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Sequential Sound Therapy in Tinnitus

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Abstract: Sequential sound therapy, which uses wide-band white noise distinguished by some unique characteristics, is applied in the treatment of tinnitus. The methodology is described, as are the differences from and similarities to tinnitus retraining therapy. We have performed sequential sound therapy in 26 patients from 2002 through part of 2003. Thirty-eight generators of sounds were adapted for use in this therapy and, of these, 34 incorporated an earphone. The results of sequential sound therapy in our 26 patients were compared with the results of tinnitus retraining therapy in 15 patients treated during the years 2000 and 2001. Satisfactory results obtained with sequential sound therapy totaled 100%, whereas only 33% of subjects treated with tinnitus retraining therapy obtained satisfactory results. In 6 patients who received sequential sound therapy, tinnitus disappeared altogether. In addition, no patient receiving sequential sound therapy has left the treatment protocol, whereas 53% of patients receiving tinnitus retraining therapy abandoned the treatment protocol.

Key Words: earphones; generators of sounds; therapy with sounds; tinnitus; white noise

Currently, tinnitus treatment involving the application of sounds is being performed according to a protocol defined as *tinnitus retraining therapy* (TRT) [1–6], which consists basically of the application of white noise of an intensity inferior to that of tinnitus to permit a patient's habituation to and decreased perception of tinnitus. Other types of tinnitus treatment using sounds have been described that involve the total masking of tinnitus by the application of white noise of an intensity greater than that of tinnitus [7–9].

TRT, which is being performed worldwide, is considered a conceptual methodology that has helped to standardize the treatment of tinnitus. The fundamentals of TRT are (1) the neurophysiological model, (2) therapeutic counseling, and (3) sound therapy.

The *neurophysiological model* is structured as a net composed of five aspects: the generation, detection, emotional aspects, and perception of, and the aversive reaction to tinnitus. Tinnitus can be generated in all auditory pathways. Detection of tinnitus takes place at the subcortical level. The emotional aspects of tinnitus are controlled by the limbic system. The perception and evaluation of tinnitus occur in cortical areas, and the aversive reaction to tinnitus emanates from the autonomic nervous system.

Therapeutic counseling for tinnitus should primarily address a patient's understanding of the condition. To assist a patient in understanding tinnitus, counseling must attempt to demystify by explaining (1) the physiology (thereby making the patient aware of all the implied mechanisms of this condition), (2) the necessity to control aversive reactions to eliminate suffering, and (3) the details of each step of treatment.

Sound therapy is created using noises from three sources, such as natural sounds from a patient's environment, sound amplification of earphones, and generators of white noise of a lower intensity than the patient's tinnitus.

Sequential sound therapy applies the two tinnitus treatments that use sounds as if they are total masking and partial masking, incorporates an intermediate step—limit masking—for interconnection, and is adapted to each individual patient and so that it can be administered in either a public health system or in private medical practice.

PATIENTS AND METHODS

The application of sequential sound therapy comprises three steps: It begins with total masking (white noise more intense than tinnitus), proceeds to limit masking

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(white noise of an intensity similar to that of tinnitus), and culminates in partial masking (white noise less intense than tinnitus). Passage from one type of masking to another depends on the obtained result and on the treated patient's opinion about the success of adapting white noise to the individual's tinnitus experience. The white noise applied is a wide-band sound.

Patients

Twenty-six patients, 21 of whom were women (median age, 69 years) and 5 of whom were men (median age, 63 years), gave their informed consent to be entered into the study. The predominant pathological findings were arterial hypertension in five patients, diabetes in three, obesity in two, a cerebrovascular accident in one, and acoustic traumatism in another. All patients began the treatment regimen by means of sound generators, according to the sequential sound therapy protocol, during the year 2002 and part of 2003. The control group was composed of 15 patients, 11 women (median age, 66 years) and 4 men (median age, 63 years). The predominant pathological findings in this group were arterial hypertension in four patients, diabetes in two, and obesity in one. The control group began the treatment regimen with white noise by means of sound generators, according to the TRT protocol, during the years 2000 and 2001.

Complementary Tests

Aside from anamnesis focused on discerning information about tinnitus [10], complementary tests that were carried out in all patients were otoscopy, tympanometry, tonal audiometry (bony and air auditory thresholds, discomfort thresholds, and pain thresholds), logo-audiometry (thresholds of voice detection, word detection, perception, understanding, and discomfort), and tinnitometry (tinnitus measurement). All these thresholds are useful during adaptation of the sound generators and the earphones.

Sound Generators

In patients treated by means of either sequential sound therapy or TRT, the sound generators used were Siemens (Germany) model TCI and TCI COMBI, the latter incorporating earphones. Both the sound generators and earphones employ digital technology. The sound generators were programmed for four application levels that exceed, match, or are below the intensity of a patient's tinnitus, as follows:

- Level 1. White noise less intense than tinnitus (–3 dB)
- Level 2. White noise of an intensity similar to tinnitus (0 dB)
- Level 3. White noise more intense than tinnitus (+3 dB)
- Level 4. White noise more intense than tinnitus (+6 dB)

Adaptation and Control

Adaptation and control were personalized. Adaptation of the sound generators and the earphones were undertaken with attention paid to each patient's intrinsic tinnitus characteristics and to whether a patient experienced any hearing loss or deafness. In patients with tinnitus and without hearing loss, sound generators were adapted, whereas in patients with tinnitus and hearing loss, sound generators with incorporated earphones were adapted.

First Month of Adaptation

During the first month of adaptation, in patients with tinnitus but without hearing loss, the sound generator was adapted for total masking (level 3 or 4) for 6 hours per day—2 hours in the morning, 2 hours at noon, and 2 hours in the afternoon. In patients with tinnitus and hearing loss, sound generators with earphones were used for 6 hours per day—2 hours in the morning, 2 hours at midday, and 2 hours in the afternoon. The function of the sound generator in this group graduated to level 3 or 4 during 2 hours of each day that proved to be most tranquil. In both groups of patients, if a patient was unable to sleep owing to tinnitus, the sound generator was used at level 3 or 4 throughout the night as well. Patients were treated weekly during this first month.

Second Month of Adaptation

During month 2 of adaptation, in patients with tinnitus but without hearing loss, the sound generator was graduated to level 2 for a 6-hour daily span selected by the patient. Each patient was given the option of passing at level 1 and at levels 3 or 4. In patients with tinnitus and hearing loss, the sound generator incorporating earphones was applied in the earphone function for as much time daily as desired by each patient, except for a 2-hour daily span during which a patient could choose the masking level of the sound generator without earphones. If a patient could not sleep at night, he or she was permitted the use of the sound generator during the entire night. Control patients generally were treated biweekly during the second month, although such treatment was personalized to the needs of the individual patient.

Third and Subsequent Months of Adaptation

In the third month of adaptation, control patients received treatment personalized according to time and

masking type. In general, treatment was applied monthly except for necessities expressed by each patient. Thereafter, patients in the control group received treatment at 3 months, biannually, and annually according to the results obtained in each case. Adaptation was carried out monaurally in unilateral tinnitus and binaurally in bilateral tinnitus.

Evaluation of Results

Results of this study were evaluated using the tinnitus handicap inventory (THI; in Spanish) [10,11], which includes 25 questions to which the patient and his or her cohabitant answered "yes," "sometimes," or "no." Results were expressed in percentages.

RESULTS

Types of Tinnitus

The various types of tinnitus identified in the 26 patients studied are detailed in Table 1.

Sound Generators Adapted

A total of 38 sound generators, of which 34 incorporated earphones, were adapted initially to the 26 patients treated by means of sequential sound therapy. The adaptation was carried out monaurally or binaurally, as outlined in Table 2. In patients with unilateral tinnitus, monaural adaptation was performed in the ear in which the patient suffered the tinnitus. After the adaptation, either immediately or after some delay, the tinnitus generally appeared in the opposite ear from that in which tinnitus originally was present (Table 3). When the tinnitus appeared in the opposite ear, adaptation of another sound generator was made for this ear.

In the 15 control group patients treated by means of TRT, 30 sound generators with incorporated earphones were adapted binaurally.

Table 1. Types of Tinnitus in 26 Adapted Patients

Tinnitus Type		Tinnitus Characteristics	
Type	Percentage of Patients	Characteristics	Percentage of Patients
Bilateral	46	Same intensity in both ears	33
		Prevalence in right ear	9
		Prevalence in left ear	58
Unilateral	54	Right ear only	36
		Left ear only	64
Total	100	Right ear	33
		Left ear	67

Table 2. Type of Adaptation in 26 Patients

Tinnitus		Adaptation	
Type	No. of Patients	Type	No. of Patients
Binaural	12	GSE, both ears	11
		GSE in one ear, GS in opposite ear	1
Monaural	14	GSE	10
		GSE in one ear, earphone in opposite ear	1
		GS	2
		GS in one ear, earphone in opposite ear	1

GS = sound generator; GSE = sound generator incorporating earphone.

Complementary Tests

Tympanometry was normal in 19 patients (73%) of patients, being smooth or plane in the remaining patients for medial ear problems. Light or moderate hearing loss occurred in 25 patients (96%), a single patient retaining audition within the normal range. The intensity of tinnitus varied between 1 and 15 dB above the air threshold of audition, even in the same patient. Similarly, but to a lesser degree, the tinnitus frequency varied for a given patient, being distributed throughout 89% of the area of acute frequencies.

Evaluation of Results

In every one of the 26 patients treated by means of sequential sound therapy, a subjective, quantitative improvement was obtained according to the THI answered by both a patient and his or her cohabitant. To date, no

Table 3. Monaural Treatment: Time of Appearance of Tinnitus in Ear Opposite That Originally Experiencing Tinnitus (n = 14)

No. of Patients	Time of Appearance of Tinnitus in Opposite Ear
2	In the same moment of adaptation
1	1 month after adaptation
1	1.5 months after adaptation
1	2 months after adaptation
1	3 months after adaptation
1	6 months after adaptation
1	3 months adapted without hearing tinnitus in opposite ear
1	4 months adapted without hearing tinnitus in opposite ear
1	5 months adapted without hearing tinnitus in opposite ear
2	6 months adapted without hearing tinnitus in opposite ear
1	7 months adapted without hearing tinnitus in opposite ear
1	7 months, with sound generator and conventional earphone in opposite ear, without hearing tinnitus in opposite ear

patient has left the treatment group. Six patients no longer perceived their tinnitus—one patient after 15 days of adaptation, three patients after the first month, and two patients after the 3-month adaptation using only the earphone function, thereafter not needing the function of a sound generator. In the 15 control patients treated by means of TRT, subjective, quantitative improvement was obtained in 33% (n = 5), and 53% left the study (n = 8).

Decreased Perception of Tinnitus

The perception of tinnitus diminished in all patients treated with sequential sound therapy: in six patients from the moment of adaptation, in one patient after 15 days of treatment, in two patients at 1 month of adaptation, in three patients at 2 months, in one patient at 3 months, in four patients at 4 months, and in three patient at 6 months.

Control of the Adaptation

Three patients, once their perception of tinnitus had decreased, experienced periods of increased tinnitus perception again that were related to stressful situations. One such patient experienced increased tinnitus perception in connection with a cerebrovascular accident suffered by his wife. Another patient's "relapse" was associated with labor problems. In a third patient, increased tinnitus perception occurred on several occasions in connection with personality dysfunctions.

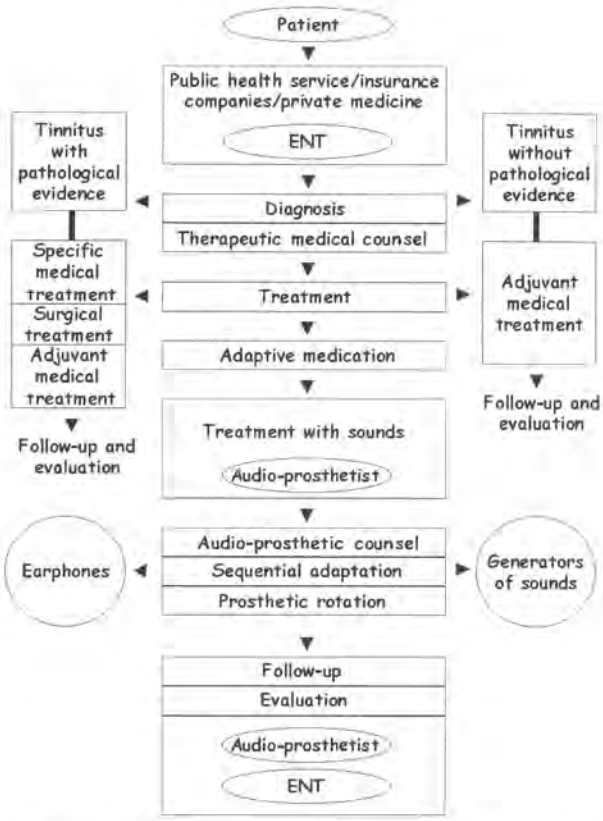

Figure 1. Flow diagram depicting a guide to clinical practice that reflects the medical procedures and audio-prosthetics integral to our (total) treatment of tinnitus. (*ENT* = ear, nose, and throat specialist)

DISCUSSION

Sequential sound therapy is an original methodology being described here for the first time. This therapeutic approach consists of a three-step sequential application of the white noise of tinnitus, first for a total masking effect, next as a limited masking effect and, finally, for partial masking. Passage from one masking type to another in a given patient depends on the result obtained in that patient and on the patient's assessment of the regulation of his or her tinnitus by this method.

In our 26 patients, tinnitus was prevalent in the left ear, coinciding with other published results in which the left ear is the most frequently affected [12–14]. Monaural adaptation is carried out in sequential sound therapy for psychological and economic reasons. A decreased perception of tinnitus is said to have occurred when the tinnitus ceases to bother a patient; this decreased perception is known objectively because the patient passes from level 3 or 4 to level 2 or 1 in the sound generator.

Some German authors have begun to advise multidisciplinary treatment of tinnitus [15,16]. The flow diagram in Figure 1 depicts a guide to clinical practice that reflects the medical procedures and audio-prosthetics that are integral to our treatment of tinnitus. This approach incorporates several methodological concepts:

1. *Concept of tinnitus*. We define tinnitus as a noise that the patient hears that it is causing him or her to suffer. A person can experience noise perception and not suffer from it. A person usually begins to suffer from such noise perception when he or she passes to a certain hypersensitivity state imposed by matters unrelated to the noise: Such matters may be of a personal nature (e.g., suffering from another illness) or related to family (e.g., deaths, solitude), employment (e.g., accident, jubilation), or civic (e.g., robberies) or political issues (e.g., social conflicts). In fact, any matter that causes hypersensitivity in a patient can fix his or her attention on the noise and cause that patient to begin suffering.
2. *Management of tinnitus*. The patient assists by varying the time intervals and the types of masking.
3. *Shared therapeutic counsel*. The otorhinolaryngologist provides medical counsel in relation to the sound therapy, and the audio-prosthetist provides audio-prosthetic counsel relative to adaptation and its control.

4. *Monaural and binaural adaptation*. Adaptation can be binaural in bilateral tinnitus and monaural in unilateral tinnitus.

5. *Tinnitus as chronic illness*. Tinnitus is considered a chronic illness if treatment has no temporal limit.

6. *Treatment as part of various health systems*. Treatment can be provided as an aspect of a national health system or as a service covered by health insurance companies or extended through private clinics.

7. *Dual evaluation*. Evaluation of the outcomes of therapy is carried out by means of the tinnitus handicap inventory as answered by both the patient and his or her cohabitant.

Table 4 lists the differences and similarities between TRT and sequential sound therapy. In both groups of patients, therapy involved similarly generated sounds and was administered by the same personnel (otorhinolaryngologist and audio-prosthetist). However, all 26 tinnitus patients treated with sequential sound therapy experienced improvement, and none left the treatment group, whereas among the 15 control patients treated with TRT, only 33% registered improvement, and 53% abandoned sound therapy. Other authors who used TRT in their patients found improvement rates varied widely, ranging between 23% and 88% [10].

The most common complaint in patients treated by TRT—that is, the presence of two noises instead of one—contributed to these patients' abandonment of therapy. This problem was not encountered among patients treated with sequential sound therapy; rather, patients felt a sense of well-being when they did not hear their tinnitus and had normal audition from the beginning of the treatment.

The evolution of masking in sequential sound therapy is described as a chain of three links: the first link being total masking, the second being partial masking, and the third being sequential sound therapy.

The therapeutic masking of tinnitus began in 1969 in Germany, where Feldmann [17] began to mask tinnitus in a total way, as much homolaterally as contralaterally and using different spectra of noises: wide-band, narrow-band, and pure-tone. Later, in 1977, Vernon [18] of the United States made important contributions to the development of this technique known currently as TRT. Hazell [19], together with Wood, contributed to the benefits of total masking in this therapeutic modality. Once the benefits of total tinnitus masking were well-known, the technique continued to be perfected. On the basis of work published by Hazell and colleagues in 1985 [20], various authors built on the foundation of the application of noises less intense than a patient's tinnitus to obtain positive results [21,22].

Many patients whom we subjected to TRT with the application of sounds less intense than their tinnitus did not experience improvement. Since 1998, we have undertaken to develop a different methodology in which sounds are applied in a sequential way. In developing this approach, we relied on prior knowledge of masking, both total and partial, and added to this limit masking. The result was sequential sound therapy. Outcomes using this methodology have improved substantially over those obtained with only total masking or partial masking. We conclude that the effectiveness of sequential sound therapy has surpassed that of TRT in the treatment of tinnitus, by modifying the application of white noise to the patient and integrating medication, surgery, adaptation, and human behavior during the entire treatment process until improvement of tinnitus is achieved.

Table 4. Differences and Similarities Between Sequential Sound Therapy and Tinnitus Retraining Therapy

	Tinnitus Retraining Therapy	Sequential Sound Therapy
Objectives	Not elimination of tinnitus but rather habituation to and decreased perception of tinnitus	Habituation to and decreased perception of tinnitus; moving toward elimination of tinnitus such that a patient need not suffer from it and is able to control it
Therapeutic counsel	Carried out by the otorhinolaryngologist in a clinic or unit specializing in tinnitus	An otorhinolaryngologist for surgical therapy and an audio-prosthetist for adaptation and control
Sound therapy	Environmental noises, earphones, and sound generators	Digital sound generators and digital earphones
Adaptation, binaural and monaural	Binaural adaptation always in unilateral and binaural tinnitus	Binaural adaptation in bilateral tinnitus and monaural adaptation at the outset in unilateral tinnitus
Duration of the treatment	1–2 years	No limit, as tinnitus is a chronic illness that moves through phases of improvement and worsening
Medicine, public and private	Private or public clinic specializing in tinnitus	Public (affiliated with insurance companies) or private surgical facility and a center for tinnitus staffed by a specialized audio-prosthetist for adaptation procedures
Evaluation	Subjective evaluation or tinnitus handicap inventory completed by patient	Subjective evaluation or tinnitus handicap inventory completed by both patient and his or her cohabitant

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