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ORIGINAL RESEARCH—OTOLOGY AND NEUROTOLOGY

Transient and distortion product evoked oto-acoustic emissions in normal hearing patients with and without tinnitus

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OBJECTIVE: To test the hypothesis that tinnitus begins with outer hair cell dysfunction by recording transient (TEOAE) and distortion product evoked (DPOAE) oto-acoustic emissions in patients with normal hearing with (study group, SG) and without tinnitus (control group, CG).

STUDY DESIGN: Case control study.

SUBJECTS AND METHODS: SG had 32 patients with pure tone thresholds below 25 dB in the 500 to 8000 Hz interval. CG had 37 age- and gender-matched patients with similar thresholds. All patients had normal tympanograms and stapedial reflexes. TEOAE were recorded with wide band click in continuous mode at 80-dB peak SPL. DPOAE were recorded with f1/f2 = 1.22 and intensities of 65 dB (f1) and 55 dB (f2) SPL.

RESULTS: DPOAE were abnormal in 68.4% of SG and in 50% of CG ($P = 0.036$). TEOAE were abnormal in 70.2% of SG and in 16.10% of CG ($P = 0.0001$).

CONCLUSION: SG had significantly higher prevalence of abnormal TEOAE and DPOAE than CG.

Subjective tinnitus refers to sound perception that occurs in the absence of an external stimulus.[1] It is a complex phenomenon, has many causes and is related to biological and psychological components.[2] According to Jastreboff[2] and Kaltenbach,[3] this symptom is generally related to noise exposure, aging, and hearing loss, but it can occur in normal hearing people.

Although tinnitus may be associated with abnormalities in any level of the auditory pathway, it very often starts in the cochlea.[1] Jastreboff[2] considers that tinnitus usually starts in the cochlea later and generates abnormal activity in the central pathways, which keeps the symptom alive. The central auditory pathways do not need to be structurally altered.

Simpson and Davies[4] stated that 85% of patients with tinnitus also have hearing loss, with 35% of them having moderate to severe auditory impairment. However, 10% to 15% of patients with tinnitus have normal auditory thresholds in the 250 to 8000 Hz test range.[5,6]

In our clinical practice, we quite often see patients who complain about tinnitus and are found to have normal pure-tone audiometry. A recent literature search showed a paucity of publications on this subject.

We hypothesized that tinnitus without hearing loss could be caused by changes in the outer hair cell (OHC) function that were not yet able to produce hearing loss. If this hypothesis is valid, transient-evoked (TEOAE) and distortion product evoked oto-acoustic emissions (DPOAE) should show the presence of OHC dysfunction in tinnitus patients with normal hearing. Consequently, the objective of the present study was to evaluate the function of the cochlear OHC by means of TEOAE and DPOAE in patients with tinnitus and normal hearing and compare this group of patients with an age- and gender-matched control group with normal hearing and no tinnitus. The results are reported in this article.

MATERIALS AND METHODS

This is a case control study processed from July 2003 to July 2005 in the Hospital de Base do Distrito Federal and in the Audiology Clinic of Hospital Santa Luzia in Brasília, DF, Brazil. The ethics Committee of the Health Department of the Government of the Federal District approved the study protocol before it was started.

The subjects were tested for TEOAE and DPOAE by the same investigator, who was blinded with respect to which subject had tinnitus. During the test session, subjects sat in

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Table 1
Percentage of normal and altered TEOAE tests according to S/N ratio and reproducibility

Test	Study group (N = 57)	Control group (N = 56)	P*
Normal	29.8%	83.9%	0.0001
Altered	70.2%	16.1%	

*χ^2 test.

an acoustically untreated test chamber where the noise level was maintained between 20 and 40 dB SPL; this was in line with the American Speech-Language-Hearing Association standards of 50 dB SPL for background noise levels.

A commercially available instrument (AuDx Plus, Biologic Systems Corp, Mundelein, IL, Brasilia/Distrito Federal) controlled by a personal microcomputer was used to test both TEOAEs and DPOAEs. The first ear to be examined was chosen randomly, but TEOAE testing always was performed first. TEOAE were performed with a wide band click in a continuous mode and with an intensity of 80 dB peak SPL. For measuring DP grams, the frequency separation of the primaries was f2/f1=1.22, with L1 and L2 set to 65 and 55 dB SPL, respectively.

The study group (SG) had 32 patients, 14 male and 18 female, 20 to 45 years old who complained of significant subjective tinnitus. The control group (CG) had 37 patients, 11 male and 26 female, aged between 20 and 45 years, without tinnitus.

Only patients who had normal audiometry (threshold below 25 dB HL at all frequencies from 250 to 8000 Hz), normal type A tympanometric curve, and present ipsi and contralateral stapedial reflexes were included. Any previous otologic disease detected in the patient's history determined exclusion of the patient from the study. In addition, neurologic diseases, acoustic trauma, vascular diseases, metabolic problems, ototoxic drugs used in the past, middle ear disease, previous ear surgery, history of vestibular problems, and recent aspirin intake were cause for exclusion.

The following parameters were considered in the TEOAE tests[7,8]: 1) signal-to-noise (S/N) ratio ≥6 dB in at least three of the four frequencies tested (1500, 2000, 3000, and 4000 Hz); 2) reproducibility of the responses of at least 70% in three of the four frequencies tested (1500, 2000, 3000, and 4000 Hz).

In the DPOAE the following parameters were considered for all frequencies tested[7,8]: 1) S/N ratio ≥6 dB in all frequencies tested; 2) amplitude of the signal in the 90th percentile of the normal distribution for the frequencies tested; 3) only the frequencies from 1000 to 8000 Hz were considered.

The statistical analysis was done considering the results in ears, not patients, because the results were independent between ears of the same individual. Commercial software (SPSS, v.13.0) was used. The level of significance considered was $P < 0.05$. χ^2 test was used to compare SG and CG with respect to abnormal results according to the above criteria; Spearman rank-order correlations were used to determine the correlation between TEOAE and DPOAE results in SG at individual frequencies. Only four TEOAE and DPOAE frequencies were correlated: 1500, 2000, 3000, and 4000 Hz.

RESULTS

The study group (SG) consisted of 57 ears from 32 patients. Fourteen were male (13 right and 12 left ears) and 18 were female (14 right and 18 left ears). Ages varied between 20 and 45 years (average, 36). The CG had 56 ears from 37 patients. Eleven were male (8 right and 8 left ears), 26 were female patients (19 right and 21 left ears). Age in this group varied from 20 to 41 years (average, 32).

SG had 57 ears tested because 7 of 32 patients had unilateral tinnitus. CG had 56 ears tested because 18 patients had one ear excluded (according to the exclusion criteria set up). There were no significant differences between the two groups with respect to gender and age. Mean duration of tinnitus in the SG was 7.2 years (standard error of the mean = 7.6). Tinnitus was bilateral in 78.1% (25 patients); 7 (21.9%) patients exhibited unilateral tinnitus; 5 (15.6%) had the symptom in the left ear; and 2 (6.3%) in the right ear.

TEOAE Results

TEOAE were abnormal in 70.2% of the patients in SG compared with 16.1% in CG. This difference was statistically significant ($P < 0.05$) as indicated in Table 1. The abnormal TEOAE in the SG were present for the 3000 and 4000 Hz frequencies mostly, while in the CG, the 1500 and 4000 Hz frequencies showed abnormalities more often. Table 2 shows the normal and abnormal TEOAE at each frequency tested in both the SG and CG. The difference

Table 2
Percentage of normal and altered TEOAE tests according to the frequencies evaluated in each group

Frequency (Hz)	Study group (N = 57) Normal %	Study group (N = 57) Altered %	Control group (N = 56) Normal %	Control group (N = 56) Altered %	P*
1500	47.4	52.6	64.3	35.7	0.070
2000	47.4	52.6	85.7	14.3	0.001
3000	31.6	68.4	91.1	8.9	0.001
4000	14.0	86.0	67.9	32.1	0.001

*χ^2 test.