A Systematic Review of Tinnitus: Mechanisms and Management Role of Hearing Aid Amplification in Tinnitus

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A systematic Review of Tinnitus: Mechanisms and Management Role of Hearing Aid amplification in Tinnitus

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Abstract

Tinnitus is defined as an auditory stimulus that is unrelated to external stimulation. There are many theories as to what causes tinnitus, therefore, there are many treatment options for tinnitus. This paper attempts to increase the audiologist's knowledge of the etiology, as well as, the most appropriate treatment for tinnitus. There are two types of tinnitus, objective and subjective. Subjective tinnitus is more common, although it is more difficult to treat than objective tinnitus. There are many theories as to what causes tinnitus. Several disorders that have tinnitus as a symptom, such as, Meniere's disease, acoustic neuroma, and dysfunction of serotonin levels, are discussed

Before treatment of tinnitus, the patient must undergo a medical and audiologic evaluation. Tests of tinnitus pitch, loudness, residual masking, and minimal masking are included. The implications of these tests on treatment are also discussed. There are many treatment options available for tinnitus, such as, electrical stimulation, medications, stress and psychological therapy, tinnitus maskers, and hearing aids. This paper focuses on mainly the treatments that are most feasible for an audiologist. In addition, included is an empirical study that was conducted to examine the effects of hearing aids and circuit type on tinnitus relief.

To conclude, this paper will summarize the steps to follow in order to manage a patient that exhibits tinnitus. Although there are some treatments that seem to be more appropriate for an audiologist to utilize, (i.e., hearing aids, maskers, and Tinnitus Retraining Therapy), none have been proven to be effective in every patient. Research is still needed in this area.

Abbreviations: TMJ: Temporomandibular-Joint; EcoG: Electrocochleography; ABR: Auditory Brainstem Response; ENG: Electronystagmography; rTMS: Repetitive Transcranial Magnetic Stimulation; TRT: Tinnitus Retraining Therapy; CBT: Cognitive Behavioral Therapy; PATM: Progressive Audiologic Tinnitus Management

Introduction

Tinnitus is loosely defined as the internal perception of sound in the absence of external auditory stimuli. The majority of people will perceive sound in the absence of external stimuli, but it is worth noting as a general theme, this is not considered pathologic tinnitus. As Kiang, Moxon, and Levine [1] explain, most people experience "transient ear noises". These noises are often described as a high pitched whistling and may be accompanied by a sudden, temporary hearing loss. These episodes can occur suddenly and unexpectedly and resolve just as suddenly. They are sporadic and short lived in nature. These "transient" episodes are considered "normal" ear noises and are different in nature from pathological tinnitus; however there are no published criteria to separate "transient" and "normal" ear noises from chronic pathological tinnitus [1]. Henry et al. [1] reviews literature that presents that pathological tinnitus lasts at least five minutes in duration. For the purpose of this review, transient ear noises will be considered in a different category than pathological tinnitus. Pathological tinnitus is permanent in nature, can be intermittent or constant, and causes variable levels of disturbance to the patient. As Davis and Refaie [2] explain, there is a tinnitus expression, etiology, and its effect on patients lives.

Classification of Tinnitus

Patients experiencing tinnitus often describe it as a buzzing, hissing, whistling, chirping, squealing, or roaring sensation inside the ears or head. Tinnitus can vary in loudness from a quiet background noise, to one that appears to mask external sounds [3]. Classifications of tinnitus can help to play in role in research and treatment [2]. However it can be difficult to classify tinnitus based on its subjective nature and unclear mechanism of generation [2]. For the most part, tinnitus can be classified by the way it is experienced by the patient. For example, tinnitus can be unilateral or bilateral. Acute tinnitus can last for days to weeks, while chronic tinnitus is more persistent, lasting for greater than six months [4].

Additionally, tinnitus can be classified as vibratory or non-vibratory, further categorized as objective or subjective, and further categorized by the hypothesized site of lesion. Vibratory tinnitus, which follows a rhythm, occurs because the patient is able to hear one's own muscle contractions, eustachian tube movements, blood flow within the vascular system, and other activities near the ear. Nonvibratory tinnitus is attributed to a more central neural activity [5]. Nonvibratory tinnitus is not rhythmic, but rather random. Central etiologies are hypothesized to arise from the temporal lobe, auditory nerve, or brainstem, whereas peripheral etiologies are believed to arise from the external auditory canal, middle ear, or cochlea [5]. Most nonvibratory tinnitus is associated with hearing loss at the peripheral or cochlear level [5].

If others can also hear the sounds experienced by the patient, the tinnitus is classified as objective. Objective tinnitus is far less common in all age groups, with an incidence of less than one percent [6]. However, it is worth pointing out that some disagree with the labeling of tinnitus as objective. As objective tinnitus can be heard by others, they argue that this goes against the definition of tinnitus, which as stated is the perception of sound in the absence of auditory stimuli. Since objective tinnitus is heard by both the patient and those near the patient, it is traced to a disorder that produces a real noise. As Hazell [7] suggests, tinnitus should, by definition, be subjective. Hazell [7] distinguishes between neurophysiologic and somatic tinnitus. As Hazell [7] suggests, somatic tinnitus has an underlying vascular, muscular, respiratory, or temporomandibular origin and requires medical evaluation as these are possible medically corrected conditions.

Subjective tinnitus is heard only by the patient. Noell and Meyerhoff [5] report subjective tinnitus can be vibratory or rhythmic in nature, but at a sound level that it is only experienced by the listener. Yet, subjective tinnitus is usually nonvibratory or irregular in pattern. Nonvibratory tinnitus can further be subcategorized to central or peripheral etiologies which will be further discussed.

Prevalence of Tinnitus

Epidemiologic studies across countries indicate that tinnitus affects approximately 10 to 15% of the adult population [2]. In the United States alone, the perception of tinnitus poses a significant clinical problem for millions of Americans. Tinnitus is estimated to affect somewhere between 40 to 50 million. Americans [5,8]. Davis [9] finds that the incidence of tinnitus is approximately 10.2% in the adult population and rises after the age of 50 years. Schwaber [10] corroborates that the majority of people report tinnitus between the ages of 40 and 70 years; while approximately 30% of the population over 65 years has chronic tinnitus. Approximately 50% of people with hearing loss also experience tinnitus [11]. The prevalence rate of tinnitus in children with normal hearing thresholds has been reported to range from 6 to 36% [12]. This prevalence rate has been reported as high as 76% for children with a documented hearing loss [12].

Clearly there is a large variability in the estimated prevalence rates of tinnitus in children. There are several hypothesizes as to how to explain this large variability in reported tinnitus rates. Many of these hypothesizes also help explain why it can be difficult to study tinnitus in children. One possible explanation for this large variability in prevalence rates is due to the difficulty involved in interviewing children. It has been suggested that children rarely complain or talk about tinnitus when they experience it [13]. Some possible explanations for this include: children do not see tinnitus as a problem and have learned to live with it, children are scared to talk about tinnitus, children do not have the vocabulary to discuss tinnitus, or children may not be concerned about tinnitus when they do experience it.

Savastano [13] reports that children rarely spontaneously complain about tinnitus, but will talk about tinnitus when probed. Savastano [13] reports a nearly 30% increase in tinnitus reports when the issue is specifically addressed to children. This is an important figure to remember as it points to the importance of probing children about tinnitus during the case history or audiologic examination. While some people experience tinnitus constantly, many people only experience tinnitus when in a quite

environment. People who only experience tinnitus in a quiet environment may be less likely to seek medical intervention for the condition as they do not find it to hamper their quality of life. However, of the approximately 40 to 50 million Americans that experience tinnitus, it is estimated that around 10 million people seek medical intervention because their tinnitus is so severe or troubling that it is negatively impacting the productivity and quality of their lives [5].

Effect of Tinnitus

Reactions to tinnitus can vary in severity from mild irritation to suicidal ideation [5]. As Han et al. [3] described, the most common reactions to tinnitus include annoyance, concentration difficulties, sleep disturbance, and decreased speech clarity. It is estimated that approximately 20 to 30% of patients with tinnitus find their tinnitus disruptive to everyday activities, mood, and sleep [14]. Both anxiety and depression are commonly reported by tinnitus patients [15]. Other psychological distresses associated with tinnitus include anxiety, depression, irritability, anger, and insomnia [16]. Herbert and Carrier [17] report that the majority of studies show that sleep difficulties are associated with tinnitus and these difficulties increase as the reported severity of tinnitus increases.

Children with tinnitus may demonstrate additional problems to those seen in adults. Savastano [13] indicates that tinnitus can cause nervousness, depression, and irritability in children. Additionally, tinnitus may make it difficult for children to pay attention, sit still, and sleep [13]. These characteristics may be very similar to those seen in children with attention deficit disorders. Tinnitus can also have a negative impact on a child's academic development. Savastano [13] indicated that tinnitus can cause learning and writing difficulties as well as a decrease in lingual capacity, and failing grades. These academic concerns emphasize the need for prompt and appropriate diagnosis and intervention. Although there is little research into the severity of tinnitus in children, Baguley [18] indicates that is reasonable to believe that psychological attributes such as depression and concentration can be attributed more to tinnitus severity than audiometric thresholds across all populations.

Processes related to Tinnitus

The sensation of hearing occurs after sound waves travel through the outer, middle, and inner ear to the cochlea, up the auditory nerve, to the brainstem, and into the auditory cortex of the temporal lobe. It is important to have a basic understanding of this process because theories of tinnitus relate to breakdowns along any one of these routes of transmission. When no sounds are present, random activity occurs in the neurons of the auditory pathway. The brain prioritizes all the sound information it receives, so the nervous system generally filters out this random neural activity thus no sound is perceived [6]. In a normal auditory system, external noise overrides any internal or random noise. However, tinnitus occurs when internal noise is given higher priority and thus dominates or accompanies external noise [18]. Regardless of the underlying pathology or pathophysiology behind tinnitus, the internal signal is processed by the central auditory nervous system and perceived as sound in the auditory cortex [1].

Neuromonics [19] explains tinnitus is the result of neurological changes within the auditory system and within parts of the brain that influence attention and emotions. In dealing with tinnitus, it is important to realize that the exact cause is not known but rather theorized. Much research on the topic still needs to be completed. As Henry et al. [1] indicate knowledge of the pathologic mechanisms and cellular events that surround tinnitus are insufficient to enable identification even in cases where the cause seems evident. Tinnitus in and of itself is often not classified as a disease, but rather as a symptom of an underlying problem [3]. This section will investigate the theorized mechanisms of pathophysiology and factors associated with tinnitus.

Classification of Path physiology of Tinnitus

Since tinnitus is described by patients in terms qualitatively similar to external sounds, such as buzzing or ringing, it can be suggested that the pathways responsible for tinnitus are the same as those that process external sounds [1]. Zenner and Pfister proposed three broad classes of tinnitus based on anatomical and functional divisions of the auditory system. These classes are comprised of conductive tinnitus, sensorineural tinnitus, and central tinnitus. These classifications compromise all divisions of the auditory system and highlight the idea that tinnitus generation can originate from the peripheral auditory system up to the level of the central auditory system or temporal lobe. As Henry et al. [1] explain, conductive tinnitus would be caused by some pathology at the level of the middle ear, such as otitis media or otosclerosis.

This would be the rarest of all classes of tinnitus. Sensorineural tinnitus contains four subclasses. These subclasses include:

1) Tinnitus related to the outer hair cells also referred to as motor tinnitus,

2) Tinnitus related to the inner hair cells also referred to a transduction tinnitus,

3) Tinnitus related to the auditory nerve also referred to as transformation tinnitus, and

4) Tinnitus related to the "extrasensory" sources also referred to as objective tinnitus. Central tinnitus relates to tinnitus originating anywhere in the central auditory pathways. Although these classes of tinnitus are not necessarily universal, they do cover all the possible cites of origin of tinnitus [1]. It is believed that all levels of the nervous system are involved in the perception of tinnitus to some degree [20].

Tinnitus and the Autonomic Nervous System

The auditory system is designed to hear and interpret sound. As such, the ears are constantly searching for meaningful sounds in the environment. Sounds that carry little meaning are quickly habituated to and ignored by the central nervous system [1]. For example, when driving in a car, one will pay attention to the radio and not the road noise. Since tinnitus is a sound that carries no meaning, habituation should be the norm [21]. Habituation is in fact the norm for more than 80% of those who experience tinnitus [3]. However, in patients who seek treatment for tinnitus, habituation does not occur. Rather, tinnitus becomes the focus. As

tinnitus becomes the focus, it becomes bothersome, disturbing, and intrusive [1]. Even if the condition underlying tinnitus (e.g. hearing loss) has been present for months or years, the patient begins to attend to tinnitus essentially making it more audible. As the patient begins to attend to the tinnitus more and more, they may begin to fear that they are going deaf or they have a serious underlying medical condition. Slowly they begin to associate anxiety, fear, and distress with tinnitus, thus paying more attention to the condition. The more the patient attends to the tinnitus, the stronger the cycle of worry and depression becomes. Psychological reactions and negative associations begin to amplify and exacerbate the perception of tinnitus [1].

PJ Jastreboff [20] believes that there are no known differences in psychoacoustical characteristics of tinnitus, such as pitch, loudness, and masking level, for those who experience tinnitus versus those who suffer from tinnitus. Therefore, tinnitus must be more than just an auditory system dysfunction. If tinnitus were related strictly to the auditory system, one would expect perceived psychoacoustical characteristics to be more intense for those with more bothersome tinnitus. However, since this is not the case, it is theorized that the level of annoyance from tinnitus is related to the degree of activation of the limbic and autonomic nervous systems [22]. Once the perception of tinnitus begins to produce annoyance and anxiety, it begins to become associated with annoyance and anxiety, and therefore tinnitus begins to lead to annoyance and anxiety.

The processes underlying tinnitus are often described as a vicious cycle. The perception of the tinnitus begins to increase as does the annoyance and anxiety thus resulting in enhanced activity of the limbic and autonomic nervous system [22]. It is in fact the limbic and sympathetic nervous system that becomes responsible for the negative reaction to tinnitus [22]. PJ Jastreboff [23] presents the development of tinnitus suffering: tinnitus is caused by abnormal neural activity which is interpreted and perceived in the central nervous system and leads to the activation of the autonomic nervous system and limbic system which are areas in the brain that are not auditory in nature.

Peripheral-Sensorineural Tinnitus

As mentioned, the site of generation of tinnitus can arise anywhere from the middle ear to the central hearing system, yet sensorineural tinnitus is believed to be the most common [1]. Sensorineural tinnitus would fall under the classification of peripheral tinnitus, arising in the inner ear. The idea that tinnitus originates in the inner ear has been supported by the idea that patients often localize tinnitus to one ear versus the other [20]. Generally, factors that are associated with hearing loss are believed to be associated with tinnitus. It serves that as sensorineural hearing loss is the most common form of hearing loss, and hearing loss is so highly correlated with tinnitus, sensorineural tinnitus would be the most common form of tinnitus.

It has been established that tinnitus is highly correlated with hearing loss. In fact, populations that have a higher prevalence of hearing loss also have a higher prevalence of tinnitus and the majority of tinnitus patients also have hearing loss [24]. Yet [25] cautions that other medical factors also increase with age and could contribute to tinnitus. These factors would include vascular disease, middle ear pathologies, diabetes, hypertension, autoimmune disorders, and neural disorders. Likewise, medical conditions 12 may lead to the increase use of medications which could also be linked to tinnitus. Thus it is always important to stress that correlation does not imply causality.

Noise exposure is commonly correlated to the onset of tinnitus. Noise induce tinnitus can be either acute or chronic, lasting for several minutes after noise exposure or lasting for extended lengths of time [3]. In the case of noise induced hearing loss, the damage to the auditory system is cochlear and thus one would surmise that as the hearing loss and tinnitus occurred at the same time, the tinnitus is also cochlear in nature [1]. This type of tinnitus is most commonly described as a high piched tonal or hiss like sound [26].

Schaette and Kempter [27] concur that there is much evidence that tinnitus is related to hearing loss, yet propose that there is little known on how hearing loss leads to tinnitus. They suggest animal studies show that tinnitus is correlated to increased spontaneous firing rate of central auditory neurons. Schaette and Kempter [27] present an experimental design that reproduced tinnitus related hyperactivity and predicted tinnitus pitch from audiograms of tinnitus patients with noise induced hearing loss and tone- like tinnitus. They theorize that decreased auditory activity due to hearing loss is counteracted by an increase in neural response gain. The increased neural response gain in effect restores the mean firing rate, but also leads to hyperactivity in the central auditory neurons. They show that hyperactivity patterns are strongest at frequencies close to perceived tinnitus pitch which also correlates to patient's audiogram in terms of hearing loss. Thus they suggest tinnitus can be caused by cochlear damage.

Tinnitus and Hair Cells

Many peripheral theories of tinnitus focus on the role of inner and outer hair cells in the perception of tinnitus. Inner and outer hair cells line the cochlear basilar membrane. Outer hair cells act as cochlear amplifiers providing 50- 60 dB of gain, while inner hair cells are the receptor cells that transduce hydraulic vibration in the cochlea to neural code enabling sound perception [23]. Due to the anatomy of the auditory system, hearing loss is often first triggered by the loss of outer hair cells. The discordant dysfunction theory holds that on each area of the basilar membrane where outer hair cells are dysfunctional and inner hair cells are more functional, the imbalance in function causes imbalance in the dorsal cochlear nucleus DCN [22].

Specifically the hair cell dysfunction causes disinhibition in the DCN. This may cause an increase in spontaneous activity which is perceived as tinnitus. This theory is used to explain why some people with normal hearing also experience tinnitus: dysfunctional outer hair cells. It is also used to explain why some people with profound hearing loss do not experience tinnitus; both inner and outer hair cells have similar levels of dysfunction. Given this theory, temporary tinnitus following noise exposure can also be explained; noise creates temporary damage to the outer hair cells and does little to the inner hair cells [23].

Central Tinnitus

As the earliest theories regarding the site of tinnitus generation pointed to the cochlea, over time the idea that tinnitus was solely confined to the inner ear began to come into question [1]. In cases of severe tinnitus, some 14 patients underwent surgical sectioning of the auditory nerve. As these surgeries did not always eliminate the perception of tinnitus, it was theorized that tinnitus is generated by the central nervous system as triggered by cochlear damage [1]. Møeller [28] suggests that abnormal auditory signals activate neural plasticity within central structures which is perceived as tinnitus. In other words, pathologies in the ear or auditory nerve result in abnormal input which leads to change in more central structures. This change is then perceived to the patient as tinnitus. So, damage to the cochlea, enhances neural activity in the central auditory system.

This is referred to as the auditory plasticity theory of tinnitus [3]. The DNC has also been implicated as a possible site of generation for tinnitus [29]. Following ototoxic drug treatments, such as cisplatin, or extreme noise exposure, the DNC can become hyperactive [29]. It is hypothesized that a reduction in auditory nerve input lead to disinhibition of the DCN and an increase in spontaneous activity in the central auditory system which is perceived as tinnitus [30].

Neurophysiologic Model of Tinnitus

The neurophysiologic model of tinnitus was first described by PJ Jastreboff [20]. The neurophysiologic model of tinnitus does not identify the mechanisms responsible for generating the neural activity that results in tinnitus, but rather the results of this neural activity [23]. The model presents three main postulates regarding clinically significant tinnitus. The first postulate holds that other systems in the brain aside from the auditory system have to be involved in the perception of tinnitus [23]. As was previously discussed, PJ Jastreboff and Hazell [22] believe this other system is the autonomic nervous system which assigns negative reactions to tinnitus. The second postulate is that tinnitus is phantom perception [20]. PJ Jastreboff [23] reported that tinnitus perception results from the detection and perception of neural activity within the auditory pathway, despite the absence of external sound.

There is no "vibratory activity" in the cochlea that is causing tinnitus. PJ Jastreboff [23] used this postulate to explain why tinnitus can often not be masked or suppressed by external sounds. The reason being, tinnitus has no connection to external stimuli. The final postulate stresses the difference between tinnitus perception and tinnitus suffering [23]. As PJ Jastreboff [23] explains, the mechanisms responsible for the generation of tinnitus neuronal activity are the same in people who experience tinnitus and those who suffer from tinnitus. He cites the lack of difference between pyschoacoustical characteristics of tinnitus, such as pitch and loudness, as support for this postulate. The difference between those who merely experience tinnitus and those who suffer from tinnitus lies in the mechanisms responsible for spreading tinnitus related neural activity throughout the brain. This abnormal spread of neural activity is present only in those whom suffer from tinnitus.

Medical Conditions Associated with Tinnitus

Tinnitus is often associated with the same otologic disorders that cause conductive and sensorineural hearing loss [31]. Causes of conductive hearing loss that may lead to tinnitus include cerumen impaction, otitis media, eustachian tube dysfunction, otosclerosis, and other diseases of the ossicles [6]. Cerumen impaction is reported by many produce a low pitched, intermittent non-vibratory sound that is resolved with the removal of the cerumen impaction [5]. Although not necessarily conductive in nature in the sense of originating from the middle ear, some dental disorder and temporomandibular-joint (TMJ) dysfunction have also been documented to be associated with tinnitus [3].

As was previously mentioned, in less than one percent of all tinnitus cases, the tinnitus can be heard by both the patient and others. This form of tinnitus, although controversial as it is experienced by others and not just the patient, is labeled objective tinnitus [6]. Objective tinnitus is often caused by disorders affecting the middle ear. Occasionally, objective tinnitus is experienced as a heartbeat or pulsatile sensation. Pulsatile tinnitus is often associated with vascular disorders. Glomus tumors also produce tinnitus that is pulsatile in nature. Glomus tumors are slow growing vascular tumors which can grow in the temporal bone or middle ear space [32]. Muscular disorders of the middle ear, such a spasm of the stapedial muscle, have also been associated with objective tinnitus [6]. Finally, eustachian tube dysfunction and patulous eustachian tubes have been linked to objective tinnitus [4].

Other comorbid conditions provide insight into tinnitus. Tinnitus is often reported following or in association with the use of drugs. Asprin, quinine and cisplatin are the most common drugs known to induce tinnitus [23]. Tinnitus associated with ototoxic drugs is often reported as a high- frequency ringing [5]. Alcohol, caffeine, and tobacco have also been linked to an increase in tinnitus symptoms [6]. Likewise, low-pitched roaring tinnitus is often a symptom of Ménière's disease [26]. Ménière's disease is often referred to as endolymphatic hydrops. Ménière's disease is believed to be related to hair cell damage due to too much endolymph in the cochlea [1]. Finally, patients with acoustic neuromas often report unilateral tinnitus [5].

Evaluation of Tinnitus

The evaluation of tinnitus consists of two processes. The first involves a complete medical evaluation. The second involves audiological testing. Since this work is focused on the role of audiology in the evaluation and treatment of tinnitus, the medical evaluation is only briefly discussed. Audiological procedures and recommended protocols are then presented. Before the treatment plan for tinnitus is decided, it is important to have a complete medical evaluation completed. It is important to remember that tinnitus is a symptom and any medical disease that might include tinnitus should be ruled out. The evaluation should include the following.

Appendix A: Tinnitus and Hyperacusis History.

Patient Questionnaire

Name: _____ Date: _____

Address: _____

Date of Birth: _____ Age: _____

Referred By: _____

1. When did you first become aware of having tinnitus?
2. If you have hyperacusis (hypersensitivity to loud sounds), when were you first aware of this problem?
3. In which ear is your tinnitus (right, left, both, not in ears, in the head)?
4. If your tinnitus is in both ears, is one louder than the other, and if so, which one?
5. What is your tinnitus sound like (for example, ringing, crickets, humming, etc.)?
6. Is the volume of tinnitus stable, or does it change?
7. Is it a pulsing sound that changes in time with your heart?
8. What seems to make the tinnitus/hyperacusis change?
9. Is it made worse by exposure to a sound?
10. If so, how long does it stay bad after sound exposure?
11. List all methods, procedures, medications, or devices you have tried for our tinnitus, and the treatment outcomes (include additional sheet if you want).
12. Have you seen ear specialists about your tinnitus?

How many?

What were you told?

13. Do you have hearing loss? If so, please describe:
14. Do you wear hearing aids?
15. Are you uncomfortable around certain sounds?
16. Do you wear ear protection (plugs or muffs)?

If so, about what percentage of time do you wear them?

17. Do you wear ear protection in quiet situations?
18. Do you experience pain in the ears from loud sounds?
19. Have you ever worked anywhere that exposed you to continuous loud sounds?
20. Estimate the percentage of time over the past month that you have been aware of the tinnitus?
21. Estimate the percentage of time over a month period (not counting sleeping) when you are:
    a. in a quiet environment (ex: quiet home; you can be understood even when speaking softly) _____%
    b. moderate environment (ex: average street, office, restaurant) _____%
    c. loud environment (ex: noisy work place, very loud radio or TV) _____%
22. Are there activities that you are prevented from doing, or that are affected by the tinnitus/hyperacusis? Indicate with an X your answers in the areas below.

Activity	Tinnitus		Hyperacusis		
	Yes	No Not sure	Yes	No	Not sure
Concentration	____	____ ____		____ ____	____
Falling asleep	____	____ ____		____ ____	____
Staying asleep	____	____ ____		____ ____	____
Restaurants	____	____ ____		____ ____	____
Social Events	____	____ ____		____ ____	____
Church	____	____ ____		____ ____	____
	Tinnitus			**Hyperacusis**	
	Yes	**No Not sure**	**Yes**	**No**	**Not sure**
Sports events	____	____ ____	____	____	____
Quiet activities	____	____ ____	____	____	____
Concerts	____	____ ____	____	____	____
Other	____	____ ____	____	____	____

23. Do you fell depressed?

If so, please explain why?

24. Did you have any depression or anxiety before the onset of tinnitus or hyperacusis? If so, when?

25. What medications are you currently taking, and what is each for (use an additional sheet if necessary)?

26. Do you have any legal action pending in relation to your tinnitus or hyperacusis, or are you planning legal action?

27. On the scale of 0 to 10 (0 = none; 10 = totally ruined), indicate the influence tinnitus and hyperacusis have on your life

28. Rank (indicate by a number) how much these concern you (1 = most and 3 = least):

First, a complete history should be obtained, where the patient describes his/her tinnitus (See Appendix A for a case history example). Questions such as, is there any associated complaints such as hearing loss, vertigo, etc., what is the past history, such as, previous tinnitus testing, illnesses and medications should be included. Also a familial history of severe tinnitus is significant. The patient's mental health should be briefly evaluated. It should be noted if any anxiety or depression is present. This will assist the clinician in determining if antidepressants or other medications are viable treatment options. Any signs of neurologic disease, such as, seizures, delirium, dementia, ataxia of gait, tremor, or dysarthria should be noted. These can indicate brain damage and can be associated with tinnitus.

Occasionally, hyperacusis, which is hypersensitivity to sound, will also accompany tinnitus. The presence of hyperacusis will need to be noted, so that further treatment can be given. Next, a general medical exam should look for the presence of cardiovascular disease, renal disease, endocrine disease, metabolic disease or collagen disease. Tinnitus is often a symptom of these diseases. Successful treatment of these diseases can sometimes alleviate the patient's tinnitus. The clinician is also advised to review the patient's medication list to see if any of the drugs used have tinnitus as a side effect. If so, it may be beneficial to reduce the prescription or replace it with an equivalent that does not cause or worsen tinnitus.

As in any routine examination, the ear should be thoroughly inspected for any abnormalities and blockage. Removal of excessive wax can sometimes be a simple solution to reducing or eliminating tinnitus. Most importantly an audiologic evaluation should be completed. This includes basic audiometric testing including pure-tone and speech, tympanograms, acoustic reflex and decay, electrocochleography (EcoG), auditory brainstem response (ABR), and Electronystagmography (ENG). Each of these tests can possibly help in identifying the nature or cause of the patient's tinnitus. Each test will tell the audiologist the site of lesion. For example, the audiogram, and tympanogram will help to determine if there is a hearing loss, distinguish between sensory and conductive, and rule out retrocochlear pathology. The presence or absence of acoustic reflexes and decay and the ABR will indicate if there is a lesion on the eighth nerve.

In addition, some patients with tinnitus will have an ABR that is dyssynchronous in all or part of the waveforms. The ENG will help in identifying disorders, such as, Meniere's disease or secondary endolymphatic hydrops, both of which have tinnitus as a symptom. Once all that is completed the evaluation of the tinnitus can begin. Appendix B has an example tinnitus evaluation form that can be used to record the results of the evaluation. There are several tests that are often used in the assessment of tinnitus, which are as follows:

Appendix B: Adapted from Pawel Jastreboff, Tinnitus and Hyperacusis Center, University of Maryland.

Tinnitus Evaluation Form						
Name: _____					Date: _____	
Tinnitus today?	Right	Left	Head	**Hyperacusis:** yes		no
Threshold for white noise:			Right	____ dB HL	Left	____ dB HL
Pitch Match:			Right	____ Hz/ NBN	Left	____ Hz/ NBN
Threshold for tinnitus pitch:			Right	____ dB HL	Left	____ dB HL
Loudness match: Right	____ dB HL @ Hz/ NBN Left ____ dB HL @ Hz/ NBN					
Minimal Masking Level (MML)					**Loudness Discomfort Levels**	
With white noise:					**(LDL) in dB HL:**	
Presentation		**Response**		**Right Ear**		**Left Ear**
Right	Right	____ dB HL		1000Hz	_____	_____ dB HL
	Left	____ dB HL				
	Both	____ dB HL		2000Hz	_____	_____ dB HL
Left	Right	____ dB HL		3000Hz	_____	_____ dB HL
	Left	____ dB HL				
	Both	____ dB HL		4000Hz	_____	_____ dB HL
Both	Right	____ dB HL		6000Hz	_____	_____ dB HL
	Left	____ dB HL				
	Both	_____ dB HL		8000Hz	_____	_____ dB HL
				Speech	_____	_____ dB HL

(1) Pitch matching

(2) Loudness matching

(3) Measure of residual inhibition

(4) Minimal masking levels (Feldmann masking curves)

Appendix C shows the specific instructions of each test. Each test is also described below.

Appendix C: Instructions for the Tests of Tinnitus.

A. Pitch Matching	
1.	Begin by presenting a few tones of different frequencies to make sure the patient can tell the difference between them.
2.	Explain to the patient at this time that he/she will be presented with two tones and will have to pick the one that sounds closest to their tinnitus. Make sure the patient understands that it is the pitch that is important not the level (loudness) of the tone.
3.	Present 1000 and 4000Hz pulsed tones alternately in the ear ipsilateral to the tinnitus (either ear if it is heard in both ears) at a comfortable level for the patient. Ask the patient to choose the one closest to their tinnitus.
4.	Present the tone that the patient chose along with another tone either one octave above or below that tone.
5.	Repeat until the patient has identified the pitch match.
6.	Use narrow band noise or white noise for patients that describe their tinnitus as a "hissing or swishing" noise
B. Loudness matching	
1.	Use the tone that the patient chose as the tinnitus match.
2.	In the ear ipsilateral to the tinnitus, start presenting the tone slightly below the patient's threshold for that tone and slowly ascend by 2dB steps.
3.	Instruct the patient to tell you when the tone is closest to the loudness that they experience the tinnitus.
4.	Stop ascending and repeat several times to ensure accuracy.
C. Measurement of Residual Inhibition	
1.	Use the tone that the patient chose as the tinnitus match.
2.	Present that tone 10dB above the loudness match for 1minute.
3.	Place into the correct category:
	a) Positive-Complete: the patient reports after the 1min presentation that the tinnitus is completely gone. (It is often interesting to time how long it takes for the tinnitus to return)
	b) Positive-Partial: the patient reports that the tinnitus is still there, but at a reduced level.
	c) Negative: the patient reports no change in the tinnitus
	d) Rebound: the patient reports that the tinnitus became louder. This patient will not be a good candidate for masking generator.
D. Minimal Masking Levels	
1.	Find the threshold for white noise.
2.	Present the white noise in the right ear slightly below the threshold and ascend in 2dB steps.
3.	Instruct the patient to tell you when he no longer hears the tinnitus in the right ear.
4.	Repeat presenting in the right ear, although this times, instruct the patient to tell you when he no longer hears tinnitus in his left ear.
5.	Repeat again, with the patient telling you when he no longer hears the tinnitus in both ears.
6.	Present the white noise in the left ear next, then both ears, each time have the patient tell you when he no longer hears tinnitus in his right, left and both ears.

Appendix D: The Effects of Hearing Aid Amplification on Tinnitus.

A. Introduction	There is some data to suggest that hearing aid use may be effective for relieving tinnitus in at least some individuals (e.g., Von Wedel, Von Wedel, & Walger, 1998; Surr, Montgomery & Mueller, 1985). Specifically, there are some circuits in hearing aids, such as, wide dynamic range compression circuits, that have inherent circuit noise that may mask the patient's tinnitus. No one to date has examined whether or not relief from tinnitus with hearing aid use is in any way related to the type of hearing aid circuitry used. Thus, the following project was designed to examine whether or not the type of circuitry is related to the alleviation of tinnitus.
B. Methods	a) Participants: All patients (n=218) who received hearing aids from August to September 2010 at Dr Talsania Hospital Ahmedabad served as participants. Participants were not excluded on the bases of sex, age, extent of hearing loss, or type of hearing loss. b) Survey Instrument: The Tinnitus Questionnaire developed by Surr, Montgomery and Mueller (1985) was used and is shown in (Table 1). The instrument was chosen since it had been used previously to evaluate the effects of hearing aid use and the alleviation of tinnitus.

Table 1: Tinnitus Questionnaire: Adapted from: Surr R. K., Montgomery, A.A., & Mueller, H.G. (1985). Effect of amplification on tinnitus among new hearing aid users. Ear and Hearing, 6(2), 71-75.

Many people with hearing impairments also have a ringing or other noise, called tinnitus, in their ears. Use of a hearing aid can affect this tinnitus. You can help us find out more about this aspect of hearing aid use by answering the following questions. _____			
1. Before the hearing aid was issued to you, did you have ringing or other noise, called tinnitus, in your ear(s)? YES IN BOTH EARS_____ YES IN LEFT EAR_____			
2. How long have you had this tinnitus? 0-1 yr_____ 1-5 yrs_____ 5-10 yrs_____ 10+ yrs_____			
3. Is the tinnitus CONTINUOUS_____, FREQUENT_____, or OCCATIONAL ___?			
4. Do you consider your tinnitus MILD_____, MODERATE_____, or SEVERE____?			
5. When you wear your hearing aid in the RIGHT EAR, does your tinnitus: STAY THE SAME_____ GET LOUDER_____ GET SOFTER_____ DISAPPEAR____ or SEEM LOUDER IN THE UNAIDED EAR_____?			
6. When you wear your hearing aid in the LEFT EAR, does your tinnitus: STAY THE SAME_____ GET LOUDER_____ GET SOFTER_____ DISAPPEAR____ or SEEM LOUDER IN THE UNAIDED EAR_____?			
7. When you wear your hearing aids in BOTH EARS simultaneously (binaurally), does your tinnitus: STAY THE SAME_____ GET LOUDER_____ GET SOFTER_____ DISAPPEAR_____ I have not tried aids for both ears simultaneously _____.			
8. If the hearing aid changes the tinnitus, how long does it take for it to return to "normal" after you remove the aid? IMMEDIATELY_____ ¼-3 HRS_____ UP TO 6 HRS_____ LONGER THAN 6 HRS_____.			
9. How long have you had a hearing aid FOR THE RIGHT EAR_____ FOR THE LEFT EAR_____?			
10. Please rate your hearing aid performance on the following situations:			
	VERY HELPFUL	SOMEWHAT HELPFUL	OF LITTLE USE
Hearing in quiet	_____	_____	_____
Hearing in a large group or party	_____	_____	_____
Hearing in a small meeting	_____	_____	_____
Effect on tinnitus	_____	_____	_____

Pitch Matching

Purpose: Pitch matching attempts to quantify tinnitus in terms of its possible frequency. It is used as a reference point for discussion for the clinician and patient. It is also used for the fitting of tinnitus maskers.

Procedure: The procedure for matching tinnitus pitch is usually a two-alternative forced choice. Two tones are presented to the patient and the patient is asked to choose which one most closely matches the tinnitus that they hear. This is continued until the match is made. Goldstein and Shulman suggest that the procedure should be repeated seven to nine times to ensure the correct match.

An octave confusion test should be performed next. This is the phenomenon where the patient has identified one tone as matching the tinnitus, when, with further testing, the match is actually one octave above or below the tone. The clinician should use the same two-alternative forced choice procedure using the tone the patient picked and the octave above and below it.

Concerns: There are some complications associated with pitch matching. First, many patients experience tinnitus that has more than one type of pitch. It may be quite difficult to decide which pitch is the predominate one, or to ignore the other pitches while attempting to match the tinnitus. Also, there are many patients who report that their tinnitus changes quite frequently, so any matching will be unreliable. Third, there is the possibility that the patient's tinnitus will be masked by the tones presented during tinnitus matching. Clinicians also have to be careful that the patient does not confuse pitch matching with loudness. It has been suggested that tinnitus loudness matching should be completed first and then the pitch matching tones should be presented at the matched level of loudness.

Implications for treatment: The results of the pitch match are very useful in the counseling of a tinnitus sufferer. First of all, it helps to validate the presence of tinnitus, which can be very comforting to the patient. The patient now knows that the tinnitus is real and that he/she is not just imagining it. Secondly, the pitch match is used for the selection and fitting of tinnitus maskers.

Tinnitus maskers are discussed in detail in the Treatment section of this paper.

Loudness Matching

Purpose: Loudness is the perceptual equivalent of sound intensity. Therefore, this test attempts to quantify the tinnitus in decibels. Similar to pitch matching, this test is also used in the counseling of the tinnitus patient.

Procedure: Tinnitus is usually found to be only a few decibels above a person's threshold for the frequency being tested. One procedure for loudness matching suggested by Goldstein and Shulman is to start at a level just below threshold and increase intensity until the patient signals a match. They use a frequency that is at or near the frequency that was matched to the patient's tinnitus.

Concerns: There is some question as to whether a tone that matches the patient's tinnitus should be used when matching loudness or whether a separate tone be used. Goldstein and Shulman also question whether to use the ipsilateral, contralateral, or sound field as reference. Henry and Meikle pointed out that loudness matches tend to be larger where hearing is normal. They suggest that recruitment may be responsible for the loudness matches being so small.

Implications for treatment: The most important reason for the loudness match is to help counsel the patient. Since most loudness matches are only a few decibels above the patient's threshold for that frequency, it is comforting to the patient see that the tinnitus really is not as loud as they perceived it to be (Hall & Haynes, in press).

Residual Inhibition Test

Purpose: The purpose of testing for residual inhibition is to determine whether the use of tinnitus maskers would be a viable treatment course.

Procedure: Residual inhibition is defined as the temporary suppression and/or disappearance of tinnitus following a period of masking. To test for residual inhibition the clinician should use the tinnitus frequency at 10dB above the loudness match for one minute. Then the post-masking effects are classified into four categories. These categories are;

a) positive-complete, where the tinnitus is completely absent for more than one minute;

b) positive-partial, where the tinnitus is still present but softer at a lower perceived level than before for more than one minute;

c) Negative, where there is no reported change in the tinnitus; and finally,

d) Rebound, where the tinnitus is actually louder after the masking stimulus is presented.

Concern: No concerns are reported for tests of residual inhibition.

Implications for treatment: It is important to find out which category each patient's tinnitus is because it lets the clinician know if instrumentation is a viable tool for the treatment of tinnitus . For example, a patient who exhibits a positive- complete or positive-partial would most likely be a good candidate for masking instrumentation. Rebound, on the other hand, would be a contraindication to maskers.

Minimal masking

Purpose: The main purpose for minimal masking is for the use of ear worn maskers.

Procedure: This is a test of the least amount of masking intensity needed to just mask the tinnitus. The patient is given a noise band or tone for about 1-2 seconds at a low level and asked if he hears his own tinnitus. This level is changed until the tinnitus is just masked. This is completed for all the frequencies, 250 to 8 KHz. The resulting curves are then classified according to Feldman's system .There are six types of curves in the Feldman's system. Type 1, convergence, the patient's threshold curve and masking curve will slope together from low to high frequencies. They will meet at the frequency of the tinnitus and all frequencies above that. Type 2, divergence, the threshold and masking curves slope further apart from low to high frequencies. Type 3, congruence, the threshold and masking curves almost overlap each other for all frequencies. This type of tinnitus can be masked by any noise just above the threshold of the tinnitus. Type 4, distance, the masking curve follows the threshold curve, but is at least 20dB above the threshold. Type 4a, is the same as type 4, but the tinnitus can only be masked by pure tones. Finally, Type 5, persistence, is found when no sound at any level can mask tinnitus. This usually happens when the patient has a severe to profound hearing loss, but occasionally it occurs with those with moderate hearing loss.

Concerns: No concerns are reported for the testing of minimal masking levels.

Implications for treatment: After the minimal masking curves have been established, the audiologist can determine whether masking is a good choice for treatment. If a patient exhibits a convergence curve, this indicates good candidacy for acoustic masking. A divergence curve shows poor but possible acoustical masking. Since congruence can be masked by any sound, a patient with this curve will be a good candidate for any type of masker. The patient with a distance curve may not be able to tolerate acoustical masking because of the level of masking required to mask the tinnitus. Finally, the patient with a persistence curve is also not a candidate for acoustical masking.

Summary of Tinnitus Evaluation

Several tests which are typically included in a tinnitus battery were described, along with the implications of results for treatment. Once these tests are completed, the audiologist can pursue a treatment for the patient. Over the years there has been many treatments developed for tinnitus. The next section will briefly describe some of the treatments available for the audiologist.

Management of Tinnitus

It is worth reiterating that of the estimated 50 million Americans with tinnitus, only 12 million seek treatment and only 2 million consider themselves debilitated by their tinnitus [8].

Therefore, the course of treatment for each tinnitus patient will be varied and unique patient characteristics should be carefully considered. Tinnitus treatment is even further complicated by the idea that the exact causes of tinnitus have not been identified. As described Henry, Dennis, and Schechter [1] identifying the mechanisms of tinnitus is of utmost importance as treatment could be directed at the cause of tinnitus rather just the consequences of tinnitus. It is noted in much tinnitus literature that since tinnitus is a subjective symptom, it is difficult to do epidemiologic and efficacy studies for treatment.

Currently tinnitus management can be broken down into several main categories. Noble identified four major classes: pharmacological, acoustic, psychological, and any combination of the aforementioned. Medical or surgical treatments and alternative medical treatments would also be worth adding to these major classes. It is necessary to gather information on both the auditory characteristics and perceived intrusion tinnitus is imposing on the patient in order to form a treatment plan.

Medical/Surgical Treatment

If an underlying medical or otologic condition is determined to be correlated with the tinnitus, surgical intervention may provide relief. In fact, De Ridder, Menovsky, and Vande Heynig [33] caution that providers immediately opt for non-surgical intervention forgetting that surgical intervention may be an option. They emphasize a thorough investigation of possible surgical solutions for those with severely troubling tinnitus. De Ridder et al. [33] summarize the most relevant pathologies that may be treatable with surgical intervention including; vestibular schwannomas and other cerebellopontine angle lesions, arachnoid cysts, Ménière's disease, otosclerosis, brain tumours along the auditory pathways, Chiari malformations, microvascular compressions of the vestibulocochlear nerve, benign intracranial hypertension, arteria carotid stenosis, glomus tumours, vascular lesions of the petrous bone and skull base, ateriovenous malformations, aneurysms, and vascular loops inside the internal auditory canal.

Dental treatment for temporomandibular joint (TMJ) problems may help patient who have tinnitus associated with their TMJ [8]. Inconsistent results have been obtained regarding stapendectomy surgery for patients whose tinnitus is associated with otosclerosis. Some patients report tinnitus symptoms improve greatly while others notice no difference. If an acoustic neuroma or glomus tumor is found, surgical removal may help alleviate tinnitus. In severe cases of Meniere's disease surgery can help improve both tinnitus and vertigo symptoms [5].

Diet/Lifestyle

Patients with tinnitus are often told to avoid certain foods, medications, and stimulants that have been linked to tinnitus [5]. Certain drugs, such as aspirin and NSAIDs, are also known to exacerbate or cause tinnitus in some patients. Patients should limit or avoid these medications if they can be linked to tinnitus onset. People with Ménière's disease are often told to avoid salt as low sodium diets are linked with an improvement in symptomology [5]. As Ménière's disease is often related to a fluid imbalance in the inner ear, reduction in sodium can help reduce fluid fluctuations in the body. Since noise exposure is highly correlated with tinnitus, tinnitus patients should be cautious regarding exposure to damaging intensity levels. Limiting noise exposure is an attempt to prevent the cochlear damage that is theorized to cause tinnitus.

Stimulants such as caffeine contained in coffee, tea, and pop has been popularly linked to an increase in tinnitus symptoms and patients with tinnitus are often told to avoid ingesting large amounts of caffeine. However, St. Claire, Stothart, McKenna, and Rogers [34] contend that although popular opinion reports that caffeine may affect tinnitus, there has been no scientifically documented link between dietary consumption of caffeine and tinnitus. In fact, they argue that encouraging patients to eliminated caffeine from their diets may in fact have adverse effects.

They note that studies have been established that can replicate symptoms of caffeine withdrawal which include but are not limited to decreased alertness, irritability, and difficulty concentrating St. Claire, Stothart, McKenna, and Rogers [34] completed a double blind study which concluded there was no evidence that abstaining from caffeine lessened tinnitus and in the short term, caffeine withdrawal added to the burden of tinnitus in some patients. It is worth noting that the results of this study found that withdrawal effects were short term, however, this study highlights the importance that clinicians must be cautions when and if encouraging patients to change their diet. The same is true for nicotine. However, unlike caffeine, the health benefits of giving up nicotine are not as questionable and favor the patient under all circumstances.

Pharmacology

Darlington and Smith [35] explained that many of the drug treatments currently used for tinnitus treatment are aimed at either the cochlea or central nervous system. More recently, antidepressants have been used in an attempt to address the emotional aspects of tinnitus [35]. As Langguth, Salvi, and Elgoyhen [36] reiterated, tinnitus has no "curative" treatments available but rather treatments exist to help patient cope more effectively with the negative impacts such as stress, agitation, and depression, that tinnitus can have on quality of life. Intratympanic administration of gentamicin has been used successfully to treat Ménière's disease and the tinnitus associated with Ménière's disease [35]. The uses of aminoglycoside antibiotics, such as gentamicin, are believed to be successful as they are ototoxic and therefore can be used to reduce tinnitus activity in the affected ear [35].

As Ménière's disease is related to fluid imbalance, diuretics have also been successfully used in the treatment of Ménière's symptomology, including tinnitus [35]. Intravenous administration of lidocaine has also been used historically to treat tinnitus [35]. Lidocaine is both a local anesthetic and anti-arrhythmic agent that is believed to target the cochlea and the central auditory nervous system to suppress tinnitus [37]. Benzodiazepines, are also used to treat 22 tinnitus as they are believed to limit hyperactivity; however, no controlled clinical trials appear to corroborate this belief [35]. Anticovulsants in small doses have also been used to try to decrease the neural hyperactivity theorized to cause tinnitus [35]. Antidepressants are historically used to treat the psychological side effects of

tinnitus. However after a thorough literature review, Robinson, Viirre, and Stein [38] concluded further trials are needed to replicate current findings on antidepressants for tinnitus patients.

As Darlington and Smith [35] indicate, obstacles for finding effective drug treatments for tinnitus can be related to the obscurity of tinnitus itself. As there are many different pathologies surrounding tinnitus and the pathophysiology cannot be clearly identified, it is difficult to identify what drug therapies should target. Additionally, the literature indicates a lack of clinical trials to test even the most commonly used drugs in tinnitus therapy (Darlington & Smith). However, Langguth, Salvi, and Elgoyhen [36] present that much research is being completed on the use of drug therapy with tinnitus patients. Yet they still acknowledge inconsistent methological rigor within existing clinical trials. Available drug trails do not appear to demonstrate long-term benefit to patients beyond the placebo effect and as such there are no FDA approved drugs for the treatment of tinnitus [36]. Langguth, Salvi, and Elgoyhen [36] recognize much off label drug use for tinnitus treatment.

The use of complementary and alternative pharmacologics in tinnitus is mainly focused on vitamins and minerals, antioxidants, and herbal medications [39]. Enrico et al. [39] report vitamin A, B1, B3, B6,B9, B12, C, E, magnesium, calcium, potassium, manganese, selenium, and zinc as the most commonly used vitamins and minerals for 23 tinnitus management. In terms of antioxidants Enrico et al. [39] site that evidence supporting their use is scarce, but admit that although antioxidants may not be a therapy for tinnitus, their use may be helpful as a supplemental treatment for patients undergoing therapy with ototoxic drugs. Ginko biloba seems to be the most commonly used herbal supplement for tinnitus management but Enrico et al. [39] caution that despite popular belief, herbal supplements are drug and thus are able to exert both therapeutic and toxic effects so they should be used cautiously. Overall Enrico et al. [39] caution that evidence regarding the efficacy of complementary and alternative medicine for tinnitus management is limited and often potential toxic effects are underestimated, thus caution should be used when attempting this type of tinnitus management.

Alternative Treatments

Repetitive transcranial magnetic stimulation (rTMS) is a promising new method of tinnitus treatment that induces electrical current into the brain through impulses of magnetic fields applied externally [40]. Although the exact pathophysiology of tinnitus is unknown, rTMS is intended to target dysfunctional neuroplastic processes in the brain. As hyperexcitability or neurons in the auditory cortex is on possible pathophysiology of tinnitus, rTMS attempts to modulate the excitability of these neurons therefore causing a decrease in the perception of tinnitus [40]. Kleinjung et al. [40] explain that rTMS can focally modulate cortical activity and as such, the assumption is made that application of rTMS to auditory cortical areas will relieve tinnitus. Current research on this treatment method is promising, but is limited 24 by small sample sizes and high variability.

Much research is needed before rTMS becomes regular clinical practice. Although acupuncture is commonly used to control pain, its use in tinnitus treatment has gained some recent popularity. Acupuncture employs needles to stimulate specific points on the human anatomy [41]. Henry, Dennis, and Schechter [1] explain that tinnitus and pain are theorized to share common mechanisms thus the recent trend toward managing tinnitus with acupuncture. However, they also report that studies seem to indicate little to no benefit in tinnitus relief for those who pursued acupuncture. Relaxation therapy, yoga, visualization, and hypnosis can also be used to help reduce the stress associated with tinnitus.

Amplification

Approximately 50% of those with hearing loss also experience tinnitus [11]. Hearing aids can be an especially good option for patients with significant hearing loss. However, due to amplification limitations in the high frequencies, hearing aids are probably not an option for patients with hearing loss confined to the very high frequencies [42]. Bo and Ambrosetti [43] advocate the use of hearing aids in the treatment of tinnitus for two reasons. First, they suggest that hearing aids allow patients to become less aware or completely unaware of tinnitus. Second, they suggest that hearings aids removes the sensation that sounds are being "masked" by tinnitus. Henry, Dennis and Schechter [1] explain this phenomenon by offering that hearing aids alone can sometime provide sufficient masking relief. As hearing aids amplify both speech and ambient noise, the speech amplification can act to divert attention 25 away from the tinnitus while the ambient noises can act to mask the tinnitus [3].

Bo and Ambrosetti [43] propose that hearing loss reduces stimulation from external sounds which can lead to auditory pathways undergoing plasticity. This neural plasticity can present itself as hyperactivity in the auditory pathways which is proposed to result in tinnitus. They suggest the amplification provided through the hearing aid provides enough stimulation to the auditory pathway to evoke neural plasticity and even restore neural functioning. Bo and Ambrosetti [43] present the rationale for hearing aids based on two neurophysiological assumptions. First, hearing aids increase the level of ambient noise and in so doing, reduce or eliminate the contrast between the internal noise of tinnitus and the silence of hearing loss. And second, as hearing aids eliminate hearing deprivation, they can overcome the deleterious effects of tinnitus through neural plasticity. In other words, if tinnitus is caused by neural plasticity through hearing loss, hearing aids can reverse this neural plasticity with sound input.

Sound Therapies

MM Jastreboff [44], states that temporary tinnitus can be induced in almost anyone if they are placed in a quiet enough environment, however the sensations these people perceive are often similar in description to the experience tinnitus patients report when in a normal sound environment. Therefore, it has been hypothesized that the "tinnitus signal" exists in majority of people's "neural networks", but it is the strength of the signal varies. The strength of the signal is generally low, but when the background noise is sufficiently reduced, tinnitus is perceived. As such, sound therapies have been used to distract from or cover up tinnitus. More specifically, sound therapies are believed to

increase the background neuronal activity in the auditory system 26 via sound stimulation, therefore distracting attention away from tinnitus. Ultimately, it is suggested that any treatment that can decrease the strength of tinnitus related neural activity can also act to lower the activation of the autonomic nervous system and limibic system [44].

According to MM Jastreboff [44], recommendations to avoid silent environments should be among the first advice given to any tinnitus patient regardless of any treatment. Sound therapies themselves may with goals ranging from masking tinnitus, distracting attention away from tinnitus, lowering stress associated with tinnitus, or lessening the tinnitus sound level [44]. Sound therapy can employ sounds ranging from a broadband sound to those associated with sounds encountered in the environment such as rain or music. Sound sources can range from table top devices to personal music devices [3]. The use of ear level devices was popular in the early 1970s when masking therapy was first presented by Vernon, however, popular opinion seems to that completely masking the tinnitus signal may prevent long term habituation [1,44]. Han, Lee, Kim, Lim, and Shin [3] explain that music therapy can be used as a desensitization method. Music can help reduce the stress and anxiety associated with tinnitus and put the patient into a more relaxed mindset. PB Davis [45] explains that music directly affects the limbic system and can in fact bypass slower linguistic based processing in the auditory cortex. The idea of using music therapy with customized thresholds is the basis the Neuromonics.

Neuromonics

The Neuromonics Tinnitus Treatment program combines acoustic stimulation with a structured program of counseling and support administered by clinician trained in tinnitus rehabilitation [46]. This form of treatment focuses on both the theorized cause of tinnitus, auditory deprivation resulting from hearing loss, and the role of the limbic system in creating a negative cycle of awareness and negative emotions surrounding the tinnitus. The Neuromonics Tinnitus Treatment is designed to stimulate the auditory system while positively engaging the limbic system. Neuromonics is a six month or longer treatment plan that aims not to cure or eliminate tinnitus, but to habituate the patient to tinnitus [46]. Treatment is based off of a general consensus as presented by Tyler [47], that tinnitus treatment is most efficacious when done in a combination of counseling and acoustic therapy.

Neuromonics employs a relaxing music signal imbedded with customized noise to allow the patient too momentarily and intermittently experience tinnitus while in a relaxed state [46]. The music stimuli with noise is customized to the patients hearing and tinnitus characteristics so it can provide relief at a comfortable listening level while also providing stimulus across a wide range of frequencies. The patient is encouraged to use the device during key times of distress so that they can acquire a sense of control over tinnitus. Over time, the patient should become desensitized to tinnitus. Davis, Paki, and Hanley [46] site five main ways the acoustic stimulus used in Neuromonics promotes desensitization. First, it stimulates the auditory pathway across a wide frequency range including very high frequencies where hearing loss is often most prominent. 28 Second, it controls correlation between the right and left ear in an attempt to stimulate auditory integration pathways. Third, it presents the therapy signal in a musical format in an attempt to foster a relaxation response and to make therapy more pleasant. Fourth, as it is a self dosing therapy, it promotes a strong sense of relief and control over tinnitus. And finally, as the patient intermittently experiences tinnitus throughout the therapy through a relaxation inducing context, it promotes systematic desensitization.

Tinnitus Retraining Therapy

Popular belief holds that tinnitus cannot be cured, but rather the underlying pathology can be treated or people can be educated and given tools to live more comfortably with their tinnitus [48]. Treatments that help reduce stress associated with tinnitus, such as Tinnitus Retraining Therapy (TRT), have been suggested as effective tinnitus management tools. Tinnitus Retraining Therapy is based off of the neurophysiologic model of tinnitus and is a multi-step therapy developed by PJ Jastreboff and his colleagues that involves counseling the patient about tinnitus by addressing fears and anxiety associated with tinnitus, while also initiating gradual habituation to tinnitus [5]. The goal of TRT is to habituation the patient to the emotional reactions surrounding tinnitus, such as fear and anxiety, and in so doing habituate the patient to the perception of tinnitus [23].

Specifically TRT consists of:

a. one -on-one directed educational counseling based on the neurophysiological model of tinnitus and

b. Sound therapy as prescribed by a trained clinician [49].

The overall goal of TRT is to train the brain to classify tinnitus as not significant so that habituation can occur [49]. The purpose of the intensive one-on-one directive educational counseling is to 29familiarize the patient with the physiologic processes underlying tinnitus. During this intensive one-on-one directive educational counseling, the patient is educated on processing of sensory information and the workings of the auditory system as well as the functioning of the limbic system. They are told that sounds become associated with experiences and in the case of their tinnitus, the brain has associated tinnitus with negative emotions. Following and supplementing the counseling, sound therapy is introduced. Sound therapy can be in the form of sound generators or environmental modifications. It is important to note it is never the goal to mask tinnitus.

This is because as PJ Jastreboff and MM Jastreboff [49] theorize, a patient cannot habituate to a sound he or she cannot hear and ultimately the goal of TRT is to allow the patient to habituate to tinnitus and remove the negative associations of tinnitus. Current research suggests that TRT is an effective treatment option for patients with tinnitus. However, this does not imply that every patient that enrolls in TRT will be successful. What studies do find is that for the majority of patients who enroll in TRT, a measurable benefit will be observed.

Counseling Measures

It appears that the higher the level of tinnitus annoyance, the higher the level of psychological distress [50]. Heinecke, Weise, and Rief [50] emphasize that although the mechanisms of tinnitus

are not fully understood; current knowledge holds that the emotional and cognitive factors hinder the habituation process. As Hallman, Rachman, and Hinchcliffe [21] reported abnormal stress reactions can contribute to the onset and maintenance of tinnitus as it may lead to hyperactivity in the autonomic nervous system causing tinnitus symptoms to continue. As such, biofeedback might be an effective treatment as 30it helps reduce hyperarousal therefore facilitating habituation [21]. Biofeedback is a relaxation process that is thought to reduce the severity of tinnitus.

In effect, patients are trained to use their own bodies to facilitate their treatment. With tinnitus patients, they may be trained to reduce muscle tension, especially in the head and neck area, to facilitate relaxation despite tinnitus [50]. It is based on the theory that tinnitus is induced or worsened by stress. As experiencing tinnitus can be stressful, tinnitus patients often find themselves in a cycle of stress, both the as tinnitus can cause stress and be exacerbated by stress. Biofeedback is thought to help reduce the stress associated with tinnitus and may also help the patient foster a sense of physiologic control over tinnitus therefore resulting in less focus on tinnitus perception. Cognitive behavioral therapy (CBT) aims to reduce the psychological distress associated with tinnitus.

Cognitive behavioral therapy does not focus on reducing the patient's perception of tinnitus in any form [6]. Instead, the therapy helps the patient eliminate some of the negative attitudes regarding tinnitus to improve their overall emotional state. Sometimes the counseling required for tinnitus patients falls out of the audiologist's scope of practice. Counseling in regard to the emotional impact of tinnitus should be conducted by a trained professional. Train counselors, such as psychiatrists, may be a necessary referral to determine if a patient can benefit from medication to help improve areas of sleeping, anxiety, or depression associated with tinnitus.

Existing Therapy Plans

Henry, Zaugg, Myers, & Schechter [51] created the Progressive Audiologic Tinnitus Management (PATM) to reflect a hierarchy of clinical services to address patient needs. Progressive Audiologic Tinnitus Management is designed for audiologists to uses as a comprehensive protocol for tinnitus management. It includes five levels of management; triage, audiologic evaluation, group education, tinnitus evaluation, and individualized management. During any level of the treatment, the patient can opt out is tinnitus becomes less bothersome. Triage involves the referral to any necessary medical personnel. This would include referrals for medical or psychological treatment. Audiologic evaluation includes a standard audiologic evaluation as well as the completion of tinnitus questionnaires.

During this stage tinnitus treatment plans such as masking or hearing aids can be discussed. Group education has been shown to be effective in the management of tinnitus as it provides a social network of encouragement and support while also being time effective. Tinnitus evaluation involves looking further into comorbid factors that can interfere with tinnitus treatment. Finally, individualized management involves the use of sound management and counseling.

Summary of Tinnitus Treatments

In summary, there are several different treatment options available for tinnitus. Those reviewed here include: electrical stimulation, medications, stress therapy, psychological/cognitive therapy, TRT, maskers, and hearing aids. Of these, the most likely to be of use in an audiological practice include: tinnitus maskers, hearing aids, and possibly TRT. There is no clear indication, however, that the knowledge currently available can help the audiologist to appropriately select the "best" treatment for any on e patient. Thus, the audiologist needs to be aware of the various treatment options and the field needs to continue research in this area.

Project Summary and Conclusions

The general goal of this work was to develop increased knowledge in the evaluation and treatment of tinnitus. To achieve this goal the available literature was reviewed to:

a) Define tinnitus;

b) Describe postulated causes;

c) Describe evaluation techniques;

d) Discern the implication of test results for treatment; and

e) Review treatment options. In addition an empirical study was conducted to examine the effects of one treatment option (i.e., hearing aids and circuit type) on tinnitus relief.

This component of the project provided experience in how; I as a Master of Audiology might choose to incorporate efficacy research in clinical practice. The overall results of this project can best be summarized in (Figure 1). This is a flow chart adapted from Hall and Haynes describing a protocol for use with tinnitus patients. To summarize the steps to follow when a patient's main complaint is tinnitus is as follows:

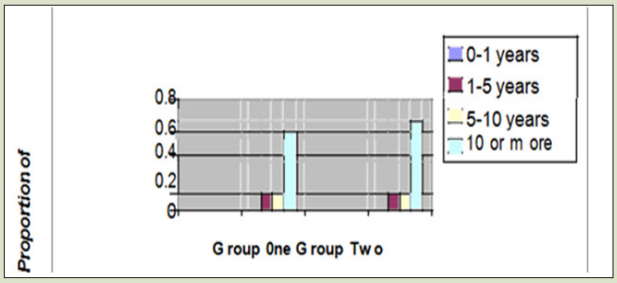


Figure 1: Years Experiencing Tinnitus.

1) Medical evaluation

a) Diagnostic studies

b) Medical/surgical treatment

2) Audiological Evaluation

a) Diagnostic studies

b) Hearing aid evaluation and/or,

3) Tinnitus evaluation

a) Pitch matching

b) Loudness matching

c) Measure of residual inhibition

d) Minimal masking levels

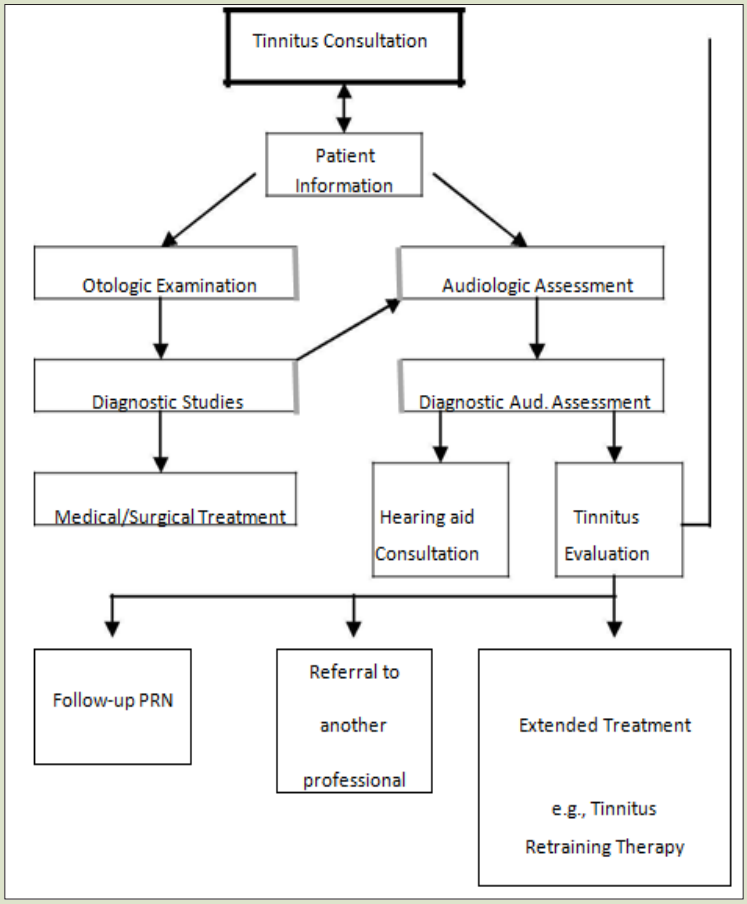
4) Tinnitus Consultation

a) Patient information (of all above)

b) Extended therapy (TRT and/or fitting of maskers/ hearing aids)

c) Referral to another professional if needed

Finally, the completion of this project has provided the author with a thorough understanding of the audiologist's role in the diagnosis and treatment of tinnitus. Audiologist must stay aware of the research in the area that is continuing to further knowledge of the etiology, as well as, the treatment of tinnitus. Perhaps one day the audiologist will be able to perform tests that tell us what type of tinnitus the patient suffers from and be able to treat it appropriately. Until then, we must do the best we can to professionally manage this population (Flow chart).



Flow Chart : Tinnitus Flow Chart.
Tinnitus Assessment and Management

Procedure

A retrospective survey study design was used to determine whether wide dynamic range compression hearing aids are an effective treatment for tinnitus as compared to hearing aids with different circuitry. A copy of the Tinnitus Questionnaire was mailed along with a letter explaining the nature of the study and a self-addressed stamped envelope. Only those patients who experienced tinnitus were asked to fill out the survey. At two weeks a reminder post card was mailed [52]. At four weeks a follow-up letter was mailed to those who had not responded along with another copy of the survey.

Results and Discussion

Question 1: Prevalence of tinnitus

The first question asked whether or not the participant experienced tinnitus. If the answer was that no tinnitus was experienced, the participant was excluded from the study. A total of 136 surveys were returned. There were 57 participants that stated they did not experience tinnitus; the remaining 79 stated they experienced tinnitus in either or both ears. This shows a prevalence of tinnitus of 58%. This is considerably higher than the prevalence of tinnitus in the general adult population, which as mentioned before, was reported to be from 4% to as high as 32%. It is postulated that the population being surveyed had more than the usual amount of noise exposure, which could explain the high percentage of those experiencing tinnitus. The 79 respondents were classified into one of two groups. Group I consisted of those individuals using WDRC (n=14). Group II consisted of those who did not use WDRC (n=65). Answers to the next survey questions are examined as a function of these groups.

Question 2: Length of time tinnitus experienced

The responses to Question 2 were: (1) 0-1 year; (2) 1-5 years; (3) 5-10 years; and, (4) 10 years +. (Figure 1) shows the proportion of individuals in each group reporting the different

lengths of time tinnitus was experienced. It can be seen that the pattern was similar for both groups. In each group, the majority of individuals experienced tinnitus for 10 years or more. In addition, there was a monotonic decrease in the proportions of respondents experiencing less years of tinnitus in both groups. Not surprisingly, the results of the Mann Whitney U Test (a non-parametric alternative to a between groups t-test) revealed that there was no statistically significant difference between the number of participants experiencing tinnitus for the length of time indicated by each of the four categories (U = 408.00, p = .54). Thus, the two groups were equivalent in terms of length of time experiencing tinnitus (Figure 1).

Question 3: Frequency of tinnitus

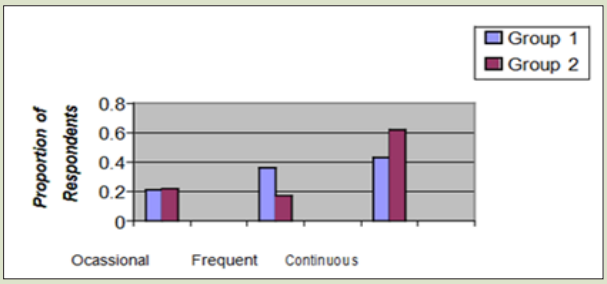


Figure 2: How Often Tinnitus is Experienced.

This question was concerned about how often the respondent experienced tinnitus. (Figure 2) shows the proportion of individuals in each group indicating that they experienced either "occasional", "frequent", or "continuous" tinnitus. It can be seen that the proportion of respondents in both groups was lowest and fairly equivalent in reporting having "occasional" tinnitus. In terms of those who report "frequent" tinnitus the proportion of respondent was greater in Group I (i.e. WDRC users) then in Group II. For "continuous" tinnitus, however, the proportion was greater for Group II than Group I. The difference between the groups in terms of how often tinnitus was experienced was statistically reliable (U= 388.5, p= 0.39). Thus, despite the different patterns seen in Figure 2, it can be concluded that the groups were essentially equivalent, in terms of how often the tinnitus was experienced (Figure 2).

Question 4: Severity of tinnitus

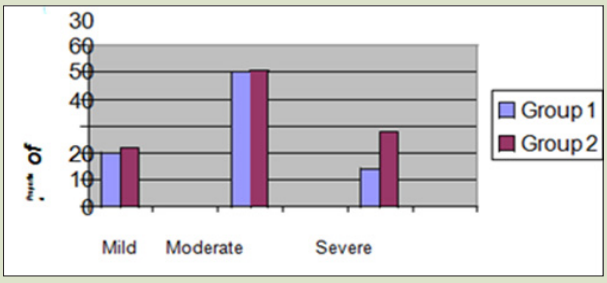


Figure 3: Severity of Tinnitus.

(Figure 3) illustrates the proportion of respondents in both groups reporting the severity of their tinnitus as "mild", "moderate", or "severe". It can be seen that the majority of respondents in both groups reported having "moderate" tinnitus. Interestingly, 14% of individuals using WDRC (i.e. Group I) and 28% of those using other circuits (i.e. Group II) reported experiencing "severe" tinnitus. These figures are higher than the percentage of individuals in the general population (2%) who consider their tinnitus to be severe. Given the pattern of responses for the two groups it is not surprising that statistical analysis failed to reveal a significant difference between the two groups (U= 353.5, p= 0.19). Thus, the groups can be considered equivalent in terms of severity of tinnitus experienced (Figure 3).

Questions 5-7: Effects of hearing aid use on alleviation of tinnitus

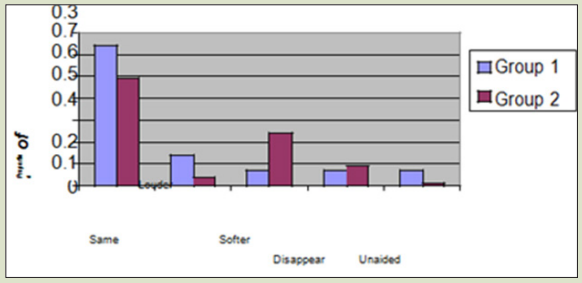


Figure 4: Alleviation of tinnitus through hearing aid use in the right ear.

The next three questions asked if hearing aid use monaurally in ether ear or binaurally caused the tinnitus to "disappear", "get softer", or "stays the same". In addition, respondents were asked if monaural hearing aid use in the right ear caused the tinnitus to get become louder in the ipsilateral or contralateral ear (i.e., question 5) and vice versa (i.e. question 6). It should be noted that some individuals reported that one of these three questions was not relevant. The data presented excludes these respondents. That is, they may not have worn an aid in the right, left or binaurally. (Figure 4) shows the effects of right hearing aid use on alleviation of tinnitus. It can be seen that the majority of respondents in each group reported that tinnitus stayed the same even with hearing aid use. Contrary to expectations, more individuals using WDRC reported that right aid hearing aid use made that tinnitus louder in both the aided and unaided ears as compared to individuals using other circuits. Furthermore, proportionally, more individuals using circuits other than WDRC reported that hearing aid use made the tinnitus "softer" or "disappear" (Figure 4).

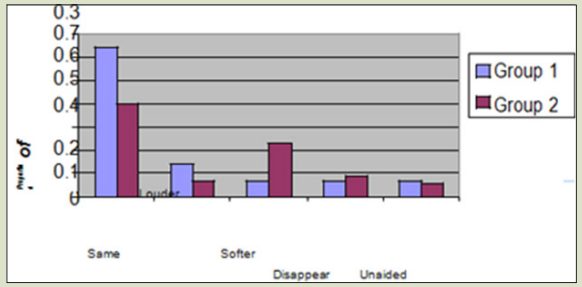


Figure 5: Alleviation of tinnitus through heading aid use in the left ear.

The pattern of responses was somewhat different for the effects of left ear hearing aid use (Figure 5). While proportionally more individuals in Group II reported that tinnitus "got softer", there were essentially no differences between the groups in terms of the proportion reporting that tinnitus "disappeared". The proportion reporting that tinnitus "grew louder" in the aided ear or "stayed the same" was higher for users with WDRC than those

with other circuits. Little differences were seen in the proportion of respondents in each group who reported that the loudness of tinnitus was increased in the unaided ear. Finally, the data in (Figure 6) also suggests that proportionally more individuals in Group II reported that binaural hearing aid use either made tinnitus "softer" or "disappear" than in Group I. These findings were disappointing as they did not provide any support for the hypothesis that the use of WDRC would provide more tinnitus relief than the use of other hearing aid circuits. When the effect of circuit type was examined for those individuals who reported that hearing aid use alleviated their tinnitus (i.e. "got softer" or "disappeared"), however, no statistically significant differences were found [(right ear; U= 22.0, p= 0.18); (left ear; U= 28.5, p= 0.37); (binaural; U= 35.5, p=0.66)] (Figure 6).

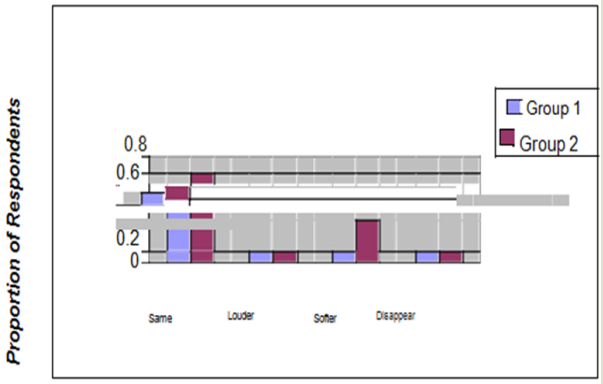


Figure 6: Alleviation of tinnitus through hearing aid use binaurally.

Despite the lack of finding a significant effect of circuit, it is encouraging to note that 39% (e.g. n= 31) of the 79 respondents reported that their hearing aids provided relief from tinnitus. This figure is fairly consistent with the data reported in Surr et al. who found that 40-50% of their new users reported relief from tinnitus. The slightly lower proportion reported here for individuals experiencing tinnitus relief may be due to the fact that respondents were not excluded for being" experienced" hearing aid users.

That is, Surr et al. only surveyed new hearing aid users, while the present study surveyed both new and experienced hearing aid users. This difference in population may account for the small difference in incidence in the two studies. In addition, severity of tinnitus did not appear to greatly affect the proportion of individuals receiving relief. These proportions were 44%, 35%, and 43% for mild, moderate and severe tinnitus, respectively. Surr et al. also concluded that severity of tinnitus did not affect relief.

Question 8: Residual inhibition

This question examined residual inhibition, which is the time it took for the tinnitus to return to its previous state after the hearing aid is removed. Of those who reported relief from tinnitus, 6% reported that the tinnitus did not return for more than six hours; 12% for three to six hours and 29% for up to three hours. Thus, approximately 52% exhibited some degree of residual inhibition. The number of respondents using WDRC and experiencing relief from tinnitus (n= 3) was too small to examine the effect of circuit type on residual inhibition.

Question 9: Rating of hearing aid performance

Table 2: Ratings of hearing aid performance as a function of group.

	Very Helpful		Somewhat Helpful		Of Little Use	
Situation	**Group I (%)**	**Group II (%)**	**Group I (%)**	**Group II (%)**	**Group I (%)**	**Group II (%)**
Hearing in quiet	72	0	21	23	7	7
In a large	1					5
group/party	14	5	36	32	50	3
		4				1
In a small meeting	43	5	50	45	7	0
		2				3
Effect on tinnitus	12	6	51	35	37	9

This last question addressed how the respondent's hearing aid performed in quiet, in a large group or party, in a small meeting and the effect the hearing aid had on tinnitus. The choices were "very helpful", "somewhat helpful" or "of little use". The results, as a function of group are shown in (Table 2). Perhaps, it is most important to note that there were essentially no differences in the proportions of respondents selecting each alternative as a function of group. It can be seen that the majority of respondents in each group reported that their hearing aids were "very helpful" in quiet and "somewhat helpful" to "very helpful" when in a small meeting. When in a large group or party, however, most reported that their hearing aids were "of little use". Most respondents in Group I or Group II reported that their hearing aid was "very" or "somewhat helpful" in minimizing the effects of tinnitus (63% and 53%, respectively). It is also of interest to note that these figures indicate that, indeed, as hypothesized, proportionally more individuals using WDRC, than do those using other circuits, report that their hearing aids are "helpful" with their tinnitus. The majority of these respondents using WDRC, however, only find the hearing aid to be "somewhat helpful".

Discussion

This study examined the effects of WDRC hearing aids on the alleviation of tinnitus as compared to all other circuits. It can be

concluded that for such aspects as, length of time tinnitus was experienced, frequency of tinnitus occurrence, and the severity of tinnitus, there was no difference between WDRC and other circuits. When the respondents were asked if hearing aids in the right, left or both ears caused the tinnitus to change (i.e. "get softer", "get louder", or "stay the same"), the results did not support the hypothesis that WDRC is superior to other circuits. In fact, when the effect of circuit type was examined only for those individuals who reported that hearing aid use alleviated their tinnitus, no statistically significant differences were found. An encouraging finding of the present study was the confirmation of Surr et al. earlier findings regarding the effects of hearing aid use on tinnitus relief [52,53].

That is, approximately 40% of hearing aid users will receive tinnitus relief from hearing aid use. Furthermore, relief will occur whether tinnitus is mild, moderate or severe. Of those individuals who reported relief from tinnitus with hearing aid use, 52% exhibited residual inhibition. It is encouraging to see that a little more than half of those reporting relief from tinnitus can remove their hearing aids and still experience that relief. Perhaps the most encouraging results are that when asked directly if the respondent's hearing aid was helpful in minimizing the tinnitus, the majority of individuals in both groups reported that, indeed, their hearing aids were "very" or "somewhat helpful". In addition, there were proportionally more individuals using WDRC reported that their hearing aid was "helpful" in the alleviation of tinnitus. It can be concluded then, that hearing aids are a viable option for the management of tinnitus in many patients that also exhibit a hearing loss. The finding that 60% of individuals do not receive tinnitus relief from hearing aid use, however, highlights the need for conducted research. Research focusing on linking tinnitus evaluation results to the most effective treatments for an individual continues to be needed.

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