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Evaluation and Treatment of 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.

Introduction

One of the greatest challenges to audiologists is the management of a patient who presents with tinnitus. Tinnitus is a symptom, not a disease, with many different causes. There are also a multitude of treatments for tinnitus. This work will focus on how the audiologist can evaluate and manage the tinnitus patient.

To begin, tinnitus is defined as an auditory sensation unrelated to external stimulation. Tinnitus may be "objective" or "subjective" and may range from mild to severe (Bentler & Tyler, 1987). The incidence of tinnitus in the general adult population has been estimated from 4% to as high as 32% (Jastreboff, 1994; Tyler, Aran, & Dauman, 1992; Stouffer & Tyler, 1990). Amongst those individuals who report tinnitus, approximately 2% experience significant debilitating problems (Sullivan, et al, 1988). These problems include: difficulties in falling asleep, depression, annoyance, and, confusion (Stouffer & Tyler, 1990). Unfortunately, determining the cause of tinnitus is not always easy. This makes the determination of appropriate therapy difficult. The first step, however, would be to determine whether the tinnitus is objective or subjective. Each of these types of tinnitus is discussed. Furthermore, specific causes of tinnitus and theories as to where tinnitus is generated will be covered.

Objective Tinnitus

Objective tinnitus, which is relatively uncommon, refers to sounds in the ear that can be heard by others. One possible cause for this type of tinnitus is that it may result from blood flowing through the jugular vein. As the blood flows, it creates sound which is perceived by the listener (Vernon, 1998). In addition, patients with hypertension will often hear venous hums (Fortune, Haynes, & Hall, 1999). Patients with this type of tinnitus will often have no other symptoms such as hearing loss, fullness, or vertigo (Fortune, Haynes, & Hall, 1999). Evidence to support blood flow as a cause of objective tinnitus comes from the work of Champlin, Muller and Mitchell (1990). During exploratory surgery with one patient, a jugular vein was isolated and clamped. This

successfully eliminated the tinnitus. Thus, if the cause of tinnitus is blood flow, surgery may provide a means of treatment.

Middle ear muscle spasms are another possible cause of objective tinnitus (Schleuning, 1998). Although, there is little evidence to support the middle ear spasm, it is possible that just as a person's eyelid flutters when experiencing high amounts of stress or fatigue so do the middle ear muscles (Schleuning, 1998). If this is the cause of tinnitus then relaxation therapy may be warranted.

The palatal musculature can undergo myoclonic contractions causing the mucous membranes of the Eustachian tube to snap together. Patients will often complain of a clicking sound and that their own voice is unusually loud (Fortune, Haynes, & Hall, 1999). Muscle relaxants can often treat this type of tinnitus.

Tinnitus can also be a roaring sound that corresponds with breathing. Patients may also complain that their own voices seem unusually loud. Individuals who report this sometimes have an Eustachian tube that is opened abnormally large. This can occur with significant amounts of weight loss (Fortune, Haynes, & Hall, 1999). Fortunately, this type of tinnitus is only experienced for a short period of time, just days or months (Schleuning, 1998). Antihistamines and nasal sprays have been used to treat this type of tinnitus (Fortune, Haynes, & Hall, 1999).

Objective tinnitus is often manageable. Unfortunately, it is rarely the type of tinnitus that the audiologist will see. Subjective tinnitus, which is more common, is the more difficult tinnitus to treat.

Subjective Tinnitus

Subjective tinnitus, which represents the vast majority of complaints, refers to sounds that only the patient can sense. The precise mechanics of this tinnitus are still not clearly understood and many possible causes have been proposed. Each of these is discussed.

With subjective tinnitus, the site of generation is important in hypothesizing the potential cause. It could either be, tinnitus aurium (in the ears) or tinnitus cerebri (in the head) (Shulman, 1997). It has been hypothesized that mild to moderate tinnitus may be generated in the ear, whereas, severe tinnitus may be generated in the central nervous system (Moller, 2000). This is analogous to pain generators. Minor pain is thought to be generated at the peripheral nerves and severe, chronic pain at the central nerves (Moller, 2000). These generators in the central nervous system are generally believed to be the result of reorganization of nerve pathways. This may be the result from novel input or the absence of input from the periphery (Moller, 2000). The tonotopic organization of the cochlea follows through the central nervous system, therefore, a high frequency hearing loss in the periphery may reduce the inhibitory input to the auditory nervous system resulting in increased excitability of the neurons, which is perceived as tinnitus (Moller, 2000).

Causes of Tinnitus

Many individuals who have a hearing loss also report the presence of tinnitus. For example, it is common to find complaints of tinnitus in individuals where hearing loss is due to excessive noise exposure (Schleuning, 1998). To test the correlation of noise exposure and tinnitus, Kaltenbach and Afman (2000) compared the spontaneous activity of the dorsal cochlear nucleus (DCN) of hamsters exposed to an intense 10k Hz tone one month previously to the activity in the DCN of unexposed, normal hamsters that were presented with a 20dB SL 10k Hz tone. The results showed the hamsters that were exposed one month previously had hyperactivity in the DCN that was similar to the stimulus-driven activity in the DCN of the unexposed hamsters. This implies that the DCN of exposed animals is behaving as though it is responding to a tone. The hamsters were possibly experiencing tinnitus. The authors concluded that, although noise exposure could cause the same hyperactivity in human DCN, further studies were needed to determine if DCN activity correlated to perceptual tinnitus in humans.

Tinnitus may also be the first sign of Meniere's disease (McFadden, 1982). This is a syndrome which is usually associated with periodic debilitating episodes of vertigo and a gradual low frequency sensorineural hearing loss (Shulman, 1997). The tinnitus is reported to be fluctuating and is often low frequency in nature (McFadden, 1982).

It has also been postulated that tinnitus arises from a dysfunction of the auditory nerve. Specifically, this is believed to be the result of tumors or arterial loops, which wrap around the nerve (Moller, 1984). This pressure alters the temporal pattern of nerve discharges and this may the cause of tinnitus (Moller, 1984). It should be noted however, that Lockwood, et al, (1999) reported data that after the auditory nerve has been surgically sectioned, the development of and persistence of tinnitus may occur. This is much like pain that persists where a limb has been amputated, called phantom limb pain. If this is the case, then the implication is that the cause of tinnitus may be central.

To further examine the hypothesis that the cause of tinnitus may be due to CNS activation, there have been several recent studies utilizing position emission tomography (PET). These studies have sought to determine the localization of tinnitus in the central nervous system (CNS). Lockwood, et al (1999) performed PET scans on four patients who could control the loudness of their tinnitus by contraction of the jaw muscles. The study revealed that changes in the loudness of the patient's tinnitus resulted in activity in the auditory regions in the temporal lobe contralateral to the ear in which they reported their tinnitus. Also, a 2000Hz tone delivered to one ear resulted in bilateral activations in the auditory cortices, in contrast to the unilateral activation from tinnitus. The authors suggested that tinnitus is not due to activity in the cochlea, but due to activity in the temporal lobe. When compared to normal controls, tonal stimulation produced more extensive activations in the brains of the tinnitus sufferers. This may be evidence for plastic cortical reorganization in the auditory system. In other words, the neurons that are usually tuned only for high frequencies are not receiving the input from the periphery and are being activated by other tones, thus the widespread activation in the brain is seen. Activation of the limbic areas of the brain was also seen in the patients with tinnitus but not in the controls. Since the limbic system is responsible for the mediation of emotions,

this may be a reason for why some tinnitus sufferers have an emotional response to tinnitus.

Mirz, et al. (1999) performed PET scans on 12 patients with severe, chronic tinnitus. Patients were scanned while they were experiencing their tinnitus and while their tinnitus was suppressed with either masking sounds or lidocaine injection. The results showed that cortical areas of the prefrontal and temporal lobes were active during the tinnitus situation but not when the tinnitus was suppressed. Subtraction of the masked condition from the unmasked condition showed activity predominately in the right hemisphere, specifically the middle frontal and middle temporal gyri, as well as, the lateral and medial posterior sites. These areas are linked to attention, emotion, and memory. The authors hypothesized that this is why severe tinnitus becomes distressing and patients cannot habituate to it.

Mirz, Gjedde, Stodkilde-Jrgensen, & Pedersen (2000) also performed PET scans on 12 normal hearing subjects while being presented with aversive sounds that imitate tinnitus. The results showed increased activity in the primary auditory cortex in both hemispheres and associative auditory regions in the right hemisphere. Anterior midline structures, inferior parietal lobe structures, and structures in the limbic system also had increased activity. The authors concluded that this tinnitus-like sound engaged the auditory sensory and processing area, causing the right prefrontal areas to pay attention. Emotional responses based on the activation of the limbic system are also generated. They hypothesized that the results could be generalized to the real perception of tinnitus.

Other aspects, such as the duration of the tinnitus, may distinguish the cause of tinnitus. Tinnitus can either be constant or intermittent. It can also be long-term or short-term and with a sudden or gradual onset. The quality will also help determine what may be causing the tinnitus. Pulsatile or click-like sensations may indicate a more peripheral type of tinnitus. Tonal or noisy tinnitus could be either peripheral or central.

There are many other possible causes of tinnitus that can be temporary, such as cerumen blockage (Coles, Baskill & Sheldrake, 1985). Often the tinnitus will be reduced

or eliminated with the removal of the excess cerumen. Ototoxic drugs have also been reported as a cause of tinnitus (McFadden, 1982). Jastreboff and Sasaki (1986) injected guinea pigs with sodium salicylate and found increased rates of spontaneous activity in the cells of the inferior colliculus (IC). The cochlear nuclei also exhibited changes in activity. There were, however, no changes in the activity level of the cerebellum. The authors postulated that the increase in spontaneous activity in the IC originated in the cochlea. The mechanical properties between hair cells and the tectorial membrane were altered, which possibly changed the temporal pattern of neuronal discharges. This is interpreted by the nervous system as sound. The authors hypothesized that this could be a cause of salicylate-induced tinnitus.

Another possible cause of tinnitus is proposed by Simpson and Davies (2000). They suggest that the perception of tinnitus may be related to a dysfunction of serotonin (5-HT) transmission. Serotonin is a neurotransmitter that helps to modulate sensory pathways, controls mood and emotion, and the perception of hallucinations. It is active in the modulation of sound perception and determining the significance of sound. The authors hypothesize that peripheral damage evokes plastic changes in the central nervous system. These changes involve serotonin function. This could result in tinnitus. Also, the disruption of sleep/wakefulness cycle and mood and emotion could add to the severity of tinnitus.

Several diseases have been known to cause tinnitus as well, such as, hypertension, anemia, migraines, meningitis, and encephalitis (Yoo et al, 1997). Tinnitus may resolve after the treatment of these disorders. Hearing loss due to head trauma has also been associated with a high pitched and constant tinnitus (Yoo et al, 1997).

In summary, there are many possible causes of tinnitus. Frequently, tinnitus is idiopathic. This does not preclude treatment, though. In order to provide the best management of tinnitus, the patient must first have a full medical and audiological assessment. The next section will be a summary of what should be involved in medical, audiological and tinnitus evaluations.

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.

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 (Fortune, Haynes, & Hall, 1999). 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 (Shulman, 1997). The ENG will help in identifying disorders, such as, Meniere's disease or secondary endolymphatic hydrops, both of which have tinnitus as a symptom (Shulman, 1997).

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:

(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.

Pitch Matching

Purpose

Pitch matching attempts to quantify tinnitus in terms of its possible frequency (Goldstein & Shulman, 1997). 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 (Goldstein & Shulman, 1997). 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 (1997) suggest that the procedure should be repeated seven to nine times to ensure the correct match.

An octave confusion test should be performed next (Goldstein & Shulman, 1997). 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 (Goldstein & Shulman, 1997). The clinician should use the same two-alternative forced choice procedure using the tone the patient picked and the octave above and below it (Goldstein & Shulman, 1997).

Concerns

There are some complications associated with pitch matching. First, many patients experience tinnitus that has more than one type of pitch (Henry & Meikle, 2000). 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 (Henry & Meikle, 2000). Third, there is the possibility that the patient's tinnitus will be masked by the tones presented during tinnitus matching (Henry & Meikle, 2000). 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 (Henry & Meikle, 2000).

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 (Goldstein & Shulman, 1997). Tinnitus maskers are discussed in detail in the Treatment section of this paper.

Loudness Matching

Purpose

Loudness is the perceptual equivalent of sound intensity (Goldstein & Shulman, 1997). 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 (Henry & Meikle, 2000; Goldstein & Shulman, 1997). One procedure for loudness matching suggested by Goldstein and Shulman, (1997) 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 (1997) also question whether to use the ipsilateral, contralateral, or sound field as reference. Henry and Meikle (2000) 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 (Shulman & Goldstein, 1997).

Procedure

Residual inhibition is defined as the temporary suppression and/or disappearance of tinnitus following a period of masking (Goldstein & Shulman, 1997). 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; 1) positive-complete, where the tinnitus is completely absent for more than one minute; 2) positive-partial, where the tinnitus is still present but softer at a lower perceived level than before for more than one minute; 3) negative, where there is no reported change in the tinnitus; and finally, 4) rebound, where the tinnitus is actually louder after the masking stimulus is presented.

Concerns

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

(Goldstein & Shulman, 1997). 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 (Goldstein & Shulman, 1997).

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 8KHz. The resulting curves are then classified according to Feldman's system (Goldstein & Shulman, 1997).

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 (Goldstein & Shulman, 1997).

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 (Goldstein & Shulman, 1997). A divergence curve shows poor but possible acoustical masking (Goldstein & Shulman, 1997). 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 (Goldstein & Shulman, 1997). 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.

Treatments for Tinnitus

Given the multitude of possible causes for tinnitus, there have been many different therapeutic techniques explored. None reviewed here has met with wide spread success. In addition, there is really no way one can predict with certainty which treatment will work for a patient. Several of these techniques will be discussed in this section, with an emphasis on counseling and instrument use as these are the two treatments that are typically offered by audiologists.

Electrical Stimulation

Electrical stimulation is one treatment that has been explored for tinnitus relief and has shown some benefit (Kuk, et al, 1989). Electrical stimulation involves applying either direct or alternating current to the cochlea. It is theorized that the patient may experience a masking of the tinnitus by the frequency signal of the electrical stimulation

that lasts even in the absence of the stimulation (Shulman, 1997). Although no study shows extraordinary improvement on tinnitus, electrical stimulation is occasionally attempted by some clinics.

Medications

Another treatment approach has been the use of various drugs or medications (Brummett, 1998). These have shown little benefit. For example, Brummett (1998) reported on the use of tocainide. There were 20 adults who participated in this study. Only one experienced a reduction in tinnitus. In addition, many of the participants experienced negative side effects.

Other drugs such as, antidepressants and tranquilizers have also been explored (Brummett, 1998; Dobie & Sullivan, 1998). The research data show a reduction in the symptoms associated with tinnitus, such as, annoyance, frustration and depression. Unfortunately, however, the effect of the drugs on tinnitus sensation, or the sound itself, is questionable (Dobie & Sullivan, 1998).

Stress Therapy

Tinnitus has also been reported to be worse in patients who experience great amounts of stress and depression. Given the relation of stress and depression to tinnitus several investigators have studied the use of stress and biofeedback therapy as a treatment for tinnitus (e.g., White, 1986; Newman, Warton & Jacobson, 1997; Yanick, 1981; House, 1978; Stubblefield, & Worster, 1988). Stress therapy consists of attempting to change the patient's attitude about the tinnitus (House, 1997). Explaining that the tinnitus is not a serious disorder and not something to worry about often helps. Biofeedback is designed to teach the patient relaxation procedures that may help him to control his stress level and ultimately, the tinnitus (Shulman, 1997). Electromyogram (EMG) activity is used to observe how relaxation techniques effect muscle relaxation. Studies have shown some promise in the relief of tinnitus from these techniques. (e.g., White, 1986; Newman, Warton & Jacobson, 1997; Yanick, 1981; House, 1978; Stubblefield, & Worster, 1988).

Psychological/Cognitive Therapy

Each patient reacts to the sensation of tinnitus differently. The same level of tinnitus can be described as extremely loud by one patient, while another patient can describe it as barely there (House, 1997). This can be correlated to the toleration of pain. Some patients are intolerant of even minor pain, while others can handle great amounts of pain (House, 1997). Often the patient who is severely disturbed by the tinnitus can be described as having additional emotional problems, such as depression or anxiety disorder (House, 1997). Treatment of these emotional problems, along with helping the patient to learn better coping strategies can often help the patient deal with his/her tinnitus (House, 1997). In fact, the aim of psychological treatments is not to remove the tinnitus, but help the patient to cope better with tinnitus (Henry & Wilson, 1998).

One psychological therapy is cognitive therapy. Cognitive therapy is concerned with changing the way a patient thinks about his/her problem (Henry & Wilson, 1998). This may be accomplished by challenging unhelpful thoughts, diverting attention away from the tinnitus to another sensation, such as breathing, or imagining pleasant scenes (Henry & Wilson, 1998). Although Henry and Wilson (1998) state that this type of therapy is effective in about 50% of their patients, this treatment is usually given be psychologists, not audiologists.

Tinnitus Retraining Therapy (TRT)

Tinnitus Retraining therapy (TRT) is based on the theory that a number of subsystems in the central nervous system, including the auditory pathways, play a role in the cause of tinnitus (Jastreboff & Jastreboff, 2000b). In addition, the limbic system is believed to be responsible for the feeling of annoyance with tinnitus (Jastreboff & Jastreboff, 2000a). Jastreboff and Jastreboff (2000a) theorize that a cycle occurs in which the perception of tinnitus and the belief that the tinnitus is something negative and uncontrollable becomes linked to a negative reaction in the brain. The negative reaction could be annoyance, anxiety or general stress. This, in turn, causes more attention to be directed towards the tinnitus. This, then, increases activation of the limbic system, which further increases the attention on tinnitus and the annoyance of it. TRT tries to stop the

cycle by habituation. In general, if a signal is not associated with danger and it is not new, it eventually undergoes habituation. The perception of sound can only be habituated, then, if it does not evoke an emotional response (Jastreboff & Hazell, 1998). Our brains have the ability to select sounds that are important to us and to ignore those that are not (Jastreboff & Hazell, 1998). If the tinnitus is not important to the patient anymore than the patient should be able to ignore the sound even if it is still there. For example, we normally do not hear our refrigerator humming in the kitchen, because our brain has decided that it is not important. The humming is always there, though, and we can hear it if we choose to listen to it (Jastreboff & Hazell, 1998).

According to Jastreboff and Jastreboff (2000b), in order to treat tinnitus, TRT utilizes two major strategies. First, directive counseling and second, the use of low level noise generators. The directive counseling seeks to remove any negative association about tinnitus. Counseling on the potential causes of tinnitus, along with background on the anatomy and physiology of the auditory system is included. The aim is to reclassify the tinnitus into a category of neutral signals (Jastreboff & Jastreboff, 2000b).

The other component of TRT is the use of low level sound generators and/or hearing aids to help decrease the strength of the tinnitus-related neuronal activity (Jastreboff & Jastreboff, 2000a). In other words, the sound generators or hearing aids interfere with the detection of tinnitus. Complete masking of the tinnitus is to be avoided because habituation cannot occur if there is no signal (Jastreboff & Jastreboff, 2000a). Instructing the patient to always avoid silence by always having low level background sounds, such as, a radio or environmental sound generator is another strategy (Jastreboff & Hazell, 1998). The most important message to convey to the patient is to avoid silence, since that is the environment in which the tinnitus will seem louder (Hall & Haynes, in press). It can be explained to the patient that, even though the tinnitus is a weak sound, it can be heard clearly if there is no other sound around. Introducing a low-level background sound will help to reduce the contrast between the tinnitus and silence (Jastreboff & Hazell, 1998).

Jastreboff and Hazell (1998) suggest that the patient should wear the sound generators at least six hours a day. After the initial appointment, several appointments will be needed to check the progress of the treatment. The audiologist may need to go through the basic explanations again, as well as, answering any questions the patient may have. If the patient is not progressing well, the audiologist may need to modify the treatment approach. With TRT, these follow-up appointments can occur up to 24 months after the initial appointment.

TRT seems to be a viable option for most patients with tinnitus. Jastreboff showed that out of 263 of his patients treated with TRT, 75% showed a significant improvement. Of those who wore noise generators, 80% showed a significant improvement. One drawback of TRT is that it is a long and slow process, sometimes taking up to 24 months before there is improvement.

There have been some criticisms to TRT (e.g., Wilson, et al., 1998; Kroener-Herwig, et al., 2000). First, it has been noted that there is a need for better experimental designs in the studies on TRT efficacy (e.g., Wilson, et al., 1998; Kroener-Herwig, et al., 2000). For example, there is a need for control groups and placebo-controlled studies with TRT. Wilson, et al. (1998) stated that studies also need to use standardized measures of tinnitus distress. There is also the chance that some patients may think of TRT as a cure , when in truth, it is just a way of learning to cope with tinnitus. Clinicians need to make sure patients understand this from the beginning so the patient does not have any unrealistic expectations (Wilson, et al., 1998). Also, because the is no strict published protocol on TRT, different treatment centers may handle TRT differently (Kroener-Herwig, et al. 2000). There is no guarantee that the patient is getting the TRT that Jastreboff developed.

Tinnitus Maskers

The use of tinnitus maskers, which produce an external sound designed to override the patient's tinnitus has been explored as well. Studies have shown varying success rates with the use of tinnitus maskers. In fact, several complications have been

found with the use of tinnitus maskers. These include: ear blockage, hyperacusis, recruitment, vertigo and increased intensity of the tinnitus (Shulman, 1997).

The efficacy of the maskers appears to be due to the patient's individual differences (Penner, 1987; Tyler, Conrad-Armes & Smith, 1984; Kitajima, Kitahara & Kodama, 1987; Letowski, & Thompson, 1985). These differences are evident in the residual inhibition test and the minimal masking curves that are obtained during the tinnitus evaluation. As mentioned before, the patients that exhibits complete or partial residual masking and convergence and congruence masking curves will more likely be successful masker wearers. Conversely, those that exhibit no residual inhibition and distance and persistence curves will not be successful with maskers.

Hearing Aids

Given the relation of hearing loss and tinnitus, it is not surprising that there is some anecdotal evidence in the literature to suggest that hearing aids may reduce tinnitus (e.g., Vernon, 1998, Bentler, & Tyler, 1987, Coles, Baskill & Sheldrake, 1985, etc.). The exact reasons for this are not known. One possibility is that hearing aids amplify environmental sounds that may mask tinnitus (Bentler, & Tyler, 1987; Jastreboff, & Hazell, 1993). The use of hearing aids also makes communication easier, thus, reducing stress. A reduction in stress may help alleviate tinnitus (Coles, Baskill & Sheldrake, 1985; Tyler, Aran & Dauman, 1992).

There are some studies in which the effects of hearing aids on tinnitus have been systematically examined. For example, Von Wedel, Von Wedel and Walger (1998), compared the results of the use of tinnitus maskers to the use of hearing aids by patients with severe chronic tinnitus in a longitudinal study from 1987 to 1993. The researchers found that of the 472 patients fit with hearing aids, 62% showed partial masking, or reduction, of tinnitus with the hearing aids. Partial masking was seen in 18.5% of the 648 patients fit with maskers. In contrast, complete masking was seen in 17.3% with hearing aids and 79% with maskers. The researchers concluded at the end of their study that

hearing aids provide a stable benefit in 90% of patients fit with hearing aids and 75% of patients fit with tinnitus maskers.

In another study Surr, Montgomery and Mueller (1985), used self report methodology to examine the effects of hearing aid use in the veteran population. A tinnitus questionnaire was mailed to 200 veterans who had received hearing aids for the first time. Based on employment status, respondents were placed into one of two groups. Group I consisted of active duty personnel. Group II consisted primarily of retired personnel. As might be expected the groups also differed in age, with the mean age of 41 years old for Group I and a mean age of 62 years old for Group II. The prevalence of tinnitus in Group I was 72% and 51% in Group II. Individually Group I reported a more recent history of noise exposure, as compared to those in Group II. This may account for the higher prevalence of tinnitus in Group I. There was no significant difference between the two groups in the subjective rating of tinnitus. When asked whether wearing a hearing aid affected their tinnitus by it becoming either softer or completely disappearing, no significant differences were found between the two groups. Similarly, there did not appear to be a relationship between severity rating of tinnitus and whether or not relief occurred. That is, 40 to 50% of those individuals in each severity rating reported some relief of tinnitus with the use of hearing aids. There did appear to be a relationship, however, between the severity of the tinnitus and the extent of relief experienced. Of those who reported mild tinnitus, 66% indicated that their hearing aids provided complete relief from tinnitus, whereas among those who reported severe tinnitus, only 8% indicated complete relief form tinnitus. The investigators concluded that approximately one-half of the new hearing aid users who reported tinnitus indicated that their hearing aid gave them some form of relief from tinnitus.

The results of a recent study conducted as part of this project, support the findings of Surr, et al. (1985). A complete description of the study is included in Appendix D. The study was based on the hypothesis that thee use of wide dynamic range compression (WDRC) might be more effective in relieving tinnitus than other hearing aid circuits. Although the results failed to support this hypothesis, an encouraging finding was that

39% (n =31) of the 79 respondents, who were both new and experienced hearing aid users, reported some relief from tinnitus. In addition, the severity of tinnitus did not effect tinnitus relief. Finally, of those who reported relief, 52% exhibited some degree of residual inhibition, as well. These findings then are very similar to those of Surr, et al. (1985), further supporting the efficacy of hearing aid use for tinnitus treatment.

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 : 1) define tinnitus; 2) describe postulated causes; 3) describe evaluation techniques; 4) discern the implication of test results for treatment; and 5) 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 Doctor of Audiology might chose 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 (2000) describing a protocol for use with tinnitus patients. This flow chart was first made available to this author through a workshop offered by Dr. Jay Hall in September 2000 at the University of Florida.

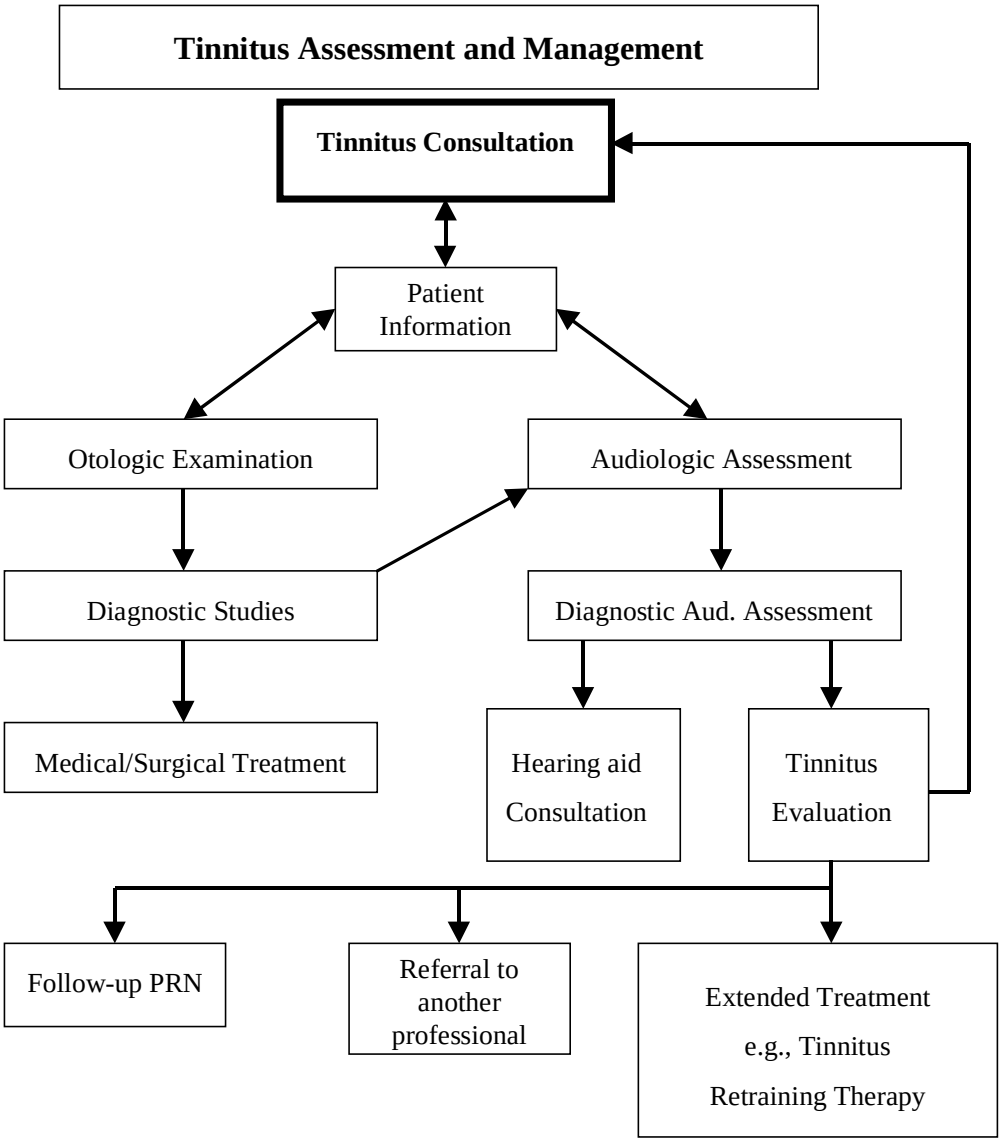
Attending the workshop highlighted the importance of continuing to a lifelong learner after the Doctor of Audiology degree is obtained.

To summarize the steps to follow when a patient's main complaint is tinnitus is as follows:

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.

Figure 1. Tinnitus Flow Chart



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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?

   Is it a pulsing sound that changes in time with your heart?

7. What seems to make the tinnitus/hyperacusis change?

8. Is it made worse by exposure to a sound?

   If so, how long does it stay bad after sound exposure?

9. List all methods, procedures, medications, or devices you have tried for our tinnitus, and the treatment outcomes (include additional sheet if you want).

10. Have you seen ear specialists about your tinnitus?

    How many?

    What were you told?

11. Do you have hearing loss?

    If so, please describe:

12. Do you wear hearing aids?

13. Are you uncomfortable around certain sounds?

14. Do you wear ear protection (plugs or muffs)?

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

15. Do you wear ear protection in quiet situations?

16. Do you experience pain in the ears from loud sounds?

17. Have you ever worked anywhere that exposed you to continuous loud sounds?

18. Estimate the percentage of time over the past month that you have been aware of the tinnitus?

19. 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) _____%

20. 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	_____	_____	_____	_____	_____	_____

21. Do you fell depressed?

    If so, please explain why?

22. Did you have any depression or anxiety before the onset of tinnitus or hyperacusis?

    If so, when?

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

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

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

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

_____ tinnitus _____ hyperacusis _____ hearing loss

27. Please write below any other information related to our tinnitus or hyperacusis:

Thank you

Appendix B

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) With white noise:			**Loudness Discomfort Levels (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

Adapted from Pawel Jastreboff, Tinnitus and Hyperacusis Center, University of Maryland

Appendix C

Instructions for the Tests of Tinnitus

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

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.

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.

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 time, 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 Wide Dynamic Range Compression on Tinnitus

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.

Methods

Participants

All patients (n=218) who received hearing aids from August to September 1998 at VAMC-Bay Pines, Florida served as participants. Participants were not excluded on the bases of sex, age, extent of hearing loss, or type of hearing loss.

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 RIGHT EAR_____
   YES IN LEFT EAR_____ NO_____ If no, do not continue, and send questionnaire back. Thank You.
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	_____	_____	_____

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. 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% (Jastreboff, 1994; Tyler & Aran, 1992; Stouffer & Tyler, 1990). 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.

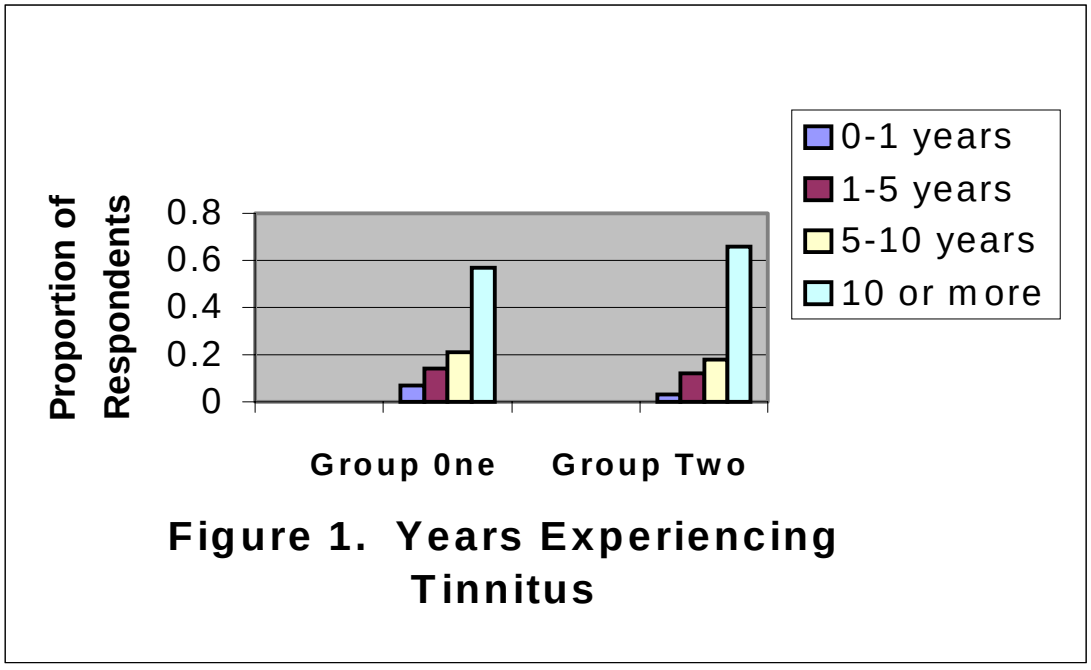

Figure 1. Years Experiencing Tinnitus

Question 3. Frequency of tinnitus

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.

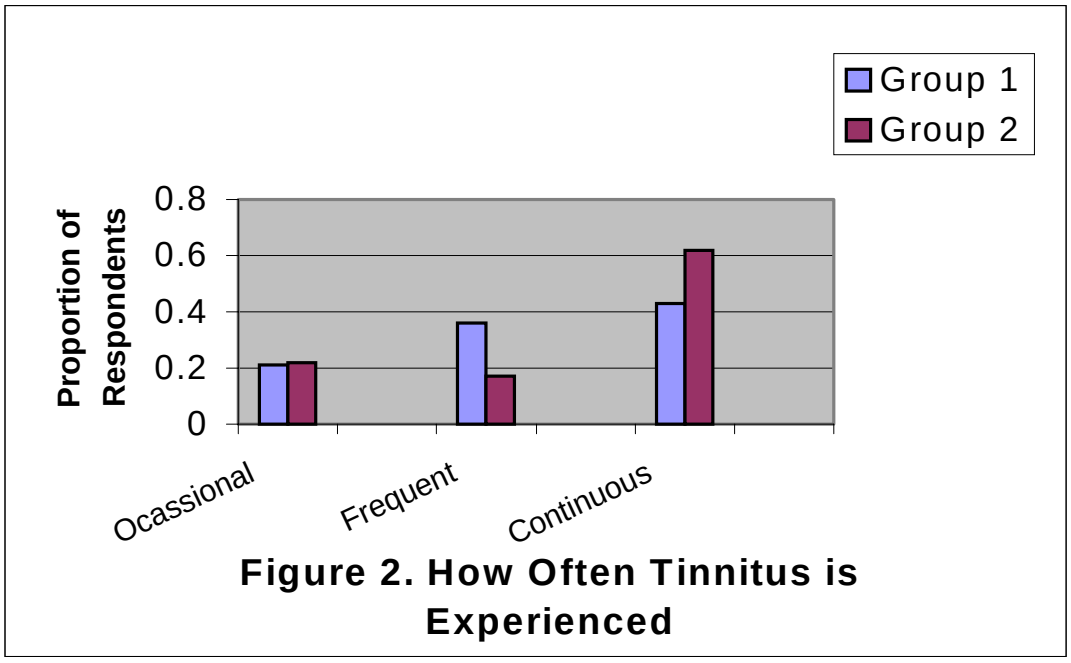

Figure 2. How Often Tinnitus is Experienced

Question 4. 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 (Sullivan, et al., 1988). 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.

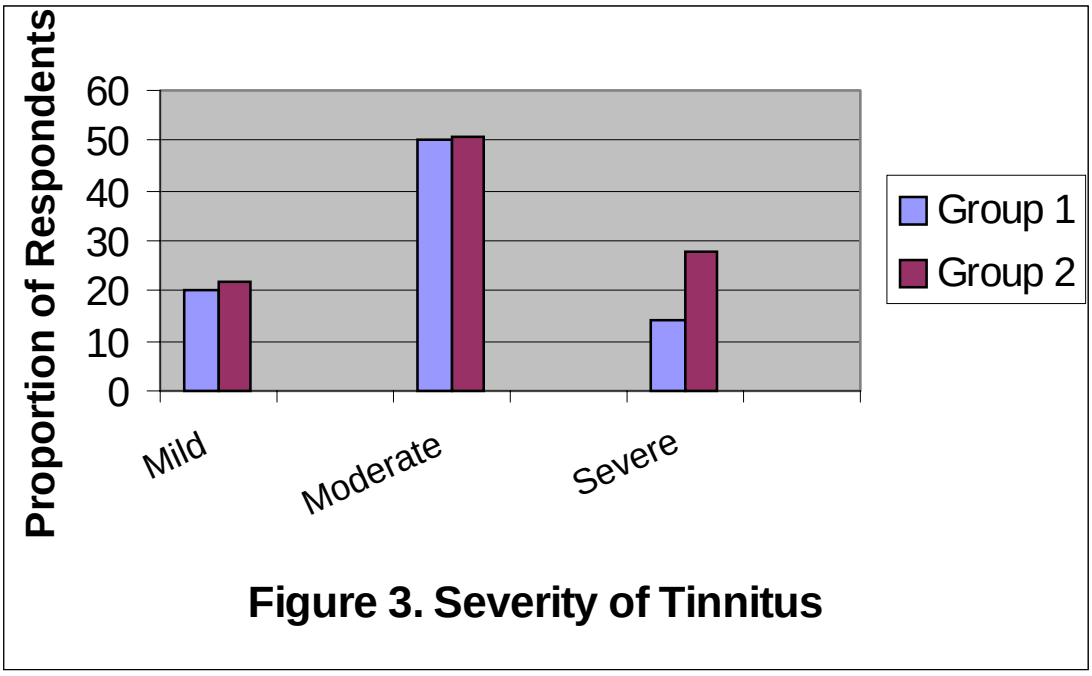

Figure 3. Severity of Tinnitus

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

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".

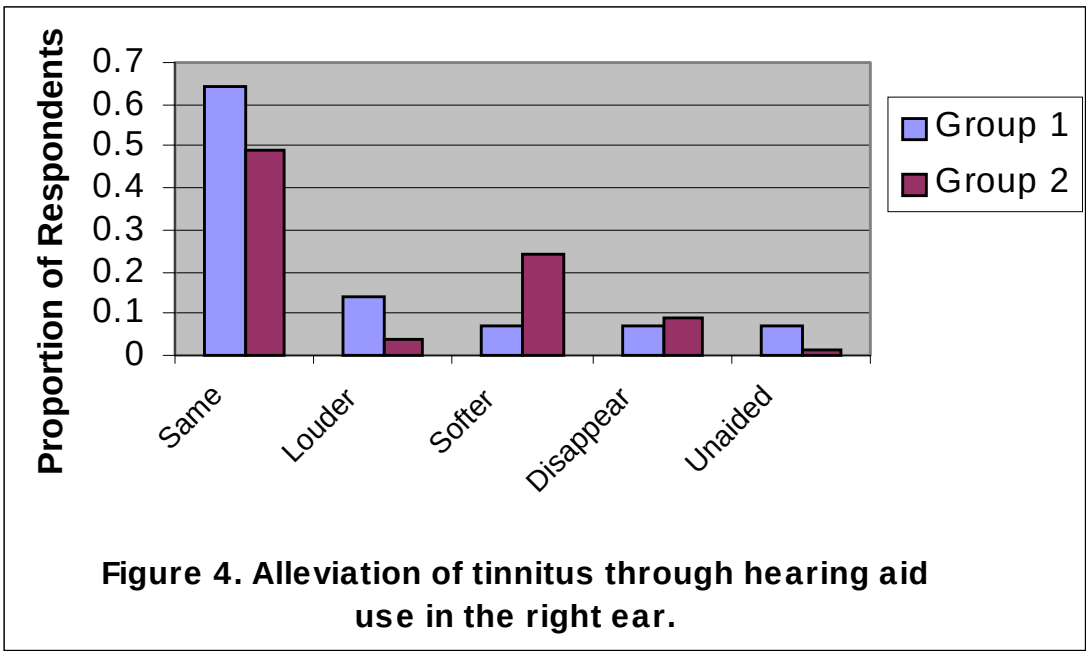

Figure 4. Alleviation of tinnitus through hearing aid use in the right ear.

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.

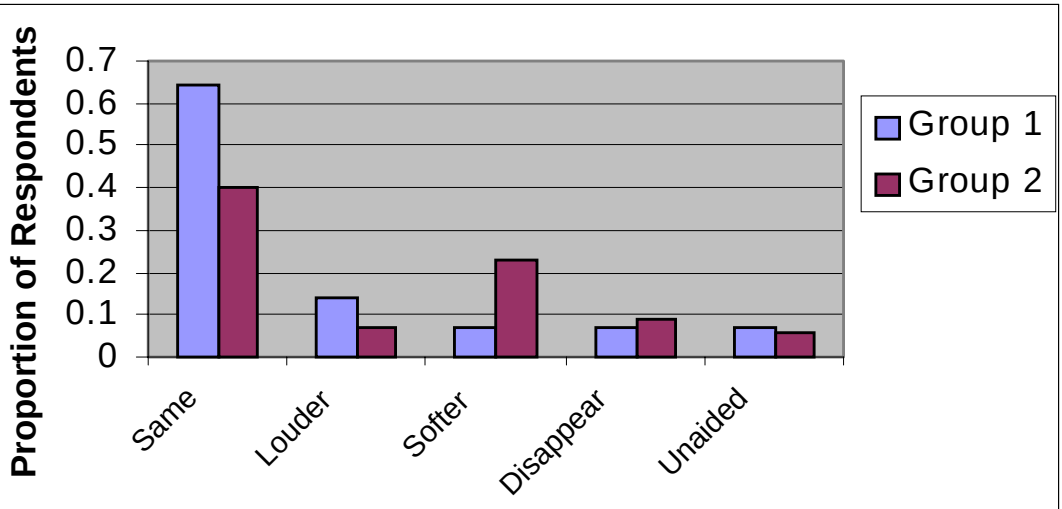

Figure 5. Alleviation of tinnitus through hearing aid use in the left ear.

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; $\underline{U}$= 22.0, $\underline{p}$= 0.18); (left ear; $\underline{U}$= 28.5, $\underline{p}$= 0.37); (binaural; $\underline{U}$= 35.5, $\underline{p}$=0.66)].

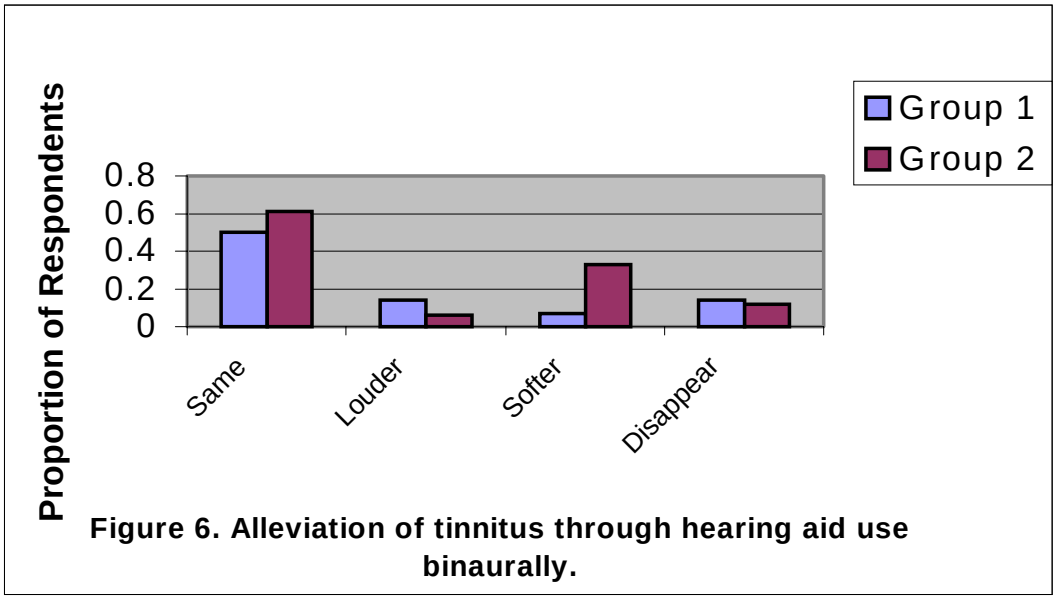

Figure 6. Alleviation of tinnitus through hearing aid use binaurally.

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. (1985), 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. (1985) 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 effect the proportion of individuals receiving relief. These proportions were 44%, 35%, and 43% for mild, moderate and severe tinnitus, respectively. Surr, et al. (1985) also concluded that severity of tinnitus did not effect 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 10. Rating of hearing aid performance

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".

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	70	21	23	7	7
In a large group/party	14	15	36	32	50	53
In a small meeting	43	45	50	45	7	10
Effect on tinnitus	12	26	51	35	37	39

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’s earlier findings regarding the effects of hearing aid use on tinnitus relief. 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 was 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.

RENEE LOKENBERG

OBJECTIVE

A highly motivated third year student currently in the AuD program at University of South Florida. Experience includes all aspects of audiology from newborn hearing screenings to veteran's hearing aids.

EDUCATION

University of South Florida Tampa, FL

- I chose to continue after completing my Master's with the AuD program to be completed December 2000.
- AuD project: I am writing a paper on the evaluation and treatment of tinnitus

MS in Audiology

- GPA = 3.5
- Thesis alternative: A survey study exploring whether wide dynamic range compression significantly reduce tinnitus as compared to other hearing aid circuits.
- Volunteer work =

  Student volunteer at AAA in Miami and Chicago.

  Committee member of National Association for Future Doctors of Audiology (NAFDA).

  Certified in adult and pediatric CPR .

  Supervised free hearing screenings for May: Better Speech and Hearing month.

University of Florida Gainesville, FL

BA in Communication Sciences and Disorders

1) GPA = 3.3
2) Volunteer work =

   Student volunteer at AAA in Ft. Lauderdale

   Cuddler Program at Shands Hospital

   Friendly visits at Alachua Nursing Home

   Transporter for Florida Wildlife

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WORK EXPERIENCE

American Institute of Balance Seminole, FL

Audiology Extern

- In this setting I have received experience in conducting full hearing and vestibular evaluations. I have gained competency in the use of OAE's, ABR's and video ENG. I complete diagnostic hearing exams and dispense digital and programmable hearing aids in a busy ENT office.

Newborn Hearing Screening Program Tampa, FL

Student Screener

- This was a nine month experience in the Newborn Hearing Screening program at Tampa General Hospital. There was an average of ten babies born every day and every one had to be screened, including the at-risk infants in the Neonatal Intensive Care Unit (NICU) using the GSI-60 DPOAE.

Central Florida Speech and Hearing Center Lakeland, FL

Audiology Extern

- In this setting I evaluated children's hearing, ages 18 months to 18 years old. My experience included OAE's, sedated ABR's, VRA, play audiometry and child amplification. I also gained experience in the Industrial Hearing Conservation Program located at the center and dispensed free listening devices provided by the state of Florida.

James A. Haley VA Medical Center Tampa, FL

Audiology Trainee

- As my first externship, I gained substantial experience in conducting full evaluations and dispensing hearing aids to veterans. I also had some experience with ABR's and ENG's.