



## Tinnitus (Phantom Sound): Risk coming for future

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### ABSTRACT

The word 'tinnitus' comes from the Latin word tinnire, meaning "to ring" or "a ringing." Tinnitus is the cognition of sound in the absence of any corresponding external sound. Tinnitus can take the form of continuous buzzing, hissing, or ringing, or a combination of these or other characteristics. Tinnitus affects 10% to 25% of the adult population. Tinnitus is classified as objective and subjective categories. Subjective tinnitus is meaningless sounds that are not associated with a physical sound and only the person who has the tinnitus can hear it. Objective tinnitus is the result of a sound that can be heard by the physician. Tinnitus is not a disease in itself but a common symptom, and because it involves the perception of sound or sounds, it is commonly associated with the hearing system. In fact, various parts of the hearing system, including the inner ear, are often responsible for this symptom. Tinnitus patients, which can lead to sleep disturbances, concentration problems, fatigue, depression, anxiety disorders, and sometimes even to suicide. The evaluation of tinnitus always begins with a thorough history and physical examination, with further testing performed when indicated. Diagnostic testing should include audiography, speech discrimination testing, computed tomography angiography, or magnetic resonance angiography should be performed. All patients with tinnitus can benefit from patient education and preventive measures, and oftentimes the physician's reassurance and assistance with the psychologic aftereffects of tinnitus can be the therapy most valuable to the patient. There are no specific medications for the treatment of tinnitus. Sedatives and some other medications may prove helpful in the early stages. The ultimate goal of neuro-imaging is to identify subtypes of tinnitus in order to better inform treatment strategies.

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### INTRODUCTION

Tinnitus is the cognition of sound in the absence of any corresponding external sound.<sup>1-2</sup> Tinnitus is a phantom sound (ringing of the ears) that affects quality of life for millions around the world and is associated in most cases with hearing impairment.<sup>3-4</sup> The word 'tinnitus' comes from the Latin word tinnire, meaning "to ring" or "a ringing" and is the perception of a sound that has no external source.<sup>5-7</sup> Tinnitus can take the form of continuous buzzing, hissing, or ringing, or a combination of these or other characteristics.<sup>6,8</sup> Tinnitus, (pronounced tih-NIGHT-us or TIN-ih-tus) is a ringing, swishing, or other type of

noise that seems to originate in the ear or head.<sup>9</sup> Tinnitus can occur when damage to the peripheral auditory system leads to spontaneous brain activity that is interpreted as sound.<sup>10</sup> A common problem, tinnitus affects about 1 in 5 people.<sup>11</sup> Tinnitus afflicts a substantial portion of the youth population.<sup>12</sup> Tinnitus affects 10% to 25% of the adult population.<sup>13-14</sup> Tinnitus can occur in children and prevalence increases with age.<sup>15</sup> Women are more likely to report tinnitus than men, and occupational noise and lower socio-economic class are also associated with increased tinnitus.<sup>16</sup> Tinnitus may be an intermittent or continuous sound in one or both ears.<sup>17</sup> Tinnitus is



the perception of pitch or noise in the absence of a corresponding auditory stimulus, experienced as one or more acute episodes by 25% of the adult population and daily or permanently by 8%.<sup>18</sup> Tinnitus isn't a condition itself - it's a symptom of an underlying condition, such as age related hearing loss, drug toxicity, ear injury or a circulatory system disorder.<sup>9, 19-21</sup> Tinnitus can arise in any of the four sections of the hearing system: the outer ear, the middle ear, the inner ear, and the brain. Some tinnitus or "head noise" is normal. Most of us will experience tinnitus or sounds in the ears at some time or another.<sup>22</sup> Tinnitus is classified as vibratory and non-vibratory and is further subdivided into objective and subjective categories.<sup>23-24</sup> There are two kinds of tinnitus:

### Subjective tinnitus

This is by far the most common type of tinnitus.<sup>25</sup> Subjective tinnitus is meaningless sounds that are not associated with a physical sound and only the person who has the tinnitus can hear it.<sup>26</sup> Everyone, if sitting in a soundproof room, hears noises in their heads. Usually these noises are masked in everyday life by all the noise going on in the world around us. If you cannot hear sounds in the outside world so well, you tend to notice the natural noises inside your head much more because they are not being masked by the environmental noises.<sup>27</sup> Tinnitus is often, but not always, linked to a hearing loss.<sup>28-29</sup> If the tiny hair cells of the cochlea are damaged, for example through certain drugs, noise exposure or as part of the aging process, the cochlea becomes less good at discriminating sounds, and your hearing is affected.<sup>30,32</sup> It is possible that these damaged hair cells also give rise to random noises which we hear as tinnitus.<sup>32</sup> This is the reason that when you consult a specialist about tinnitus, you will have a hearing test. Damaged hair cells in the inner ear may be a cause of tinnitus.<sup>31, 33</sup>

### Objective tinnitus

Objective tinnitus is the result of a sound that can be heard by the physician. This type of tinnitus is uncommon.<sup>34</sup> Objective tinnitus can be further subdivided into 3 groups: pulsatile, muscular, and spontaneous.<sup>27</sup> Pulsatile tinnitus can occur when

there is an increased blood flow to the ear, such as during an infection and inflammation, but also because of anatomical abnormalities of the blood vessels.<sup>26</sup> It is the turbulent blood flow that is heard directly by the inner ear<sup>35-36</sup>, and it usually occurs in time with the heart beat (pulsatile tinnitus)<sup>30</sup> Vascular tinnitus is the most common form of pulsatile tinnitus, particularly when the tinnitus corresponds with the pulse of patients.<sup>35</sup> Vascular tumours of the middle ear are rare, but also can give a pulsatile tinnitus.<sup>37-39</sup> Muscular tinnitus is often described as a "clicking" noise and is most commonly due to palatal myoclonus or contractions of the tensor tympani or stapedius muscles.<sup>13, 40-41</sup> Noises may be caused by spasms of small muscles in the middle ear (often heard as a clicking sound) or by abnormalities of the blood vessels in and around the ear.<sup>30</sup> Tinnitus occurs at the cochlea as an increase in spontaneous activity. Spontaneous tinnitus has been linked to vibrations of the outer hair cells of the cochlea known as spontaneous otoacoustic emissions.<sup>42-43</sup> Such objective tinnitus which can be heard by the examining doctor may require further investigation by an ear, nose and throat surgeon or audiological physician, and may in some instances have a surgical cure.<sup>44-47</sup> Tinnitus can be extremely disturbing to people who have it. In many cases it is not a serious problem, but rather a nuisance that may go away. However, some people with tinnitus may require medical or surgical treatment. Prior to any treatment, it is important to undergo a thorough examination and evaluation by your otolaryngologist and audiologist.<sup>46-49</sup> An essential part of the treatment will be your understanding of tinnitus and its causes. Most people learn to live with tinnitus, but it can often have a significant impact on day to day life. For example, it can affect concentration and cause sleeping problems and depression.<sup>50-51</sup>

### What causes tinnitus?

Tinnitus is commonly defined as hearing a sound in the absence of external sounds. Tinnitus is not a disease in itself but a common symptom, and because it involves the perception of sound or sounds, it is commonly associated with the hearing system.<sup>1, 3-4, 52</sup> In fact, various parts of the hearing system, including the inner ear, are often responsible for this symptom.<sup>53-54</sup> At times, it is relatively easy to



associate the symptom of tinnitus with specific problems affecting the hearing system.<sup>55</sup>

### **Common causes of tinnitus**

In many people, tinnitus is caused by one of these conditions:

#### ***Age related hearing loss***

For many people, hearing worsens with age, usually starting around age 60. Hearing loss can cause tinnitus. The medical term for this type of hearing loss is presbycusis.<sup>21-23</sup>

#### ***Noise Exposure***

One of the preventable causes of tinnitus is excessive noise exposure. In some instances of noise exposure, tinnitus can be noticed even before hearing loss develops, so it should be considered a warning sign and an indication of the need for hearing protection in noisy environments.<sup>56-57</sup> Tinnitus caused by short term exposure, such as attending a loud concert, usually goes away; Long term exposure to loud sound can cause permanent damage.<sup>58-59</sup> Loud noises, such as those from heavy equipment, chain saws and firearms, are common sources of noise related hearing loss.<sup>60</sup>

#### ***Earwax blockage***

Earwax protects your ear canal by trapping dirt and slowing the growth of bacteria.<sup>61</sup> Excessive ear wax, especially if the wax touches the ear drum, causing pressure and changing how the ear drum vibrates, can result in tinnitus.<sup>62-64</sup>

#### ***Ear bone changes***

Stiffening of the bones in your middle ear (otosclerosis) may affect your hearing and cause tinnitus.<sup>65-67</sup> This condition, caused by abnormal bone growth, tends to run in families.<sup>68-69</sup>

### **Other causes of tinnitus**

Some causes of tinnitus are less common, including:

#### ***Meniere's disease***

True Meniere's disease consists of three primary symptoms-episodic vertigo, hearing loss, and tinnitus.<sup>57, 70-72</sup> Tinnitus can be an early indicator of

Meniere's disease, an inner ear disorder that may be caused by abnormal inner ear fluid pressure.<sup>73-75</sup>

#### ***TMJ disorders***

Problems with the temporomandibular joint, the joint on each side of your head in front of your ears, where your lower jawbone meets your skull, can cause tinnitus.<sup>13, 76-80</sup>

#### ***Head injuries or neck injuries***

Head or neck trauma can affect the inner ear, hearing nerves or brain function linked to hearing.<sup>81-82</sup> Such injuries generally cause tinnitus in only one ear.<sup>83-85</sup>

#### ***Acoustic neuroma***

This noncancerous tumor develops on the cranial nerve that runs from your brain to your inner ear and controls balance and hearing.<sup>86-88</sup> Also called vestibular schwannoma, this condition generally causes tinnitus in only one ear.<sup>89-90</sup>

#### ***Blood vessel disorders linked to tinnitus***

In rare cases, tinnitus is caused by a blood vessel disorder.<sup>91-93</sup> This type of tinnitus is called pulsatile tinnitus.<sup>94-96</sup> Pulsatile tinnitus may signal the presence of cardiovascular disease or a vascular tumor in the head and neck or the ear.<sup>97-98</sup> Causes include:

#### ***Head and neck tumors***

A tumor that presses on blood vessels in your head or neck (vascular neoplasm) can cause tinnitus and other symptoms.<sup>99-102</sup>

#### ***Atherosclerosis***

With age and buildup of cholesterol and other deposits, major blood vessels close to your middle and inner ear lose some of their elasticity - the ability to flex or expand slightly with each heartbeat.<sup>103-106</sup> That causes blood flow to become more forceful, making it easier for your ear to detect the beats. You can generally hear this type of tinnitus in both ears.<sup>96,100</sup>

#### ***High blood pressure***

Hypertension and factors that increase blood pressure, such as stress, alcohol and caffeine, can make tinnitus more noticeable.<sup>36, 107-109</sup>



### **Turbulent blood flow**

Narrowing or kinking in a neck artery (carotid artery) or vein in your neck (jugular vein) can cause turbulent, irregular blood flow, leading to tinnitus.<sup>93, 110-112</sup>

### **Malformation of capillaries**

A condition called arteriovenous malformation (AVM)<sup>113-114</sup>, abnormal connections between arteries and veins can result in tinnitus.<sup>115-116</sup> This type of tinnitus generally occurs in only one ear.<sup>116-117</sup>

### **Medications that can cause tinnitus**

Medications can also damage inner ear hair cells and cause tinnitus.<sup>118-121</sup> These include both non-prescription medications such as aspirin and acetaminophen and prescription medication including certain diuretics and antibiotics.<sup>122-125</sup> Generally, the higher the dose of these medications, the worse tinnitus becomes.<sup>126</sup> The unwanted noise disappears when you stop using these drugs. Medications known to cause or worsen tinnitus include:

**Antibiotics** including polymyxin B, erythromycin, vancomycin and neomycin; **Cancer medications** including mechlorethamine and vincristine; **Water pills (diuretics)** such as bumetanide, ethacrynic acid or furosemide; **Quinine medications** used for malaria or other health conditions; **certain antidepressants** may worsen tinnitus; **Aspirin** taken in uncommonly high doses (usually 12 or more a day).<sup>1, 6, 126-129</sup>

Anyone can experience tinnitus, but these factors may increase your risk:

### **Loud noise exposure**

Prolonged exposure to loud noise can damage the tiny sensory hair cells in your ear that transmit sound to your brain.<sup>130-132</sup> People who work in noisy environments - such as factory and construction workers, musicians, and soldiers - are particularly at risk.<sup>60, 133-135</sup>

### **Age**

As we age, the incidence of tinnitus increases. The number of functioning nerve fibers in your ears declines, possibly causing hearing problems often associated with tinnitus.<sup>136-139</sup>

### **Gender**

Men are more likely to experience tinnitus.<sup>139-140</sup>

### **Smoking**

Smokers have a higher risk of developing tinnitus.<sup>141, 143</sup>

### **Cardiovascular problems**

Conditions that affect your blood flow, such as high blood pressure or narrowed arteries (atherosclerosis) can increase your risk of tinnitus.<sup>108, 144-148</sup>

### **Can Children Be At Risk For Tinnitus?**

It is relatively rare but not unheard of for patients under 18 years old to have tinnitus as a primary complaint. However, it is possible that tinnitus in children is significantly underreported, in part because young children may not be able to express this complaint. Also, in children with congenital sensorineural hearing loss that may be accompanied by tinnitus, this symptom may be unnoticed because it is something that is constant in their lives. In fact, they may habituate to it; The brain may learn to ignore this internal sound.<sup>149-156</sup> In preteens and teens, the highest risk for developing tinnitus is associated with exposure to high intensity sounds, specifically listening to music.<sup>20, 60, 157-160</sup>

### **SYMPTOMS OF TINNITUS**

The sound of tinnitus may be constant or it may come and go intermittently. It may be throbbing. Tinnitus is the unwanted perception of sound. It can be high-pitched whistling, buzzing, ringing, hissing, humming or roaring like the ocean.<sup>16</sup> It can affect one or both of your ears. These sounds may be constant or can come and go. In approximately 90% cases tinnitus appears related to hearing loss.<sup>9</sup> Factors like age, hearing status and previous noise induction influences the prevalence outcome. The prevalence of tinnitus in children has been reported and estimates range from 3% to 58%.<sup>14</sup> The prevalence of psychiatric disorders, especially anxiety and depression is high in tinnitus patients.<sup>161</sup> Positive symptoms arise after lesions of the nervous system. They include neurogenic pain, tinnitus, abnormal movements, epilepsy and certain neuropsychiatric disorders.<sup>162-163</sup> Hearing and labyrinthine dysfunction can occur as consequences of head and Neck injuries, because damaged hair cells



in the inner ear may be a cause of tinnitus.<sup>83</sup> The term Middle Ear Myoclonus has been invoked to explain symptoms of tinnitus presumably caused by the dysfunctional movement of either of the two muscles that insert in the middle ear.<sup>164-165</sup> Tinnitus due to middle ear myoclonus seems to occur in young patients and to be related to stress or noise.<sup>165-166</sup> Disorders of the inner ear can cause hearing loss, tinnitus, vertigo and imbalance.<sup>167</sup> Chronic subjective tinnitus is a common feature of clinical otosclerosis.<sup>168</sup> The sound may beat in time with your heartbeat (known as pulsatile sound).<sup>30</sup> Rarely, some people may experience tinnitus in the form of snippets of tunes, music or songs. This is called musical hallucinations.<sup>169</sup> Tinnitus patients, which can lead to sleep disturbances<sup>170</sup>, concentration problems, fatigue, depression, anxiety disorders, and sometimes even to suicide.<sup>171-172</sup>

#### DIAGNOSIS OF TINNITUS

The evaluation of tinnitus always begins with a thorough history and physical examination, with further testing performed when indicated.<sup>173,175</sup> Pulsatile (Unilateral) tinnitus may be caused by more serious pathology and typically merits specialized audiometric testing and radiologic studies.<sup>91,176</sup> Diagnostic testing should include audiography, speech discrimination testing, computed tomography (CT) angiography, or magnetic resonance angiography (MRA) should be performed.<sup>6</sup> Early diagnosis and appropriate intervention may save patients from unnecessary morbidity.<sup>177-178</sup> When you are evaluated for tinnitus, the first thing the doctor will do is obtain a complete history, investigating potential causative factors, and perform a thorough, targeted physical examination. If the tinnitus is one sided (unilateral), associated with hearing loss, or persistent, an audiogram (hearing test) should be obtained early in the evaluation. You may opt for an audiogram in any case. There is no need for radiologic testing (X-rays, CT scans or MRI scans) unless your tinnitus is unilateral, pulsatile, or associated with asymmetric hearing loss or neurological abnormalities.<sup>34</sup> Neural mechanisms that detect changes in the auditory environment appear to rely on processes that predict sensory state.<sup>179</sup> If atherosclerosis is suspected as a cause of pulsatile tinnitus, CT arteriography (CTA) of the neck and head

should be considered. If compression of the jugular vein is a possible cause, a neck CT may be performed that extends to the upper mediastinum to include the entire course of the jugular veins.<sup>1,34</sup> Tinnitus patients show a deviation from the norm of different resting EEG parameters, characterized by an overproduction of resting state delta, theta and beta brain activities, providing further support for the microphysiological and magnetoencephalographic evidence pointing to a thalamocortical dysrhythmic process at the source of tinnitus.<sup>180-181</sup> Investigation of human spontaneous brain activity in tinnitus has been scarcer and usually investigates altered spectral power in diverse frequency bands of the ongoing MEG/EEG.<sup>182</sup> Using fMRI as an indicator of neural activity<sup>183-184</sup>, Modern neurophysiological and imaging tools have greatly benefited our understanding of the abnormal functioning of the central nervous system as a major cause of chronic tinnitus. Low frequency repetitive transcranial magnetic stimulation (rTMS) has been proposed as an innovative treatment for chronic tinnitus.<sup>184-185</sup> Residual inhibition is a transient suppression of tinnitus after auditory stimulation has stopped. Positron emission tomography to study brain regions underlying residual inhibition.<sup>187-188</sup>

Spontaneous magnetoencephalographic activity was recorded in awake, healthy human controls and in patients suffering from neurogenic pain or tinnitus.<sup>189</sup> Spontaneous neuronal activity in individuals with and without tinnitus perception.<sup>190</sup> Tinnitus-related distress correlates with theta oscillatory activity which is known to be associated with depressivity and anxiety.<sup>191</sup> Tinnitus subjects with a longer history of tinnitus showed less variability of their auditory alpha activity which might be an indicator for reduced adaptability of the auditory cortex in chronic tinnitus.<sup>192</sup> Gamma oscillations have been proposed as bases for the perception of tinnitus.<sup>18, 193</sup> MEMRI advancing the field of auditory neuroscience in general and tinnitus research in particular.<sup>194</sup> Contrast enhanced magnetic resonance imaging (MRI) is the most appropriate study to be performed unilateral nonpulsatile tinnitus. MRA/V and CTA/V are both useful in the evaluation of pulsatile tinnitus.<sup>195</sup> Positron emission tomography (PET) scanning and functional magnetic resonance imaging (fMRI) studies indicate that a loss of cochlear input to



neurons in the central auditory system can result in abnormal neural activity in the auditory cortex.<sup>5</sup> Tomography and magnetic resonance imaging of the temporal bone are very helpful for visualization of an aberrant carotid in the middle ear.<sup>196</sup> Your doctor will try to determine how bothersome your tinnitus is, by asking certain questions or having you complete a self-assessment questionnaire.

### PREVENT TINNITUS

Noise-induced hearing loss, the result of damage to the sensory hair cells of the inner ear, is one of the most common causes of tinnitus.<sup>16</sup> Anything you can do to limit your exposure to loud noise—by moving away from the sound, turning down the volume, or wearing earplugs or earmuffs—will help prevent tinnitus or keep it from getting worse. All patients with tinnitus can benefit from patient education and preventive measures, and oftentimes the physician's reassurance and assistance with the psychologic aftereffects of tinnitus can be the therapy most valuable to the patient.<sup>197</sup> Tinnitus is an increasing health concern across all strata of the general population. Although an abundant amount of literature has addressed the many facets of tinnitus, wide ranging differences in professional beliefs and attitudes persist concerning its clinical management.<sup>15</sup> Repeated loud noise exposure can be a cause of tinnitus as well as hearing loss. Loud music may cause short term symptoms, but repeated occupational exposure (for example, musicians, factory and construction workers) requires less intense sound levels to cause potential hearing damage leading to tinnitus.<sup>198</sup> Minimizing sound exposure, therefore, decreases the risk of developing tinnitus. Sound protection equipment, like ear muffs, may be appropriate at work and at home when exposed to loud noise. A variety of medications may be ototoxic (damage the ear). If tinnitus develops while you are taking a medication, stop the medication and discuss other options with your health care professional.<sup>199</sup> Clinicians need to be guided by the patient's point of care, patient motivation and expectations of sound therapy.<sup>200</sup> Management of tinnitus therefore requires diagnosis and treatment expertise by physicians to adequately address existing etiologies and comorbidities, as well

as relevant expertise by non-physician specialists such as audiologists and psychologists.<sup>201</sup>

### TREATMENT OF TINNITUS

There are no specific medications for the treatment of tinnitus.<sup>7</sup> However, there are several potential treatment options that offer patients varying degrees of symptomatic improvement and enhanced quality of life.<sup>136</sup> Sedatives and some other medications may prove helpful in the early stages. At the moment there's no single treatment for tinnitus that works in the same way for everyone. However, research to find an effective treatment is continuing. There are several options available that can help patients with tinnitus.<sup>30</sup> For subjective tinnitus in particular, effective therapeutic options with guidelines about key diagnostic criteria are urgently needed<sup>[45]</sup>. If the otolaryngologist finds a specific cause for your tinnitus, he or she may be able to offer specific treatment to eliminate the noise. This may include removal of wax or hair from the ear canal, treatment of middle ear fluid, treatment of arthritis in the jaw joint, etc. Some patients with hearing loss and tinnitus have a modest improvement in coping with the tinnitus using hearing aids with or without built in ear level maskers. Sound therapies that involve simple things like background music or noise or specialized ear level maskers may be a reasonable treatment option.<sup>202</sup> The effects of tinnitus on quality of life may be improved by a course of counseling with cognitive behavioral therapy (CBT), which usually involves a series of weekly sessions led by a trained professional.<sup>203</sup> Cochlear implantation (CI) is standard of care for those with severe to profound hearing loss who no longer derive benefit from a hearing aid. CIs have a significant suppressive effect on tinnitus in most CI users.<sup>204</sup> Tinnitus can be so bothersome that it causes depression or anxiety; Additionally, in a patient with depression and/or anxiety, it may be very difficult to tolerate the additional burden of tinnitus. MBSR is a promising treatment option for chronic bothersome tinnitus.<sup>205</sup> Consultation with a psychiatrist or psychologist with treatment directed to the underlying condition can be beneficial. Routine prescription of medications including antidepressants, anticonvulsants, anxiolytics, or intratympanic injection of medications, is not recommended for treating tinnitus without an



underlying or associated medical problem that may benefit from such treatment. The ultimate goal of neuro-imaging is to identify subtypes of tinnitus in order to better inform treatment strategies.<sup>206</sup> Patients with tinnitus may have low blood zinc levels and clinical and subjective improvement can be achieved by oral zinc medication.<sup>207</sup> Benzodiazepine use for subjective tinnitus does not have a robust evidence base. Clonazepam has the most evidence to support its use and is relatively less likely to lead to abuse because of its longer half life, but caution is still needed given the other serious side effects.<sup>208</sup> Clonazepam is a very useful and safe drug for the symptomatic treatment of patients suffering from cochleovestibular disorders.<sup>209</sup> Nortriptyline had positive effects, and subgroup analyses revealed that women and patients who also complained of insomnia showed the greatest benefit.<sup>210</sup> Melatonin, a hormone produced by the pineal gland, may be a promising treatment option for tinnitus.<sup>211</sup> Melatonin clinical effectiveness in the treatment of tinnitus cannot be given in the light of the biases observed in the considered evidence. Melatonin seems to improve sleep disturbance linked to tinnitus.<sup>212</sup> Tinnitus is a prevalent condition for which patients may seek treatment with acupuncture since no conventional treatment has been shown to be effective. Acupuncture has been used to treat tinnitus for a long time in Far Eastern countries such as China and Korea.<sup>213</sup> There are several good treatment strategies based on psychological and neurophysiological models of tinnitus that promote habituation to the symptom.<sup>214</sup> Biofeedback is a relaxation technique teaching people to control certain autonomic body functions. The goal is to help people manage tinnitus-related distress by changing the patient's reaction to it.<sup>5</sup> The use of neurofeedback in the treatment of chronic tinnitus is an emerging field of research. Neurofeedback training was significantly superior in reducing tinnitus-related distress than frequency discrimination training.<sup>215</sup> The transcranial magnetic stimulation (rTMS) and selective serotonin reuptake inhibitor (SSRI) play potential roles in the reduction of tinnitus severity.<sup>216</sup> The rTMS is a safe treatment for tinnitus in the short term; however there were insufficient data to provide any support for the safety of this treatment in the long term.<sup>217</sup> Low frequency repetitive transcranial

magnetic stimulation (rTMS) of the auditory cortex has been shown to significantly reduce tinnitus severity in some patients.<sup>218</sup> Targeting several core regions of this network by rTMS might constitute a promising strategy to enhance treatment effects. This study intends to test the effects of a multisite rTMS protocol on tinnitus severity.<sup>219</sup> High frequency pulsed electromagnetic energy (Diapulse) at the settings used in the study showed no role in the therapy of patients with chronic tinnitus.<sup>220</sup> Quantitative EEG power spectral mapping (QEEG) is a simple and relatively inexpensive method for measuring regional brain activity and various EEG abnormalities in temporal lobe and other areas have been described in tinnitus patients.<sup>220,221</sup> Chronic electrical stimulation of the secondary auditory cortex seems safe and warrants further investigation as a potential therapeutic intervention for the suppression of tinnitus.<sup>222</sup> Cost effective and easy to implement, telemedicine is likely to represent an important part of the future of tinnitus therapies and should be progressively integrated by otolaryngologists.<sup>223</sup> The patient presented with brief and frequent paroxysms of vertigo and tinnitus, which were eliminated by carbamazepine.<sup>224</sup> Tricyclic antidepressants are probably helpful for patients with severe tinnitus, especially, severe tinnitus accompanied by sleep disturbance.<sup>225</sup> The observed changes in spontaneous brain activity stem from the reduction of the tinnitus sensation.<sup>226</sup> Histamine and its receptor subtypes are strongly involved in neuronal and inflammatory processes in vestibular areas, targeting the H<sub>4</sub>R could be a novel way to gain a treatment for tinnitus.<sup>227</sup> An N-methyl-d-aspartate (NMDA) receptor antagonist has been proposed as a pharmacologic approach for treatment of synaptopathic tinnitus.<sup>228</sup> Dietary supplements for tinnitus treatment are frequently advertised on the internet, television and radio. There is no evidence that any of these supplements, including ginkgo biloba, melatonin, zinc, lipoflavonoids, and vitamin supplements is beneficial for tinnitus. Acupuncture may or may not be helpful in tinnitus; There are not enough quality studies of this treatment for tinnitus to make a recommendation. Transcranial magnetic stimulation is a new modality but it cannot be recommended for tinnitus at this time, as long term benefits are not proven.



### Acoustic CR Neuromodulation

Acoustic coordinated reset (CR) neuromodulation is a non-invasive desynchronizing stimulation therapy that aims at counteracting pathological neural synchrony in subjects with subjective tonal tinnitus.<sup>229-231</sup>

### Deep brain stimulation

Deep brain stimulation is a minimal-invasive and reversible type of functional neurosurgery.<sup>232-233</sup> None the less, complications of the surgery, hardware failure and of stimulation-related side effects should be bared in mind. The potential risk of complications should be carefully weighed against the potential benefits of Deep brain stimulation.<sup>234-235</sup>

### Therapeutic Noise Generator

Device which looks like a hearing aid and recommended for people with no hearing loss. It produces a blend of external sounds which stimulate most fibres of the hearing nerve helping to deviate attention away from the tinnitus.<sup>236-238</sup>

### Tinnitus Retraining Therapy (TRT)

Tinnitus retraining therapy (TRT) is a clinical implementation of the neurophysiological model of tinnitus. It is necessary to use tinnitus-specific validated questionnaires to assess tinnitus severity before, during, and after treatment.<sup>238-239</sup> Aims to reduce and ultimately eliminate tinnitus perception. This is a very structured approach to managing tinnitus. Basically, TRT assumes that the tinnitus has been prioritised as an important signal.<sup>240</sup> TRT uses sounds at a particular level to try to reduce the priority of the tinnitus so that you no longer hear it. It is based on the idea that we can get used to sounds, e.g. the sound of the fridge or air conditioner, so we can also get used to this sound of tinnitus.<sup>241-242</sup> The process of getting used to the tinnitus sound is called habituation. TRT uses sound generators and counseling to attempt to retrain how the brain processes sound so that you habituate to the tinnitus.<sup>243</sup> Tinnitus retraining therapy (TRT) uses non-psychiatric tinnitus specific educational counseling and sound therapy in a habituation based protocol to reduce the patient's tinnitus evoked negative reaction to, and awareness of, the tinnitus, with the ultimate goal of reducing the tinnitus impact

on the patient's quality of life.<sup>244</sup> Most people working in the tinnitus field will use elements of TRT but the strict method is not frequently used because there is limited evidence for its effectiveness.

**Cognitive Behaviour Therapy (CBT):** Cognitive behavioral therapy (CBT) is the best evaluated treatment for tinnitus. The general aim of CBT in patients with tinnitus is to improve awareness and facilitate the modification of maladaptive patterns on the cognitive, emotional, and behavioral level.<sup>245</sup> This is one psychological approach that can be useful in managing tinnitus.<sup>246</sup> It was originally used to treat depression; however, it is now used for other disorders including anxiety, panic attacks and tinnitus [240]. The idea is that when you became aware of your tinnitus, you responded to it negatively. For example, you may have thought there was something seriously wrong with your hearing (a belief) and this led to you being anxious (an emotion), and you then tried to feel better, for example by avoiding silence (a behavior). Some beliefs and behaviors are helpful and that's great – keep doing them! But some beliefs and/or behaviors are unhelpful and CBT helps you to recognize them, and then you work together with the clinician (usually a psychologist, audiologist or hearing therapist) to find different ways of responding to the tinnitus so it becomes less bothersome.<sup>247-248</sup> Treatment strategy might best be CBT based, moving toward a more multidisciplinary approach. There is room for the involvement of different disciplines, using a stepped care approach. This may provide brief and effective treatment for a larger group of tinnitus patients, and additional treatment steps can be provided for those suffering on a more severe level.<sup>249-250</sup>

**Tinnitus Desensitization Therapy™ (TDT):** Tinnitus Desensitization Therapy™ is a habituation based tinnitus treatment developed by The Tinnitus Clinic for the treatment of all forms of subjective tinnitus.<sup>251</sup> This therapy has achieved significantly successful clinical results. The therapy is designed to provide you with control over your tinnitus.<sup>252-253</sup>

**Hyperacusis therapy:** Hyperacusis is a hearing disorder that causes everyday noise like traffic or conversation to be perceived as being





disproportionately loud and sometimes causing discomfort or even pain.<sup>22, 254</sup> The Tinnitus Clinic has successfully worked with many patients, providing a comprehensive and effective Hyperacusis reduction therapy that delivers a progressive and sustainable reduction in Hyperacusis symptoms over time.<sup>255</sup> Sophisticated sound generator systems are employed, along with supporting therapies, in order to provide control over auditory awareness and to desensitize the overactive auditory system. Awareness and over time enable you to fully habituate to your tinnitus perception so that the noise becomes noninvasive.<sup>256-258</sup>

### Surgery

Most people won't need surgery to treat tinnitus. However, if your tinnitus is caused by a physical problem, for example, a non-cancerous tumour near your ear (acoustic neuroma) and your surgeon may recommend having the tumour removed.<sup>259-260</sup> Chronic otitis media (COM) may cause inner ear damages or middle ear surgery may improve.<sup>261</sup> Surgery has a small but definite role in tinnitus management. Its place with regard to pulsatile tinnitus and that associated with specific conditions such as otosclerosis or Ménière's disease.<sup>7</sup>

### What's being done in research on tinnitus treatments?

Tinnitus remains a symptom that affects the lives of millions of people. Research is directed not only at its treatment, but also at understanding why it occurs. Repetitive transcranial magnetic stimulation may hold some hope. Research has shown some short term relief, but long term benefit is yet unproven. Currently, there are only a small number of drugs in development for the treatment of tinnitus. One of these is neramexane, a non-competitive, voltage-dependent NMDA antagonist which also blocks nicotinic cholinergic receptors expressed on hair cells in the inner ear.<sup>262</sup> D-cycloserine and other putative neuroplasticity-facilitating agents could be investigated in the future as a strategy to enhance neuroplasticity-based tinnitus treatments.<sup>263</sup>

### CONCLUSION

Tinnitus isn't a condition itself - it's a symptom of an underlying condition, such as age related hearing

loss, drug toxicity, ear injury or a circulatory system disorder. Tinnitus can arise in any of the four sections of the hearing system: the outer ear, the middle ear, the inner ear, and the brain. Tinnitus remains a symptom that affects the lives of millions of people. Most people learn to live with tinnitus, but it can often have a significant impact on day to day life. For example, it can affect concentration and cause sleeping problems and depression. Research is directed not only at its treatment, but also at understanding why it occurs. Research has shown some short term relief, but long term benefit is yet unproven. The effects of tinnitus on quality of life may be improved by a course of counseling with cognitive behavioral therapy (CBT), which usually involves a series of weekly sessions led by a trained professional. Currently, there are only a small number of drugs in development for the treatment of tinnitus. Prior to any treatment, it is important to undergo a thorough examination and evaluation by your otolaryngologist and audiologist.

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