Otoacoustic Emissions and Tinnitus in Normal Hearing

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ABSTRACT

Objective: To compare cochlear outer hair cells function in normally hearing patients with and without tinnitus.

Methods: Twenty four tinnitus patients were selected as a study group based on having normal hearing threshold levels in the frequency range between 750 to 6000 kHz. The control group consisted of 24 otologically normal subjects who have normal hearing threshold levels without tinnitus and were selected to match the study group by age and gender.

Results: Significant differences in distortion product otoacoustic emissions amplitude at $P< 0.05$ were found between the study group and the control group in the frequency range between 750 to 6000 Hz.

Conclusions: There is an association between tinnitus and reduced distortion product otoacoustic emission amplitudes indicating reduced cochlear outer hair cells function.

Key words: Cochlear outer hair cells activity, Normal hearing, Otoacoustic emission, Tinnitus

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Introduction

Tinnitus is a common, yet poorly understood disorder defined as a sound perception in the absence of external stimulus. This symptom is highly associated with hearing loss.[1] The association between tinnitus and hearing loss has been well described. According to different reports, 85 to 96% of patients with tinnitus present with some levels of hearing loss and only 8 to 10% have normal hearing. In this last group, the isolated presence of tinnitus suggests that it may be a primary symptom of diseases that are only diagnosed after the onset of hearing loss. The origin of tinnitus in this group is still more obscure than in those with concomitant hearing loss.[2]

Recent advances in the study of the cochlear mechanical process suggest that one source of tinnitus may be related to cochlear mechanical activity; damage to outer hair cells of the cochlea is believed to be one of principal mechanism of tinnitus. If the outer hair cells of the human cochlea are to be involved in the generation of tinnitus, testing of otoacoustic emissions could provide a reliable means of recording outer hair cells dysfunction.[3]

Otoacoustic emission (OAE) is a phenomenon that may occur in a large group of normal hearing subjects. This emission may be spontaneous or may be a response to given auditory stimuli transiently evoked otoacoustic emissions (TEOAE) and distortion product otoacoustic emissions (DPOAE). The primary purpose of otoacoustic emission test is to determine cochlear status, especially hair cell

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functioning. DPOAE is a type of otoacoustic emission in which the stimulus consist of two different pure tones at two different frequencies (i.e. F1 and F2; F2>F1) and two intensity levels (i.e. L1 and L2; L1>L2) the relationship between L1/L2 and F1/F2 dictates the frequency response. DPOAEs can be recorded with better reliability at higher frequencies than TEOAE. Therefore, it is useful for detection of cochlear damage.[4]

Patients with tinnitus and normal hearing constitute an uncommon group and there is rare literature on tinnitus cases with normal hearing, just a few papers studied tinnitus in normal hearing patients usually involving less than 20 cases.[5]

Shiomi *et al.* investigated the cochlear activity in nine tinnitus patients with normal hearing and 55 tinnitus patients with hearing loss using DPOAEs. Significant decreases in DPOAEs amplitude over a limited frequency range were observed in 93.3% of 14 ears of the normal hearing tinnitus group and in 96% of the 15 ears of the hearing impaired tinnitus group. The averaged DP-Gram of the normal hearing tinnitus group was significantly different from that of the normal subjects.[3]

Igna *et al.* studied the otoacoustic emission in patients with complaints of tinnitus and normal hearing, only 10 patients of the evaluated 104 patients with tinnitus met the inclusion criteria that were to have thresholds of 20 dB or less in each frequency at tonal audiometry. The results of their study showed that 60% had otoacoustic emission absent or lowered in one or more of the tested frequencies.[6]

Favero *et al.* studied the medial olivocochlear bundle effect in a group of 44 patients with tinnitus and 44 patients without tinnitus using DPOAEs, the results observed among subjects with and without tinnitus showed an association between absence of contra lateral suppression and presence of tinnitus at all tested frequencies studied. They concluded that there was a clear association between diminished effectiveness of the medial olivocochlear bundle and the presence of tinnitus.[7]

Vicky *et al.* studied a group of 306 tinnitus ears with and with out hearing loss; they found that DP-Gram amplitude in 94.8% of tinnitus ears with sensory neural hearing loss were lower than normal amplitude or was absent within a frequency range associated with elevated pure tone threshold. In 59% of cases with normal hearing and tinnitus, the amplitude of DPOAEs at frequencies near the tinnitus frequencies were decreased and there were no detectable SOAEs.[8]

Gouveris *et al.* compared the cochlear outer hair cell function in 32 ears with acute tonal tinnitus and normal hearing threshold, with 17 ears of normal hearing with out tinnitus; they found that tinnitus ears exhibited relatively increased amplitude of DPOAEs at higher frequencies (4-6.3kHz) when compared with the group of normal ears and relatively decreased DPOAEs amplitudes at middle frequencies (1650-2400 Hz).[9]

Granjeiro *et al.* compared the transient and distortion product otoacoustic emissions in patients with and without tinnitus and normal hearing, they found that DPOAEs amplitudes were smaller in 68.4% of the tinnitus group than in the control group in the frequency range 3000 and 4000 Hz.[10]

From the previous studies, it is clear that most of the studies compared tinnitus in groups of patients with and without hearing loss using different types of otoacoustic emission at limited frequencies (not all frequencies).

The present study is different from that as it is comparing cochlear outer hair cells function in normally hearing patients with and without tinnitus using diagnostic distortion product otoacoustic emission protocol at all audiometric testing frequencies ranged from 750-6000 Hz, in order to test the hypothesis that cochlear outer hair cells' function may be involved in the generation of tinnitus.

Methods

This is a retrospective study. Two groups of otologically normal subjects with no history of ototoxic, no otropic drug intake, no exposure to noise or any history of ear surgery, were included in the present study. The study group consisted of 24 patients with tinnitus and normal hearing threshold levels of both genders with an age range from 20 to 56 years. The control group consisted of 24 patients who have normal hearing threshold levels without tinnitus with an age range from 20 to 56 years to match the study group. Hearing threshold levels were considered to be within normal if they were less than 20 dB HL at all tested frequencies.

At the beginning of the study random selection of 60 patients with tinnitus of different ages groups and both sexes who were referred to the audiology department at King Hussein Medical Centre for audiological assessments was done. Assessments

were as follows:

1. Otoscopic examination: otoscopic investigation of the external and middle ear were carried out on each ear of 60 patients by Ear Nose and Throat specialist doctors to evaluate any disorders; of the 60 patients otoscopic examination revealed that there were 14 patients who had middle ear disorders. These disorders were otitis media with effusion in six patients; perforated tympanic membrane in eight patients. Those 14 patients were excluded from the rest of the assessments. The rest of the assessments were limited to the 48 patients who have had normal otoscopic examination.
2. Pure tone audiometery: hearing threshold levels measurements in the region of 750-6000Hz were carried out on each ear of the 48 patients using descending of 10dB step size and 5dB step size to determine the lowest hearing threshold levels at all tested frequencies. All measurements were carried out by a qualified audiologist in an isolated test booth using clinical diagnostic audiometer (Interacoustic type AC 40). Of the 48 patients, normal hearing threshold levels were found in 24 patients bilaterally defined as hearing threshold levels 20 dB HL or less; conductive hearing loss was found in four patients bilaterally and in six patients unilaterally; sensorineural hearing loss was found in four patients bilaterally and in two patients unilaterally; and high frequency hearing loss was found in eigh patients. Those 24 patients who showed different types of hearing loss were excluded from the rest of the assessments; therefore the rest of the assessments were limited to the 24 patients who have normal hearing threshold levels with tinnitus. The control group of 24 subjects included in the present study was otologically normal without tinnitus; never had any ear infection; nor exposed to noise or had any ear surgery. This control group underwent all assessments carried out on the study group including otoscopic examination, pure tone audiometry, tympanometry and distortion product otoacoustic emissions
3. Tympanometry: test of the middle ear function was carried out on each ear of the 24 patients using middle ear analyzer (Interacoustic); the findings revealed no abnormalities that may interfere with the accuracy of DPOAEs.
4. DPOAEs protocol DP-gram in the frequency range 750-6000Hz using Escourt system were recorded from each ear of the selected 24 patients with tinnitus (the study group) and 24 patients without tinnitus (the control group) who showed normal audiological findings. Recording were repeated twice to ensure the reliability of the results.

Results

Table I shows the mean hearing threshold levels and standard deviation of both groups, the study group with tinnitus (n=24) and the control group without tinnitus (n=20). There are some differences in the mean hearing threshold levels between the study and the control groups. The differences being in the size of 5 dB HL at all tested frequencies which are not significantly different at $P< 0.05$.

Table II shows the mean and standard deviation of distortion product otoacoustic emissions amplitude in dB of both groups. It is apparent that there are differences between the mean DPOAEs amplitudes of both groups, these differences being in the size of 10 dB at all tested frequencies.

Inferential Statistics

One way ANOVA test was used to calculate the significant differences at $P<0.05$ between the mean hearing threshold levels and the mean DPOAEs amplitude of the study and the control groups.

No significant differences in the mean hearing threshold levels between the two groups were noticed at all tested frequencies.

Significant differences in the mean DPOAEs amplitude at $P<0.05$ were noticed at all tested frequencies between the two groups, these differences being in the size of 10 dB.

Discussion

The results of the present study revealed significant decreases in the DPOAEs amplitude over the tested frequencies range in all tinnitus patients with normal hearing compared to non tinnitus patients with normal hearing. Hearing threshold levels did not significantly differ between tinnitus and non tinnitus normal hearing patients, but DPOAEs amplitudes of

Table I. Mean and standard deviation of hearing threshold levels of the study group and control group

Frequency(Hz)	Mean and SD of hearing threshold levels (dB) of the study group with tinnitus		Mean and SD of hearing threshold levels (dB) of the control group without tinnitus		Differences in the mean hearing threshold levels (dB) between the study and control group
	Mean	SD	Mean	SD	
750	18.37	4.44	13.25	5.83	5.12
1000	17.	4.38	11.25	4.77	6.25
2000	16.37	4.41	10.75	4.16	5.62
3000	19.5	3.54	15.75	4.16	3.75
4000	22.5	3.58	15.37	5.30	7.13
6000	19.12	4.15	13.25	5.83	5.87

Table II. Mean and standard eviation of distortion product otoacoustic emissions amplitudes (dB) of the study and control group

L1 dB	L2 dB	F1(Hz)	F2(Hz)	Gm(Hz)	DP-NF of the study group		DP-NF of the control group		Differences in DP means between control and study group
					Mean	SD	Mean	SD	
60.8	55.4	4686	5623	5133	4	0.7	16.2	0.14	12.2
65.4	55.3	3327	3983	3640	2.4	0.28	12.4	0.54	10
56.7	55.4	2343	2811	2566	4.8	0.14	13.2	0.56	8.4
65.9	55.4	1640	1968	1797	4.9	0.42	13.2	0.56	8.2
52.4	56.0	1171	1406	1283	6.4	0.28	16.2	0.14	9.8
51.0	47.3	843	1031	932	-6	0.28	4.2	0.28	10.2
61.4	54.9	609	750	676	-2.2	0.28	8.5	0.41	10.7

L1: intensity level of stimulus 1 L2: intensity level of stimulus 2 F1: frequency of stimulus 1
F2: frequency of stimulus 2 GM: frequency of distortion product DP: distortion product amplitude (dB)
NF: noise floor

tinnitus patients were significantly lower than normal patients, which implies that decrease of DPOAEs amplitudes may be related to the presence of tinnitus.

Our results are consistent with the results obtained by Shiomi *et al.*,[3] Igna *et al.*,[6] Fvaero *et al.*,[7] Vicky *et al.*,[8] and Granjeiro *et al.*[9] that there was a significant decrease in DPOAEs amplitudes over a limited frequency range observed in the normal hearing tinnitus group when compared to the non tinnitus normal hearing group. Even most of the previous studies showed that the decreased amplitudes of the DPOAEs were just in limited frequencies. This may be due to the protocol of testing used in each study, as some of the protocols may just screen for specific frequencies either at mid or high frequencies, whereas in our study we used the diagnostic protocol from 750-6000Hz.

In contrast our results do not agree with the results obtained by Gouveris *et al.*[9] stating that tinnitus ears exhibited relatively increased amplitude of DPOAEs at higher frequencies (4-6.3kHz) when compared with the group of healthy ears and relatively decreased DPOAEs amplitudes at middle frequencies. The discrepancy between our results and Gouveris *et al.* results may be due to the existence of an acute progressive lesion of the cochlea such as recruitment which is the abnormal growth of loudness as the intensity of sound increased, given that all in Gouveris *et al.*'s study group had acute symptoms, or could be that the increased amplitude of the DPOAEs in this precise frequency region stems from the fact that most of their patients perceived tinnitus at the 4-6kHz frequencies and hence that a primary lesion of the cochlea exists at this precise region, or any damage to the inner hair cells of the cochlea may result in the increased DPOAEs amplitudes.

Decreases in the DPOAEs amplitudes indicate dysfunction of the outer hair cells. This dysfunction may be due to the reduction in the outer hair cells activity which results from the imbalance between the external hair cells and internal hair cells. The external hair cells are more prone to damage and when it occurs, they fail to perform the inhibition over the inner hair cell function. This loss of inner

hair cells inhibition results then in tinnitus. Tinnitus in turn, which is an unpleasant sound, may act as a noise which resulted in a decrease of the DPOAEs amplitudes due to increase internal ear noises heard by the patients as ringing noises. This noise is one of the factors that result either in absence or decrease in DPOAEs amplitudes. In the presence of these results, tinnitus masker could be a good solution for the relief of annoyance resulted from tinnitus.

Conclusion and Recommendation

It can be concluded that there is an association between tinnitus and reduced cochlear outer hair cells activity which indicate that the outer hair cells of the cochlea are involved in the generation of tinnitus. Further research needs to be carried out on the effectiveness of tinnitus maskers used by this group of patients.

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