Distortion Product Otoacoustic Emissions in Tinnitus Patients

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Abstract: Tinnitus is a symptom that affects a great number of patients. Its diagnosis, treatment, and follow-up are difficult, owing to its subjectivity. The authors propose the use of distortion product otoacoustic emissions (DPOAEs) in tinnitus evaluation. They studied three groups: controls, having no complaint of tinnitus and normal hearing; group 1, presenting tinnitus and normal audiometry; and group 2, presenting tinnitus and sensorineural hearing loss. The results showed 3.6% of DPOAE alterations in the control group, 18.8% in group 1, and 61.3% in group 2. This study shows a correlation between DPOAE alterations and tinnitus complaint, but many patients with tinnitus do not present with DPOAE alterations. The authors conclude that DPOAEs constitute a useful audiological method for evaluating patients complaining of tinnitus.

Key Words: hearing loss; otoacoustic emissions; tinnitus

Tinnitus is a sound sensation perceived by a patient without external stimulus. Its intensity may vary from a mild, sometimes ephemeral, almost imperceptible degree to a disabling degree, interfering with affected patients' everyday chores because of its incessant characteristics. The literature reports cases of suicide in patients with tinnitus, mainly when tinnitus is associated with depression [1]. Tinnitus is controversial and not well understood. Doubts still linger concerning its pathophysiology, diagnostic methods, and best therapeutic management. It is a challenge even among specialists in this field. This fact is partially due to the great difficulty encountered in characterizing the disorder objectively.

Many studies have tried to create an animal model [2] or a method for evaluating tinnitus by means of objective and reliable procedures. Although recent findings attributable to technological advances have enhanced the understanding of cochlear electrophysiology, a diagnostic method that could fulfill these requirements completely has yet to be developed. As sensorineural tinnitus is closely related to some kind of cochlear dysfunction or disease, a reasonable inference is that a method that could evaluate the integrity of ciliated cells—the most important ones in electromechanical sound transduction—could be used to define this symptom objectively, providing a better understanding of its mechanisms and pathophysiology and, consequently, a less empirical treatment.

Otoacoustic emissions (OAEs), described by Kemp [3] in 1978, increased hopes for a better understanding of tinnitus, as they directly evaluate the cochlea, especially the external hair cells. However, initial tests using spontaneous OAEs were frustrating, and the studies performed with transient OAEs have not reached a consensus. Thus, distortion product OAEs (DPOAEs) would be convenient for this purpose, because they permit the analysis of a larger spectrum of frequencies, providing a segmented analysis of practically all of the extension of the cochlea. The aim of this study is to verify any existence of alteration in DPOAEs in patients who complain of tinnitus; whether any relation exists between the affected side and these possible alterations; and whether the DPOAEs are an objective method for tinnitus evaluation.

SUBJECTS AND METHODS

One hundred and twenty-five patients were included in this study. Fifty-six complained of tinnitus in one or

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both ears. They were followed up at the tinnitus outpatient clinic of our department. The remaining 69 patients constituted the control group. These patients had a negative clinical history of hearing loss and presented no complaint of tinnitus and had normal otoscopy results; their audiological thresholds were normal (<25 dB hearing level); and they had normal acoustic emittance tests.

All patients were subjected to anamnesis and otorhinolaryngologic examination, followed by pure-tone audiometry, speech audiometry, and DPOAE examination. Data related to age, gender, presence of hearing problems, unilateral and bilateral tinnitus, and degree of its severity were obtained. Tinnitus was considered mild when noticed by patients only occasionally; moderate when constant but not disturbing; and severe or intense when disturbing, disabling, and interfering with daily chores.

Pure-tone and speech audiometry were performed in sound-insulated rooms. Air conduction was tested for the frequencies of 250, 500, 1,000, 2,000, 3,000, 4,000, 6,000, and 8,000 Hz, and bone conduction thresholds were obtained for frequencies at 500, 1,000, 2,000, 3,000, and 4,000 Hz. The patients were then divided into two groups, according to the degree of hearing loss. Group 1 included the patients with normal audiometry results, and group 2 included patients with sensorineural hearing loss of up to 50 dB. Patients with hearing thresholds higher than 50 dB hearing loss (HL) were excluded, as they would be out of range for the OAE tests.

The DPOAEs were evaluated in an acoustically insulated room, using two pure tones—L1 and L2—equal to 70 dB sound pressure level (SPL), with frequencies f_1 and f_2, respectively, with $f_2/f_1 = 1.2$. Data analyses were performed using the DPgram; frequency graph (represented by the geometrical average of f_1 and f_2); and distortion product (DP) amplitude, which was always measured in 2 f_1–f_2. The fifth percentile for each separate frequency was adopted as the minimum value for DP amplitude. In case of noise floor (NF), the ninety-fifth percentile was adopted as the maximum value. To consider OAE present in a given frequency, its values should be within these limits. The Chi-square test was used for the statistical analysis of the data.

RESULTS

Fifty-six patients complaining of tinnitus in one or both ears were included in this study. Thirty-nine (69.6%) were female, and 17 (30.4%) were male. Age varied from 28 to 76 years (mean, 54.41 years). In relation to the affected side, 29 patients (51.8%) presented with bilateral tinnitus, whereas 12 (21.4%) and 15 (26.8%) presented with tinnitus on the right and on the left, respectively. Twenty-nine patients (51.8%) presented with severe tinnitus; 24 (42.9%) with moderate tinnitus; and only 3 (5.4%) with mild tinnitus. As to hearing symptoms, 35 patients (62.5%) reported no dysfunction; 8 (14.3%) complained of bilateral hearing loss; 7 (12.5%) complained of hearing loss in the left ear; and 6 (10.7%) presented with hearing loss in the right ear.

Table 1. Distribution of Distortion Product Otoacoustic Emission Examination Results, According to Studied Groups

Otoacoustic Emission	No. of Controls (%)	No. of Group 1 Subjects (%)	No. of Group 2 Subjects (%)
Altered	5 (3.6)	6 (18.8)	49 (61.3)
Normal	133 (96.4)	26 (81.2)	31 (38.7)
Total	138 (100.0)	32 (100.0)	80 (100.0)

Note: Chi-square test observed value = 92.76 (significant); critical value = 5.99.

The analysis of the three groups (controls, group 1, and group 2), according to the DPOAE results, showed an increased percentage of ears with DPOAE alterations in group 1 as compared to the control group (18.8% and 3.6%, respectively) and an even higher percentage in group 2 (61.3%; Table 1). The Chi-square test showed the presence of a significant relationship between otoemission classification and the studied groups. As to the distribution of DPOAE alterations depending on the side of the ear presenting with tinnitus, we observed that in the absence of any specific statistical test, owing to the low frequencies of some pairs (Table 2), when the tinnitus was bilateral, a higher percentage of bilaterally altered DPOAEs also occurred (44.8%). However, when referring to unilateral tinnitus, we observed less correspondence among the DPOAE results (25% on the right and 33.3% on the left).

Analysis of all the patients together revealed a coincidence between the side affected by tinnitus and the alterations in the DPOAE in 21 cases (13 bilateral, 3 on

Table 2. Distribution of Distortion Product Otoacoustic Emission Results, According to Side of Tinnitus Occurrence

Otoacoustic Emission	Bilateral No. (%)	Right No. (%)	Left No. (%)	Total No. (%)
Normal	8 (27.6)	3 (25.0)	8 (53.3)	19 (33.9)
Bilateral alteration	13 (44.8)	3 (25.0)	2 (13.4)	18 (32.1)
Right-side alteration	1 (3.4)	3 (25.0)	0 (0.0)	4 (7.1)
Left-side alteration	7 (24.1)	3 (25.0)	5 (33.3)	15 (26.8)
Total	29 (100.0)	12 (100.0)	15 (100.0)	56 (100.0)

Table 3. Distribution of Tinnitus Site, According to Studied Groups

Site	No. of Group 1 Subjects (%)	No. of Group 2 Subjects (%)	Total No. of Subjects (%)
Bilateral	7 (43.8)	22 (55.0)	29 (51.8)
Unilateral	9 (56.2)	18 (45.0)	27 (48.2)
Total	16 (100.0)	40 (100.0)	56 (100.0)

Note: Chi-square test observed value = 0.22; critical value = 3.84.

the right, and 5 on the left), totaling 37.5%. The analysis of hearing loss and the side revealing tinnitus showed no significant relation between the location of the tinnitus and the hearing level in the pure-tone audiometry (Table 3). Group 1 contained 43.8% cases of bilateral tinnitus and 56.2% cases of unilateral tinnitus. A higher percentage of individuals with bilateral tinnitus was observed in group 2 (55%).

DISCUSSION

Tinnitus

Establishing when tinnitus was first reported in the literature is difficult. Nevertheless, it is one of the most frequent complaints not only in an otolaryngologist's clinical practice but in general medical practice. The increase in the number of patients looking for medical assistance to cure or obtain relief from tinnitus is attributable to many reasons. Society's modernization may be the most important one. Noise exposure at factories and in big cities, more and more frequent owing to industrialization, is still a significant factor that leads to hearing losses, despite campaigns to heighten awareness of and protection against sound damage. Hearing loss is related to the origin of the tinnitus. However, modern life's stresses and their effect on an individual's humor and personality may increase anxiety and direct attention to a symptom that, without these aggravations, might be imperceptible. The use of ototoxic drugs (aminoglycosides, antineoplastic drugs, diuretics, etc.); inadequate diets (rich in carbohydrates and fats); and smoking and alcoholism are also contributing factors that influence cochlear metabolism and its micromechanisms. Another factor that may contribute indirectly to a rise in the number of tinnitus cases is the increase in the population's life expectancy. This study revealed a greater concentration of individuals whose age was in the forties and fifties, which agrees with the data obtained by other authors [4]. This can be explained by a greater incidence of presbycusis in this age group. A higher incidence in females (69.6%) was also observed.

Twenty-nine of the total pool of patients (51.8%) reported bilateral tinnitus. These data are similar to those obtained by Sanchez et al. [4], who reported 50% bilateral cases and an incidence of 69% in females. The higher percentage can be explained by a higher incidence of labyrinthine disease in females [5] and by their higher life expectancy in comparison with males. Systemic diseases, vascular diseases, noise exposure, and presbycusis itself affect both ears in a similar way, without a preference regarding side. This may be the reason for the higher incidence of bilateral complaints. The great number of patients who consider tinnitus to be of moderate (51.8%) to severe (42.9%) degree reflects their type of job. In a manner similar to that of other reference hospitals, most of the patients who seek help at the outpatient department have already been subjected to several kinds of treatment in other clinics, without satisfactory results.

DPOAEs and Tinnitus

The group presenting normal hearing (group 1) was chosen for direct comparison with the control group in relation to the influence of tinnitus on these emissions, with a special interest in the alterations that could be found, as both groups presented with hearing within normal limits (thresholds of 25 dB HL or less), and the symptom of tinnitus was the only factor that distinguished them. The presence of DPOAEs in patients with thresholds lower than 50 dB HL was established as a criterion for the definition of the second group (group 2); in those with thresholds higher than this, analyzing or accessing the value of the DPOAE data would be difficult or impossible, owing to a large influence of associated hearing deficits. Those in group 1, however, showed a percentage of altered DPOAE examination results (18.8%) higher than those in the control group (3.6%), and this difference is significant by the Chi-square test (see Table 1).

Taking into account that only tinnitus distinguished both groups and that the DPOAE examination specifically indicates the integrity of the external ciliated cells, we can assume a relation between this symptom and early cochlear alteration. This micromechanical cochlear alteration detected by DPOAE is not sufficient to modify the audiometric thresholds; even with high-frequency audiometry, the threshold change has not yet been demonstrated. Conversely, a great percentage of normal DPOAEs (81.2%) was found in this same group of individuals presenting with tinnitus complaints and normal audiometry results. As the examination only shows the external hair cells' membrane contraction ability, one may conclude that factors other than the integrity of the external hair cells are responsible for the generation of tinnitus.

One of the possibilities is that the DPOAE method's own sensitivity may not detect the minimum cochlear alterations needed to produce tinnitus but that, with the progress of the dysfunction, eventually the DPOAEs will be affected. Also, other cochlear dysfunctions, such as minimum alterations in the hair cells' electrochemical gradients or in synapses along the auditory pathway and in their neurotransmitters, are able to lead to a series of events that can be interpreted as tinnitus. They do not, however, affect the mechanisms of OAE generation.

A higher percentage of DPOAE alterations was observed in group 2 (61.3%) as compared to the other two groups. These differences were statistically significant by the Chi-square test (see Table 1). However, what must be considered is that sensorineural hearing loss may be caused by other mechanisms that do not produce alterations in the contraction activities of the external hair cells and that these different mechanisms may also generate or aggravate tinnitus.

In a study on DPOAEs due to hearing loss, Harris [6] observed alterations in DP amplitudes for the audiometric thresholds between 20 and 50 dB HL in fewer than 20% of cases. The data obtained in this study reinforce the relation between cochlear damage and tinnitus objectively demonstrated by OAE. The importance of the medial olivocochlear efferent system must be underscored. Damaged hair cells may receive a higher efferent stimulus from this system, which could affect adjacent areas with healthy hair cells, provoking their hyperactivity and resulting in tinnitus [7,8].

DPOAEs induced by contralateral acoustic stimulation may be a possible key for a better study of patients with tinnitus, as it is a method that evaluates specifically the efferent pathway. However, more investigations are required to test its real worth.

Table 2 shows an analysis of the relation between the alterations in the DPOAE examination and the side experiencing the tinnitus complaint. The low frequency of some matches does not allow for statistical analysis; however, a higher number of affected ears with altered DPOAEs were seen in the cases of bilateral tinnitus (44.8%). When the tinnitus is unilateral, few cases present with altered DPOAE examination (25% and 33.3%, respectively). Coincidence is seen in 21 of the 56 cases (37.5%: 13 bilateral, 3 on the right, and 5 on the left).

Therefore, in our opinion, the DPOAE examination proved to be useful in the evaluation of patients with this tinnitus, particularly when it is of cochlear origin.

The localization of the lesion involved in the production of tinnitus is extremely important for the treatment management. Although early alterations were detected, before altered pure-tone thresholds and, according to some authors, before high-frequency audiometric thresholds, DPOAE findings alone cannot explain all cases in an adequate manner. This is justified by the complexity and different levels of onset, from auditory pathway to cerebral cortex, of the different pathologies that cause tinnitus. We believe that the DPOAE examination is one more tool for otorhinolaryngologic and audiological diagnosis. It is capable of objectively characterizing a symptom that so often is subjective and multifactorial.

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