Review Article

Surgical Treatment of Tinnitus

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Abstract

Tinnitus is the perception of sound in the absence of an external sound and often results in a disorder of the somatosensory system or the auditory system. Tinnitus is a common clinical symptom that can be debilitating. The risk factors for tinnitus include hearing loss, ototoxicity, head trauma, and depression. Tinnitus is only a symptom that might be the result of different underlying pathologies. The exact treatment of tinnitus has often several options because of its etiological heterogeneity. Although much progress has been made, tinnitus is still considered a scientific and clinical enigma. The search for effective tinnitus treatment faces considerable challenges. Despite numerous trials, no drugs have been approved by the Food and Drug Administration for the treatment of tinnitus. There are different types of treatment for tinnitus that have been tested in properly controlled trials. These treatment options include pharmacological, acoustic-physical, psychological, and surgical. In clinical practice, no pharmacological agent has been shown to have a lasting effect on the presence or severity of tinnitus. Surgery has a small but definite role in the treatment of tinnitus. Surgical intervention is often helpful in relieving most of the objective tinnitus. This review article discusses the epidemiology, indications, and different surgical approaches for tinnitus.

Keywords: Cochlear implantation, surgical treatment, tinnitus treatment

Introduction

Tinnitus is defined as the abnormal perception of sound in the ear in the absence of an external source of the sound.[1] Tinnitus is a common clinical symptom that exists in two types such as objective and subjective tinnitus.[2] Subjective tinnitus refers to the auditory experience of the patient's perception of sound in the absence of external acoustic stimulus around the ear or in the brain.[3] Objective tinnitus refers to tinnitus that involves real physical sound wave vibrations that can be experienced by others or recorded by instruments.[4] There is no effective treatment available, although much research is underway on mechanisms and possible treatments. The symptoms and treatment in the case of patients with tinnitus present a dilemma for clinicians. The symptoms may be distressing, but it is often difficult to treat if we do not understand the etiology. Surgery for tinnitus can be classified into procedures directed specifically for the elimination of tinnitus versus those directed at independent primary otological diseases whose symptoms include tinnitus.[5] For the latter types, although there may be an independent primary goal for which the surgical procedure is undertaken, tinnitus may be expected to improve secondarily. Surgical intervention for any otological disorders associated with tinnitus might be effective for that condition, but the tinnitus may persist. The objective of this article is to review the various surgical treatment options for tinnitus, targeting different disruption sites along the auditory pathways, as well as to indicate novel neuromodulatory techniques as the mode of tinnitus control.

Methods of Literature Search

Multiple systematic methods were used to find current research publications on the surgical treatment of tinnitus. We started by searching the Scopus, PubMed, Medline, and Google Scholar databases online. A search strategy using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines was developed. This search strategy recognized the

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abstracts of published articles, while other research articles were discovered manually from the citations. Randomized controlled studies, observational studies, comparative studies, case series, and case reports were evaluated for eligibility. There were a total number of 62 articles (20 case reports, 16 cases series, and 26 original articles) [Figure 1]. This article focuses only on the details of the surgical treatment of tinnitus. This review article describes the epidemiology, clinical manifestations of tinnitus, indications, and different surgical approaches for the treatment of tinnitus. This analysis provides a better understanding of the surgical treatment of tinnitus. It will also catalyze further study of the surgical treatment of tinnitus and the development of newer techniques for the better management of tinnitus.

Epidemiology

Tinnitus is a common but poorly understood clinical entity. The exact prevalence of hearing loss among patients with tinnitus is high but often difficult to determine. Tinnitus is found in 10%–15% of the population.[6] Clinically problematically tinnitus accounts for about 20% that is 2%–3% of the population.[6] The high prevalence of tinnitus shows that this clinical entity is a global burden. The prevalence of tinnitus increases with age and is expected to rise in the future, owing to increased exposure to noise or loud sounds.[7] In one recent systematic review, approximately 80% of studies showed a higher prevalence of tinnitus in males than in females, whereas an inverse pattern exists for severe tinnitus, with more females being affected than males.[8]

Clinical Manifestations

Tinnitus is derived from the Latin word tinnire and refers to a condition where a patient experiences a ringing, buzzing, or hissing auditory sensation in the absence of an external sound.[2] Tinnitus can be constant or intermittent, and many patients experience it for more than one sound.[9] It can be localized to one or both ears, or centrally within the head, although some patients present an external point of origin. The onset of tinnitus may be abrupt but is often insidious in nature.[10] The perceived intensity of tinnitus may vary, and some people experience exacerbation with the arousal of stress. Many patients with tinnitus believe that they are suffering from a serious medical problem, but this rarely happens. Most treatments for tinnitus are unsuccessful, and attempts made to develop evidence-based treatment have been prevented by a poor understanding of the pathophysiology of tinnitus. Despite these limitations, many cases of tinnitus are managed satisfactorily.

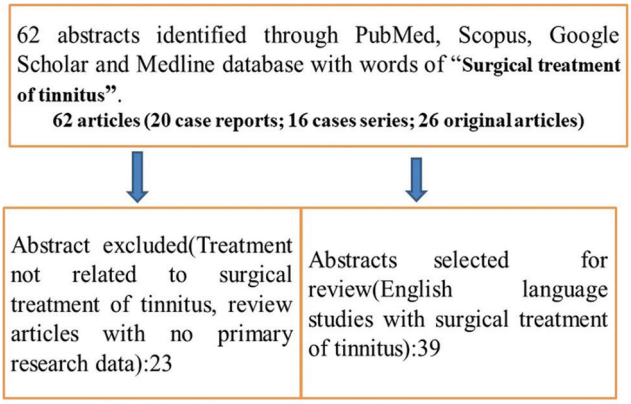

Figure 1: Methods of literature search

Surgical Indications

Currently, there is a wide variety of surgical treatment options [Table 1] aimed to resolve the phantom auditory sensations that underlie tinnitus.[11] There are attempts made to resolve tinnitus at various levels of the auditory system, with different degrees of success.

Subjective tinnitus

The surgical treatment directed primarily and specifically at the medication of subjective tinnitus is limited. There are different approaches have been tried, but none are sufficiently reliable and effective for controlling tinnitus.[12] Vagus nerve stimulation has been tried for controlling subjective tinnitus. There are variable benefits were found; however, long-term efficacy is still lacking.[13] Tinnitus suppression is often found a secondary benefit of deep brain stimulation for other indications such as Parkinson's disease.[14] Most patients who undergo cochlear for profound hearing loss have subjective tinnitus and show relief from it after using the device. Hence, cochlear implantation is often considered a tinnitus reliever. Intratympanic steroids are helpful for the primary treatment of refractory and subjective tinnitus.[15] This study was directed at patients with cochlear symptoms of fewer than 3 months.[16]

Objective tinnitus

The surgical intervention for objective tinnitus is more commonly performed and also effective in comparison to subjective tinnitus. Surgical treatment is more

Table 1: Surgical treatment options for tinnitus

Tinnitus-specific surgical treatment	Surgical treatment giving secondary benefit on tinnitus
Subjective	
Cochlear or cochlear nerve stimulation Vagus nerve stimulation Deep brain stimulation Intratympanic steroid injection	Hearing restoration surgery: Ossiculoplasty, cochlear implantation, and other implantable devices Intratympanic steroid injection (e.g., Meniere's disease or sudden sensorineural hearing loss)
Objective	
Stapedius and/or tensor tympani tenotomy Sigmoid sinus wall reconstruction Eustachian tube dysfunction-middle ear ventilation/Eustachian tuboplasty Internal jugular vein ligation	Superior canal dehiscence syndrome-Surgical closure of dehiscence Excision of paraganglioma

commonly performed and more effective for objective tinnitus than subjective types. Objective, rhythmic, and nonpulse-synchronous tinnitus is often caused by the middle ear myoclonus. The palatal myoclonus should be included in the differential diagnosis and excluded before considering the surgery. The stapedius and tensor tympani muscle or both can be the etiology for objective tinnitus. The exact differentiation of the muscle resulting in the symptom is not possible preoperatively, although when the symptom occurs following facial nerve infection, inflammation, or trauma, the stapedius muscle is more likely to be the etiology. The stapedius muscle is usually the case when the tinnitus is often evoked by facial movements or loud sounds.[17] Exploration of the middle ear with lysis of the tendon of the involved muscle, or both if the causative muscle is undetermined, can be done after more conservative measures have failed.[18]

Surgical Treatment of Tinnitus

Eustachian tube dysfunction causing tinnitus

Pulsatile tinnitus is a common clinical presentation of Eustachian tube dysfunction. Eustachian tube dysfunction causes alteration in the middle ear pressure which manifests conductive hearing loss and produces abnormally heightened self-perception of vascular somatosounds.[19] The exact choice of an appropriate treatment needs to distinguish between the more dilatory dysfunction with resultant reduced function and the underaeration of the middle ear, typically occurring by nasopharyngeal and paranasal sinus inflammatory diseases or chronic otitis media, on the one hand, and patulous Eustachian tube, which is often found in patients with rapid weight loss, on the other hand. If the medical treatment fails for Eustachian dysfunction, surgical intervention can be done. Ventilation tube insertion is the most common and simplest surgical intervention. The dilation of the Eustachian tube can be done in case of Eustachian tube dysfunction. The cartilaginous part of the Eustachian tube is the only portion that can be safely and effectively dilated. For this cause, a patient who has had a lifetime of chronic otitis media with no rhinitis or pathology in the nasopharynx, and who has chronically poor Eustachian tube function, is not a suitable candidate for such a surgical procedure, as the pathology is likely on the middle ear side of the Eustachian tube, if not along its entire length altogether.

Tinnitus in otosclerosis

Tinnitus is a common and underestimated symptom besides conductive hearing loss in otosclerosis.[20] Low-pitch tinnitus is more likely to be resolved following stapedotomy for patients with otosclerosis. High-pitch tinnitus may not resolve even after the closure of the air–bone gap at tinnitus frequencies. Traumatic surgery such as total stapedectomy has an unfavorable outcome compared to partial stapedectomy or stapedotomy for resolving tinnitus.[21] One study showed that the prognosis of the tinnitus was better after stapedotomy compared to partial stapedectomy, and the use of argon laser during surgery did not change the outcome.[22]

Tinnitus due to sigmoid sinus wall defect

The pulsatile tinnitus may be caused by a sigmoid sinus wall defect or diverticulum. This can be treated by reconstruction of the sigmoid sinus wall through the transmastoid approach which is a safe and effective technique.[23]

Cochlear implantation

More than 80% of patients with bilateral profound sensorineural hearing loss have tinnitus. Cochlear implantation eliminates or improves tinnitus in up to 86% of these cases, although 9% of cases present worse postoperative tinnitus.[24] Cochlear implantation is also being studied for treatment in case of single-sided profound sensorineural hearing loss and normal or near-normal hearing in the other ear. Although this treatment is appropriate in only a small proportion of patients with tinnitus, initial reports suggest that it is very successful in this subgroup.[25] Patients with unilateral sensorineural hearing loss and tinnitus who undergo implantation of an osseointegrated bone conduction device for their hearing loss often improve in their subjective tinnitus.[26]

Middle ear muscle contraction and tinnitus

The stapedius or tensor tympani muscle contraction may result in tinnitus, and it is often evoked by facial movements or loud sounds.[17,27] Middle ear exploration and lysis of the tendon of the affected muscle can be done in case of failed conservative treatment.[18]

Surgical brain modulation

Currently, neurostimulation trials are ongoing for assessing the effect of auditory cortex stimulation, frontal cortex stimulation, thalamic and caudal stimulation as well as amygdalohippocampal stimulation, yielding suppression rates between 10% and 70%.[28] Other potential targets include the anterior cingulate, the medial geniculate bodies, the periaqueductal gray/tectal longitudinal column, and the dorsal cochlear nucleus. A proper understanding of tinnitus and its potential neuromodulation treatments is relatively simple for a neurosurgeon specialized in pain or pain physicians, based on pathophysiological and clinical analogies.

Vestibular schwannoma and tinnitus

Tinnitus is a common symptom in patients with vestibular schwannoma.[29] Previously, most surgeons aimed to remove completely the tumor while preserving the facial nerve function and hearing. However, currently, more attention has been paid to the quality of life of the patient.[30] Treatment options for vestibular schwannomas include a few conservative managements with serial magnetic resonance imaging (MRI), microsurgery, and/or stereotactic radiosurgery/radiotherapy.[31] The improvement of tinnitus following stereotactic radiation, whether with single or multiple fractions, has been largely unpredictable; however, some patients have improved after treatment.[32]

Intratympanic steroid perfusion

Intratympanic perfusion of steroids has been employed for different otological conditions associated with tinnitus such as Meniere's disease, sudden sensorineural hearing loss, and

acute labyrinthitis. Many patients undergoing intratympanic perfusion of steroids for inner ear diseases with tinnitus report improvement in tinnitus following the procedure.[26]

Neuromodulation of the vagus nerve

Classical neuromodulation is applied to the nervous system for altering the ongoing electrical current in the vagus nerve. Although classical neuromodulation interferes with the activity of the vagus nerve but does not drive it in a controlled way. One study demonstrated that it is possible to drive plasticity in a controlled way using stimulation of the vagus nerve paired with tones. This is helpful to reverse the tinnitus percept and pathological neural plasticity in the noise-exposed rats with behavioral features of tinnitus.[13]

Microvascular decompression

Microvascular compression of the vestibulocochlear nerve at the cerebellopontine angle can cause tinnitus.[33] Unilateral tinnitus and abnormality in abnormal auditory brainstem response must be investigated with MRI to confirm the conflict between the vestibulocochlear nerve and the vertebral loop, posterior inferior cerebellar artery loop, and/or anterior inferior cerebellar artery loop.[34] The vascular pathology compressing the vestibulocochlear nerve results in tinnitus similar to the microvascular compression of the trigeminal nerve entry zone leading to trigeminal neuralgia and hemifacial spasm. Surgical decompression of the trigeminal of the auditory nerve from vascular pathology reduces tinnitus significantly.[34] Thus, microvascular decompression of the vestibulocochlear nerve within the cerebellopontine angle is a potential treatment method for patients suffering from neurovascular conflicts confirmed by high-resolution MRI.[35]

Laser treatment

Low-level laser treatment is used in some cases of chronic pain, although the mode of action remains conjectural. Based on similarities between chronic pain and tinnitus, lasers have been developed by manufacturers for application in the case of tinnitus. Although the result of lasers in a few studies has suggested a benefit of laser treatment, most suggest that it is ineffective.[36]

Conclusion

Tinnitus today is still clinically challenging, and most patients want a treatment that could reduce or even abolish their phantom sound. No treatment can yet be considered well established for relieving tinnitus. The successful treatment of patients with tinnitus begins with differentiating the objective type from the subjective variety of tinnitus. Surgery has a small but definite role in the treatment of tinnitus. However, tinnitus is a difficult disorder to treat despite many surgical interventions aimed at eliminating the aberrant neuronal activity in the auditory system. Tinnitus caused by pathologies such as vestibular schwannomas or neurovascular compression of the vestibulocochlear nerve at the level of the brainstem may be treated effectively by stereotactic radiosurgery and microvascular decompression, respectively.

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Conflicts of interest

There are no conflicts of interest.

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