Tinnitus and Sound

William Hal Martin, Ph.D., Robert L. Folmer, Ph.D.
and Baker Y-B. Shi, M.D., Ph.D.
Oregon Health & Science University, Portland, Oregon

Introduction

Sally woke up and looked at the clock on the nightstand. It read 3:05 AM, far too early for her alarm to be going off. She heard something, but it wasn't the sound of her alarm. It sounded like the teapot was whistling. Who could possibly be boiling water at this time? Husband Al was snoring next to her so it wasn't him. Perhaps one of them had bumped the stove knob before coming to bed and the water had slowly crept to a boil. She pulled herself from bed and went in the kitchen. The sound she heard was as clear as day, but the stovetop was cold and so was the kettle. She wandered through the house, trying to localize the sound, but it sounded like it was in the middle of her head. "Al," she said, shaking him from sleep. "What's that sound?" Al heard nothing, told her she was crazy and to go back to sleep. She figured it was coming from outside the house, a transformer or something that Al couldn't hear. She would solve the mystery in the morning. She tossed and turned until the alarm finally did go off. The shrill sound refused to let her sleep. Nor would it for more than moments during the next two years. In the morning, it was there again, crystal clear. Al denied hearing "anything" and gave her a strange look. He really didn't believe her. She must be losing her mind.

This account is not uncommon. Sometimes it is precipitated by a fun evening of dancing at a loud night club, or going to a rock concert with friends, or an unexpected explosive sound like a firecracker. A strange, new sound starts and no one else can hear it. Just you. And you can't hide from it no matter where you go. You never experience peace and quiet again.

Tinnitus, the experience of sound in one's head or ears in the absence of external sound, is an aberrant auditory phenomenon occurring in a significant number of people. Estimates of the number of people experiencing tinnitus range from 13 to 19% of the general population. Regardless, the number in the United States alone appears to be upwards of 40 million people. Of those, approximately 10 million experience it with such severity that they seek medical attention and 2.5 million are considered disabled by it. Figure 1 shows a graph of the ages and genders of patients at the time of their first clinical visit to the Oregon Health & Science University Tinnitus Clinic.

Tinnitus may be almost universally experienced in some form. It is most often reported as a ringing sound but can include a wide range of sounds such as hissing, roaring, buzzing, cricket sounds, popping or crackling. The vast majority of tinnitus events resolve spontaneously within a matter of seconds, hours or days. Most of those cases that persist are mild and not problematic to the individual. Some forms of objective tinnitus, related to mechanical factors, can be treated surgically or medically. Even subjective tinnitus, when related to tumors of the auditory nerve or disease processes of the middle ear, may be relieved by medical intervention. However, there are numerous cases of subjective tinnitus that do not dissipate. Clinical experience with such subjective tinnitus indicates that the likelihood of tinnitus resolving is extremely small if it has been present for six months to a year or longer. To date, there is no known cure for chronic tinnitus.

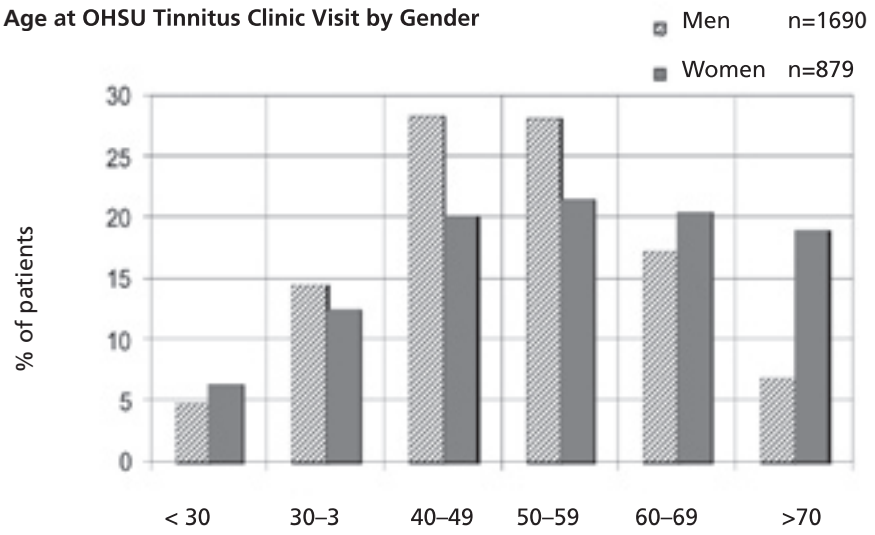

Figure 1. Age of patients at the time of their first visit to the OHSU Tinnitus Clinic.

Causes

Tinnitus can be divided into two categories; objective and subjective. Objective tinnitus is caused by some mechanical process in the head or neck and can often be heard by the clinician as well as the patient. In cases of constricted blood flow, patients will hear a pulsing or wooshing sound that corresponds to their heart rate. Other sounds such as clicking or popping arise from malfunctions of the Eustachian tube (connecting the middle ear to the airspace at the back of the nose and throat) or from spasms in the muscles attached to the tiny bones of the middle ear. Objective tinnitus can often be treated by medical or surgical intervention.

Subjective tinnitus can only be heard by the individual who has it. A wide range of events, diseases or disorders may trigger it. The most common triggers of tinnitus are inner-ear disease or noise damage. The Oregon Tinnitus Data Archive (www.tinnitusarchive.org) records of patients seen at the Oregon Health & Science University Tinnitus Clinic in Portland, Oregon indicates that 39% have no idea what triggered their tinnitus. About 20% attribute the tinnitus onset to significant noise-exposure, either over a long period of time or resulting from a short blast. Head and/or neck injuries were reported to have triggered tinnitus in 12% of patients followed by ear and sinus infections at 9%. Other illnesses, reactions to medications, stress, temporomandibular ("jaw") joint problems and other medical conditions accounted for the balance of the reports. In most cases, more than one factor was indicated as being associated with the onset of the tinnitus.

Tinnitus can be particularly bothersome to professional musicians who rely on their auditory acuity to perform complex, blended musical pieces, especially in concert with other musicians. The presence of an internally generated sound (tinnitus) over which the individual has no control, can be distracting, confusing and a source of frustration to the musician. Wearing earplugs can reduce the likelihood of further damage, but the exclusion of ambient noise increases the perception of the tinnitus and makes the tinnitus even more problematic.

Increasing evidence from brain research suggest that subjective tinnitus is due to abnormal brain activity triggered by a disruption of the delicate balance in nerve activity levels. It is considered to be analogous to phantom limb pain; experienced pain in a limb, hand or foot that has been traumatically amputated. The model is that the areas of the brain responsible for processing sound input are receiving erroneous information from a damaged end organ (e.g. a sound-damaged cochlea) or neural pathway (e.g. a tumor growing on the hearing nerve). The hearing section of the brain interprets the error signals in the only way it knows how . . . as sound.

Children infrequently report tinnitus but do experience it. If it is a chronic but non-problematic condition, children think that it is the normal state of affairs. Unless asked explicitly, they tend not to spontaneously complain about it. Acute cases, especially triggered by noise exposures or head and neck trauma or ear infections, are the most common events reported by children related to tinnitus onset.

Treatment And Management

The initial step in tinnitus care is to systematically identify and address any active disease processes that can be medically and/or surgically treated. Medical *treatment* of a disease provides a good probability that the tinnitus will resolve.

If either the disease or damage cannot be treated, as in the cases of age-related hearing loss, noise-induced hearing loss or chronic Meniere's disease, tinnitus *management* strategies can be employed to provide the patient with significant relief. Several tinnitus management tools have been developed over the years. The majority of patients with problematic tinnitus benefit from these strategies.

Acoustic Therapy

Acoustic therapies employ the use of sound to provide immediate relief and/or to facilitate long-term changes in the auditory-neural system's influence on the perception of tinnitus.

Masking has been used to provide immediate relief by presenting competing sound to either reduce or eliminate perception of the tinnitus. Masking may be accomplished from a number of sources. Ear-level maskers or sound generators provide continuous background sound that may be controlled by the user. Hearing aids (when warranted by the presence of a hearing loss) may amplify background environmental sounds to levels that provide adequate distraction for the patient. Some ear-level units combine amplification and sound generation capabilities to further meet the needs of those with hearing loss and tinnitus. External devices and recordings are available that generate environmental types of sounds or bands of noise that diminish the perception of tinnitus for many.

It has been postulated that exposure to continuous, low-level, broad-band sound might take advantage of neuronal plasticity (the ability of the brain to adapt to change by growing new neural connections) and facilitate habituation to the tinnitus signal. This is a long-term process that may take from three months to two years to complete. The strategy is based upon the idea that sub-cortical and cortical centers along the auditory pathway are critically involved in the detection and perception of tinnitus. It also postulates that non-auditory structures such as those found in the limbic system (those brain structures involved with emotions) are critically involved in the perpetuation and enhancement of tinnitus through linking of emotional significance to the tinnitus signal. Functional imaging studies of the brain have provided evidence for neural activities in the auditory cortex, limbic system and inferior colliculus that appear to be related to tinnitus. These results indicate that tinnitus activity is represented across several different levels and regions of the brain. Education and counseling regarding the nature of the individual's hearing health, tinnitus, and tinnitus mechanisms, as well as validation and reassurance are critical components of "retraining" strategies. Figure 2 presents a schematic of the neurophysiological model of tinnitus.

It is difficult to manage individuals with profound hearing loss using acoustic therapy since with such patients the auditory input is not available to either provide immediate relief or long-term stimulation. Reports contend that up to 93% of those whose hearing loss was ameliorated via cochlear-implants, found some relief from their tinnitus.

Medications

In parallel to acoustic therapy, several drugs have been used in attempts to provide tinnitus relief. Most reports using medications are either anecdotal or poorly controlled. However, there are some medications that have been reasonably evaluated and appear to be effective. Alprazolam (Xanax) is a benzodiazepine developed as an anti-anxiety treatment. In relatively high doses, it reduced both the objectively matched and subjectively scaled measures of tinnitus loudness. Nortriptyline is a tricylic medication developed to treat depression. It was shown to assist depression and reduce the matched tinnitus loudness. One reason that these specific medications have been helpful is because they address three of the most commonly reported factors that exacerbate and stem from tinnitus; anxiety, insomnia and depression. Patients in the Oregon Tinnitus Data Archive report a wide range of problems associated with their tinnitus (Table 1). It is essential to effectively treat parallel, tinnitus-exacerbating medical issues as part of a tinnitus management program.

Surgery

Surgical intervention, in the form of severing the hearing nerve to provide relief from tinnitus, has had mixed results. Patients often wake up with no hearing, and only tinnitus, and that often exacerbated compared to the pre-operative condition.

Summary

When appropriately applied, acoustic therapy, counseling/education, and medications in combinations specifically selected for an individual's personal needs can often provide tinnitus relief.

Table 1—Problems reported as a result of having tinnitus by patients in the Tinnitus Data Archive (www.tinnitusarchive.org) from the Oregon Health & Science University Tinnitus Clinic.

Concentration problems	85%
Anxiety	84%
Discomfort in a quiet room	83%
Difficulties in social interactions	74%
Sleep difficulties	73%
Feeling depressed	70%

Noise-related tinnitus can almost always be prevented through the appropriate application of simple safety measures (www.dangerousdecibels.org). When listening to a sound system that has volume control, it is best to turn down the volume to sound levels at which you can still carry on a conversation without having to raise your voice to be understood. If you are listening to a personal stereo system (e.g. CD player or MP3 player) and you cannot understand someone speaking to you 3 feet away without removing an earphone, the listening level is probably dangerous. Lowering the volume slightly will allow you to enjoy the music and avoid noise-induced hearing loss and tinnitus. Sound drops half of it's sound pressure level (6 dB) when you double the distance from the sound source. Moving away from a loud sound is another means of avoiding damage to your ears. Finally, hearing protection (e.g. earplugs or earmuffs) are readily available, inexpensive and quite effective at reducing sound levels to safe levels (see accompanying article by Berger).

DR. MARTIN is professor of Otolaryngology / Head & Neck Surgery and professor of Public Health & Preventive Medicine at the Oregon Health & Science University in Portland. He is one of the senior scientists at the Oregon Hearing Research Center where he serves as a multi-program director over the OHSU Tinnitus Clinic, the tinnitus research program, intraoperative neurophysiological monitoring services and over the Dangerous Decibels® hearing loss and tinnitus prevention program. Dr. Martin's doctorate is from the University of California, San Francisco and Santa Barbara in Speech and Hearing Science, emphasizing neuroscience and computational physics. His postdoctoral fellowship was at the Technion in Haifa, Israel, focusing on dipole localization modeling of the human auditory system.

Contact information:
William Hal Martin, Ph.D.
Oregon Health & Science University
NRC04
3181 SW Sam Jackson Park Rd.
Portland, OR 97239
Tel: 503 494 7954
Fax: 503 494 5656
Email: martinw@ohsu.edu

ROBERT FOLMER, PH.D. is an associate professor of Otolaryngology/Head & Neck Surgery and Chief of Clinical Services for the OHSU Tinnitus Clinic. His interests are in neuroimaging of tinnitus and the psychological impact of tinnitus on patients.

BAKER Y-B. SHI, M.D., PH.D. is an assistant professor of Otolaryngology/Head & Neck Surgery and Medical Director of the OHSU Tinnitus Clinic and of the Northwest Center for Voice and Swallowing Disorders. His research interest is in the neurobiology of tinnitus and in the development of predictive indicators of appropriate medical interventions for tinnitus.

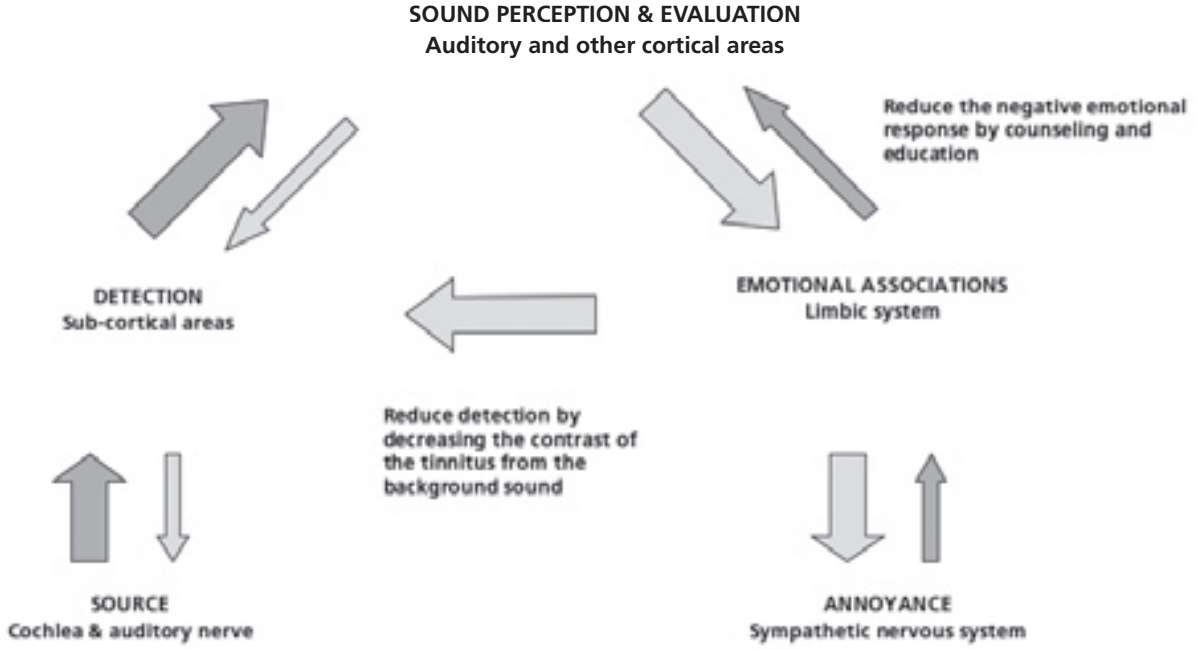

Figure 2—Simple schematic of the neurophysiological model of tinnitus. Note that the tinnitus begins in the ear (SOURCE), is detected by the lower parts of the brain (DETECTION), processed (SOUND PERCEPTION & EVALUATION) by the upper parts of the brain (Auditory and other cortical areas), then reactions set in from the limbic system. The later systems feed back into the earlier stages (DETECTION), increasing the brain's preoccupation with the tinnitus sound, causing anxiety and fear, and making the tinnitus become a serious problem for the patient.