxiety and frustration. Also, increased exposure to external sounds can contribute to reorganization of neural pathways responsible for tinnitus perception. Acoustic therapy can be a vital component of an effective tinnitus management program when used in conjunction with other strategies [23].

Transcranial direct current stimulation (tDCS) with tinnitus retraining therapy (TRT): TRT has a counseling and sound enrichment component (discussed above). tDCS involves two electrodes sending a low current through the brain. Some studies have shown tinnitus relief after tDCS for 82% [24] of the cohort studied while others have only shown improvement for 39.5% [25]. A study by Rabau et al examined the effect of tDCS in combination with TRT. In this study, the tDCS treatment group received a constant current of 2mA for 20 minutes with a fade-in and fade-out of 10 seconds. The sham tDCS group received 10 seconds of 1mA current. The results of this study are yet to be published [26].

Hearing aids: Hearing aids are another form of acoustic therapy that can be beneficial to the tinnitus patient who may also have significant hearing loss. However, tinnitus does not cause hearing loss, but hearing loss makes it more likely for a person to hear tinnitus. Hearing aids do NOT amplify tinnitus. Hearing aids usually reduce the loudness of tinnitus by amplifying external sounds. Using hearing aids to stimulate the auditory system can contribute to permanent reduction in neural activity responsible for tinnitus generation and perception [27].

Music therapy: Active Music Therapy is conducted under the guidance of a music therapist. This is a standardized therapy consisting of nine (9) fifty (50) minute sessions attended on five (5) consecutive days [28,29].

Pharmacotherapy: Pharmacotherapy to treat tinnitus includes antidepressants such as nortriptyline and amitriptyline and benzodiazepines such as clonazepam and oxazepam; however, these medications have limited benefits and chronic benzodiazepines should be used cautiously especially for patients being treated with opioids. Gabapentin is another medication which has had inconclusive results; while it helps some patients, in those with

tinnitus secondary to trauma this effect is variable [30]. Melatonin and niacin have not been found to be effective. Zinc deficiency may increase the risk of cochlear hair cell death (in animal models) but zinc supplementation has yet to be found helpful [31].

Transcutaneous electrical nervous stimulation (TENS): Due to the similarities between tinnitus and central neuropathic pain, TENS may be a useful treatment by interfering with the somatic components of tinnitus. In one study, 20 healthy individuals aged 18-65 were treated with InteriX (a TENS unit modified to sense difference in skin potential and adapt accordingly to prevent overstimulation) for 60 minutes once a week for 2 months at 70Hz. The tinnitus handicap inventory (THI) index decreased by 15.1 points (-27%, $p < 0.0007$); the visual analog score (VAS) decreased 1.45 points ($p < 0.0006$). The quality of life improved (2.4 point reduction; $p < 0.0006$). In other studies, however, there has been both improvement and worsening of symptoms. This may be due to the parameters used for stimulation and/or placement. InteriX may be a better instrument versus traditional TENS due to its ability to adjust the amount of stimulation based on cutaneous feedback [32].

Dental/Orthodontic treatment: TMJ treatments including splints, occlusal adjustments, and jaw exercises have been shown to be more effective than no treatment but just as effective as biofeedback therapy, progressive relaxation, and counseling [33].

One study examined the relationship between tinnitus and TMD therapy in 40 participants with moderate or severe tinnitus. The TMD therapy included a dental splint, a six hour class on coping skills and how to reduce oral habits such as clenching, physical therapy which included stretching exercises and posture training, and/or medications (for three of the subjects). 21 subjects had resolved tinnitus, 12 had significant improvement, 7 had unchanged symptoms, and no subjects developed worse symptoms. Participants who were younger (20-40 years old) were more likely to improve, as were patients who experienced moderate rather than severe tinnitus [34].

Osteopathic Manipulative Treatment (OMT): OMT is an established treatment option to address the underlying structural and functional imbalances which may contribute to peripheral tinnitus. Somatic dysfunction of the head, neck, and shoulders, similar to the cervicogenic somatosensory tinnitus mentioned above, has long been clinically observed as an etiology of tinnitus. A complete and discerning osteopathic physical exam including placatory findings of restricted motion can identify structural etiologies of tinnitus. Gentle osteopathic modalities addressing somatic dysfunction in the cranial and cervical regions may improve or restore the normal functions of delicate neurovascular structures resulting in clinical improvement. In general, an osteopathic approach to tinnitus will include a thorough history and evaluation with the added skill of discerning palpation.

This added dimension of placatory findings of disturbances in the soma that affect function may be of particular benefit not only in amelioration of symptoms (treatment) but in elucidating cause (diagnosis). The goal of an osteopathic approach is always



to restore structure and function as much as possible back to the homeostatic baseline. This approach does not preclude other modalities but rather encompasses them as part of a whole person approach. In addition to tinnitus, chronic somatic dysfunction can mimic a spectrum of conditions including Meniere's disease, Temporomandibular Joint Disorder, Trigeminal Neuralgia, vision changes, headache, otitis media, chronic sinusitis and other conditions [35]. Myofascial pain syndrome has also been reported as a specific etiology of tinnitus. A double blinded, randomized study in Brazil of 75 individuals with tinnitus and myofascial pain syndrome showed effective relief with trigger point injections.

The treatment arm had 10 sessions of myofascial trigger point deactivation/injections around the ear and in the cervical spine which resulted in statistically significant improvement in symptoms ($p < 0.001$) and revealed a statistically significant relationship between pain relief and tinnitus relief ($p < 0.013$). The severity or intensity of tinnitus symptoms was also noted to frequently be affected by physical manipulation [36]. As traditionally described in the cranial osteopathic arena, tinnitus develops due to general dysfunction of the vestibulocochlear nerve (eighth cranial nerve), the trigeminal nerve (fifth cranial nerve) and/or Eustachian tube (ET) often attributed to the abnormal rotation of one or both temporal bones. One structural explanation for the auditory symptoms of tinnitus has been attributed in part to the "friction of blood rushing around the elbow bend in the carotid artery, immediately adjacent..." to the ET. With external rotation of the temporal bone, the ET is held continuously open resulting in "a low-pitched roar."

With internal rotation, the ET may be continuously closed accompanied by a "... high-pitched humming or buzzing [37]." Several other mechanisms of tinnitus have also been offered generally grouped as "Eustachian tube dysfunction" (ETD). ETD is thought to involve abnormal pressure differentials within the ET that affect the function of the middle ear including the tympanic membrane. Etiologies of ETD beyond cranial/temporal somatic dysfunction include mass effect from neoplasms, chronic sinusitis whether infectious or related to airborne allergens, upper respiratory tract infections, rapid changes in surrounding pressure (i.e. air travel, scuba diving, etc.), adenoid tonsillar hypertrophy and others.

In addition, dysfunction of the pharyngeal musculature including the tensor veli palatini muscle which controls the medial opening of the ET within the nasopharynx and the tensor tympani muscle related to tympanic membrane function is another possible cause of ETD and tinnitus. The tensor veli palatini muscle and the tensor tympani muscle share innervations by the medial pterygoid branch of the mandibular nerve, the third branch of trigeminal cranial nerve (V).

OMT of the temporal bones, the occipitomastoid sutures and the temporomandibular joints are the general basis for the cranial approach to OMT of tinnitus. Several specific techniques have evolved to treat ETD including the Gal breath Technique and Muncie/Modified Muncie Technique. The Gal breath technique, first described in 1929 by William Otis Gal breath, DO, involves turning

the affected side of the head away from the examiner who then applies a gentle pumping force to the mandible on the affected side drawing the mandible inferiorly and medially to drain accumulated fluid from the ET.

The Muncie or Modified Muncie Technique treats the nasopharyngeal opening of the Eustachian tube (and tensor veli palatini muscle) through intra-oral OMT with a gloved finger. In one study, 20 healthy patients 18-65 years old were treated once a week for 2 months with OMT. The THI index decreased by 8.5 points (-16.2%, $p < 0.037$); the VAS decreased by 0.45 points. The perceived quality of life did not change. Regarding cervicogenic somatosensory tinnitus, researchers in the Netherlands were able to show a statistically significant reduction in the tinnitus intensity Visual Analog Scale (VAS) after manual treatment. Over 120 individuals were treated between 7 and thirteen times for 30-60 minutes. The results showed statistically significant reductions in VAS scores for patients with both cervicogenic somatosensory tinnitus and tinnitus sensitization. (CST alone, $P = .01$; CST and TS, $P < .001$), and the differences between the groups was clinically significant ($P < .001$).

Discussion

Though the benefit of acupuncture, hyperbaric oxygen, and tinnitus counseling alone have yet to be illustrated, studies exist showing benefit for acoustic therapy, hearing aids, music therapy, transcutaneous electrical nervous stimulation, dental treatment, pharmacotherapy, and osteopathic manipulative treatment.

Conclusion

The soundest approach to treating tinnitus is elucidating cause which will then dictate therapeutics. Once cause is determined, specific individualized treatments may follow. Tinnitus etiologies, treatment modalities, and success rates are widely varied thus proving troublesome to clinicians of all health disciplines. With so many cases of tinnitus ultimately categorized as idiopathic, diverse treatments are often applied toward multiple therapeutic targets that may or may not yield results.

As hinted above, each etiology of tinnitus may exist within a multifactorial spectrum thus exacerbating treatment coordination especially when symptomatic patients seek relief from non-medical modalities and practitioners. The profound impact on the patient and the inherent difficulties in efficiently finding a specific etiology can exacerbate the condition's morbidity and lead to clinical frustration. While an active area of research with the potential for significant advances, the current efficacy of the most commonly used primary care options, pharmaceutical treatment and subspecialty management, is less than optimal.

To better serve those patients who have not responded to pharmaceutical treatment or who return to clinic after subspecialty evaluation with unchanged symptoms, an awareness of the treatment options available outside of one's field will likely lead to a greater understanding the role that other practitioners can play in managing the patient and possibly better outcomes. In cases of

objective tinnitus, identifying and treating the underlying condition (whether hypertension, multiple sclerosis, or arteriovenous shunts) will likely resolve the tinnitus.

The diagnosis and treatment of these conditions are described elsewhere and outside the scope of this paper. Though options for healing central tinnitus and tinnitus resulting from neural damage are currently limited, treating any peripheral dysfunctions that compound the symptomatology may result in the reduction of symptoms. For peripheral tinnitus, a multidisciplinary treatment approach addresses the various possible components of the underlying disease process and is most likely to lead to the reduction or resolution of symptoms. In both OMT and dental/orthodontic approaches, structural components such as the position of the temporal bones or the occlusal surface can be addressed with positive outcome.

Cervicogenic somatosensory tinnitus has a definite structural component that may be addressed with osteopathic treatment of the cervical and cranial dysfunctions. For patients with idiopathic tinnitus, clinicians can encourage patients to pursue a diverse range of therapeutic options beyond pharmacology and subspecialty evaluation. While an evidence-based approach should underly all clinical actions, the response of an idiopathic condition to unknown therapeutic mechanisms should not preclude their use.

Referral to dentists or orthodontists, referral to audiologists, utilization of hearing aids or tinnitus dampening devices, tinnitus retaining therapy (with and without transcranial direct current stimulation), music therapy, behavioral therapy related to reducing factors that lead to jaw clenching and bruxism and osteopathic manipulative treatment are all therapeutic options that can be considered. In addition, therapeutic options with less of an evidence basis such as acupuncture, tinnitus therapy, hyperbaric oxygen and others may also be considered for patients who have not responded to other modalities.

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