ORIGINAL ARTICLE

Tinnitus Measurement With Conventional Audiometer Versus High-frequency Audiometer

Miguel A. López-González, a,∗ Esther Cambil, b Antonio Abrante, a Rocío López-Fernández, b Elizabeth Barea, b Francisco Esteban a

a UGC Otorrinolaringología, Hospital Universitario Virgen del Rocío, Sevilla, Spain
b Centro Integral de Acúfenos, Sevilla, Spain

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Abstract
Introduction and objectives: Determinations of the psychoacoustic characteristics of tinnitus (frequency and intensity) are valid for diagnosis, treatment, monitoring and research purposes. The aim of this work is to compare the frequency of the tinnitus measured with a standard audiometer and a high frequency audiometer.

Methods: We used a conventional audiometer (frequency range: 125–12,000 Hz) and a high-frequency audiometer (frequency range: 125–18,000 Hz) to measure the frequency and intensity of tinnitus in 47 patients with tinnitus as a continuous ringing.

Results: We found statistically significant differences between the determination of the frequency of tinnitus made with conventional and high-frequency audiometers, as well as a correlation between high-frequency tinnitus and distress expressed by patients.

Conclusions: (1) The frequency of tinnitus determined by high-frequency audiometer is greater than the frequency determined by conventional audiometer; (2) the higher the frequency of tinnitus, the more discomfort the patient manifests; and (3) there is no relationship between the intensity and discomfort caused by tinnitus.

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Medición de acúfenos con audiómetro convencional versus audiómetro de alta frecuencia

Resumen
Introducción y objetivos: Las determinaciones de las características psicoacústicas del acúfenos (frecuencia e intensidad) son válidas para el diagnóstico, tratamiento, seguimiento y fines de investigación. El objetivo de este estudio es conocer si se encuentran diferencias entre las determinaciones de la frecuencia e intensidad del acúfenos con metodología convencional o metodología de alta frecuencia.

∗ Corresponding author.
E-mail address: malopez@cica.es (M.A. López-González).

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Introduction

The psychoacoustic study of tinnitus known as acufenometry or tinnitometry was standardised in 1981 by a panel of experts convened in London during a Symposium of the Ciba Foundation. They agreed on 4 key measurements to describe tinnitus: (a) determining its frequency, (b) determining its intensity, both described by Fowler in 1944, (c) level of masking of tinnitus, described by Feldman in 1911 and (d) residual inhibition, described by Vernon in 1988.

Knowledge of the psychoacoustic characteristics of tinnitus is helpful for its diagnosis, to select a therapeutic approach, to control treatment during its evolution and to compare results during investigation. Tinnitometry is a subjective test, like tone audiometry, which attempts to get as close as possible to the reality of a patient with tinnitus. A psychological evaluation should be performed together with this study, in order to observe how the symptom of tinnitus affects the patient, or vice versa, how the psychopathological comorbidity creates or worsens the symptom of tinnitus. It is noteworthy that some measurements of tinnitus intensity which find minimum values originate a considerable psychological impact on certain patients.

In this work we have studied the measurement of tinnitus frequency and intensity using a conventional audiometer and a high-frequency audiometer, with the clear and precise objective of finding the differences and limitations of both methods.

Materials and Methods

We conducted a descriptive, interobserver study of a cohort of patients.

Patients

A total of 47 patients were treated at our hospital due to continuous, idiopathic, subjective tinnitus in the form of beeps, during the year 2010 and until the first half of 2011.

General Demographic, Clinical and Audiological Information

By gender, women represented 40% of the sample and men represented 60%. The mean age was 48.7 years, with a range between 27 and 82 years. The mean time of evolution of tinnitus until care was obtained was 6.6 years, with a range between 2 months and 30 years. Tinnitus occurred bilaterally in 21% of cases, in the right ear in 32% and in the left ear in 47%. The audiometry was normal in 32% of cases, revealed mild sensorineural hearing loss in 32% and moderate sensorineural hearing loss in 36%. In cases of deafness, the type of curve was an inverted U in 4% of cases, flat in 13% and descending in 83%.

Methods

We performed an ENT examination, tympanogram, audiometry and analogue visual scale test. The conventional audiometer measured frequencies of 125, 250, 500, 1000, 2000, 4000, 6000, 8000 and 12 000 Hz (Ampliad 311, Type 1 ICE-645, ANSI 53-6, ISO 389, Milan, Italy), and the high-frequency audiometer measured frequencies of 125, 250, 500, 1000, 2000, 4000, 6000, 8000, 9000, 10 000, 11 000, 12 000, 14 000, 16 000 and 18 000 Hz (two-channel Ampliad 321, Type 1 ICE 60645-1-60645, ZA-E, 60645-4, HF AE ANSI 53.6, Milan, Italy). We determined both the frequency and the intensity of tinnitus for both audiometers according to the method of paired sounds.

Statistics

We performed a descriptive, statistical study of the data, representing qualitative variables through absolute and relative frequencies, and quantitative variables through mean and standard deviation. The statistical analysis was performed using the Wilcoxon non-parametric test of signed ranks and the Spearman correlation coefficient, as well as the IBM SPSS 19 software.

Ethical Considerations

The study was conducted according to the principles of the Declaration of Helsinki (1975, 1983). The research protocol, patient information sheet and written informed consent form were approved by the Ethics Committee of the hospital.
Figure 1  Determination of the frequency of tinnitus using a conventional audiometer (light bars) and a high-frequency audiometer (dark bars). The means±standard deviations of the frequencies are also represented. The difference is statistically significant for both the right ear ($P<.002$) and the left ear ($P<.001$).

Results

Results are reflected comparing the conventional audiometer versus the high-frequency audiometer.

The determination of tinnitus frequency (Hz) (mean±standard deviation) with the conventional audiometer was as follows: frequency in the right ear, 9560±2370; frequency in the left ear, 8820±3010; and with the high-frequency audiometer it was: frequency in the right ear, 12580±3040; frequency in the left ear, 12570±3340, with statistical significance (Fig. 1). The determination of tinnitus intensity with the conventional audiometer was as follows: intensity in the right ear, 9.7±7.5; intensity in the left ear, 8.9±7.2; and with the high-frequency audiometer it was: intensity in the right ear, 8.5±8.6; intensity in the left ear, 9.4±8.6. There were no significant differences between any of the intensity measurements comparing the conventional audiometer and the high-frequency audiometer. For the right ear $P=.275$ and for the left ear $P=.555$.

Regarding tympanometry, 81% of cases presented a type A curve and 19% presented a type B curve.

Regarding the study of correlation between visual analogue scale and frequency of tinnitus (nonparametric Spearman correlation): with conventional audiometer in the right ear, $r=.053$, $P=.844$; with conventional audiometer in the left ear, $r=.140$, $P=.544$. A statistically significant correlation was obtained with the high-frequency audiometer in the right and left ears (Fig. 2).

Regarding the study of correlation between visual analogue scale and intensity of tinnitus (nonparametric Spearman correlation): with conventional audiometer in the right ear, $r=.118$, $P=.763$; with conventional audiometer in the left ear, $r=.357$, $P=.234$; with high-frequency audiometer in the right ear, $r=.172$, $P=.694$; with high-frequency audiometer in the left ear, $r=.293$, $P=.371$.

No differences were found in the frequency and intensity of tinnitus, as determined by conventional audiometer or high-frequency audiometer, in relation to gender (female, male), age (above and below the median=48 years), duration of tinnitus (less than or equal to 5 years, over 5 years), hearing (normal, mild, moderate), type of audiometric curve (inverted U, flat, decreasing), tympanogram and location of tinnitus (bilateral, right ear, left ear).

Discussion

From the diagnostic point of view, the subjectivity of tinnitus generates uncertainty about how to approach it and frame it within organic, psychological and social pathology. From the standpoint of treatment, it is important to be aware of the variations caused by different therapies. Specifically, there is a treatment for tinnitus based on its frequency, known as phase-shift or counterphase. In this treatment, the frequency of the predominant tinnitus is determined and therapy is applied on it. If Hertz readings do not correspond to the real value, this type of treatment is much less effective or even ineffective. This study has shown that the use of a high-frequency audiometer enables patients to identify frequencies corresponding to their tinnitus which are much higher than those measurable with a conventional audiometer (Fig. 1). Therefore, the results of counterphase therapy in such cases would be much more effective. The evolution of tinnitus can be followed with greater clarity through high-frequency tinnitus. Similarly, different treatments using psychotherapy, medication and magnetic or electrical stimulation could be evaluated more accurately by obtaining tinnitus values which were closer to reality, such as those obtained with a high-frequency audiometer. Tinnitus can be used during the evolution of tinnitus, in a similar manner to audiometry during hearing measurements. Although both are subjective measurements, they have great diagnostic and therapeutic value.

A more adequate identification of tinnitus frequency values leads us to select the high-frequency audiometer, since it offers greater validity and accuracy of Hertz measurements. This, in turn, offers patients a greater range of pure tones with which to match their tinnitus.

The correlation found between high-frequency tinnitus (greater than 8000Hz) and the visual analogue scale

Figure 2  Correlation between visual analogue scale and frequency of tinnitus, using the high-frequency audiometer on the left ear with statistical significance ($r=.474$; $P<.030$). The statistical correlation in the right ear for the high-frequency audiometer was $r=.452$; $P=.079$ (not shown).
indicates that the higher the frequency of tinnitus, the more discomfort it causes (Fig. 2). By contrast, no differences were found in the measurements of tinnitus intensity between determinations made with a conventional audiometer and with a high-frequency audiometer. Tinnitus intensity, like pain intensity, does not reflect the level of discomfort suffered by patients, since the experience of pain or tinnitus depends on the subjective perception, idiosyncrasy and vulnerability of each patient.

We have not found any other studies in the literature which compare the results of measuring tinnitus with a conventional audiometer and with a high-frequency audiometer.

Conclusions

(1) The frequency of tinnitus determined with a high-frequency audiometer is higher than that determined with a conventional audiometer; (2) the higher the frequency of tinnitus, the greater the discomfort expressed by patients; and (3) there is no relationship between the intensity of tinnitus and the discomfort it causes.

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Conflict of Interests

The authors have no conflicts of interest to declare.

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