Comparison of the Transient Evoked Otoacoustic Emissions (TEOAEs) and Distortion Products Otoacoustic Emissions (DPOAEs) in Normal Hearing Subjects With and Without Tinnitus

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Abstract The aim of this study was to investigate the possible role of cochlear outer hair cell function with TEOAE and DPOAE tests in patients with normal hearing and tinnitus. 25 tinnitus patients with normal hearing sensitivity selected as study group. Control group consist of 50 normal hearing subjects without tinnitus. All subjects had thresholds below 25 dBHL at frequencies 250–8,000 Hz, tympanogram type A and normal acoustic reflex thresholds. TEOAE were recorded with click stimulus at 80 dB SPL at 1,000, 2,000, 3,000 and 4000 Hz. DPOAE were measured at frequencies 1,000–8,000 Hz and intensity of L1 55 dB SPL and L2 65 dB SPL. Amplitude of DPOAE and TEOAE were decreased in all frequencies in study group. There was significant difference regarding prevalence abnormal TEOAE and DPOAE between study group and control group. There was relationship between dysfunction of outer hair cells and tinnitus in subjects with normal hearing.

Keywords Tinnitus · Otoacoustic emission · Outer hair cell

Introduction

Etiological diagnosis, prognosis and treatment of tinnitus are still challenging in clinical practice. Tinnitus is a serious problem that is defined as a sense of sound without external stimuli. About 35 % of adults have had some experience with tinnitus [1]. Persistent tinnitus may rapidly become a source of serious disability at psychological, communicational and socio-professional levels [2] correlated with sleep disturbance, irritability, depression and anxiety [3]. Hearing dysfunction as the symptom of tinnitus is not yet physiologically understood and physiological alterations occur at various levels of the auditory pathway [4].

Tinnitus can be perceived out of a cochlear origin as in patients with acoustic neuroma or Meniere's disease. The origin of tinnitus can also be found in limbic tumor, involving other regions such as the upper cervical region. The most probable origin of the noise-induced tinnitus is the ear level [5]. The pathophysiology of tinnitus generally concerns neuroplastic changes in the central auditory system, probably initiated by some form of cochlear damage. There is a possible critical role for cochlea and outer hair cells (OHCs) in its pathogenesis as well [6–8].

Otoacoustic emissions (OAEs) test could provide a reliable means of recording of the outer hair cells human cochlea dysfunction in case of involvement of these cells in generation of tinnitus [9, 10]. OAEs are sound produced in the cochlea, detected in the outer ear canal. These emissions are recordings of the mobility and mechanical capacity of OHC [10]. Several authors investigated the

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possible relationship between tinnitus and OHC function by comparing OAEs in individuals suffering from tinnitus and normal hearing subjects [11].

Changes in the amplitude of distortion-product otoacoustic emissions (DPOAEs) and transiently evoked otoacoustic emissions (TEOAEs) have been reported in association with tinnitus in articles. In some studies, tinnitus patients were found to have lower DPOAEs [12] or lower TEOAEs [13, 14] comparing to non-tinnitus control individuals. Other studies reported increased DPOAE [15, 16] or TEOAE amplitude [17, 18]. Subjects involved in these studies showed differences in hearing thresholds, however, it was not clear if the observed abnormalities in DPOAEs and TEOAEs were a condition related to the development of tinnitus or due to the mismatch of hearing thresholds.

The Aim of this study was to examine the cochlear function in tinnitus subjects with normal hearing sensitivity by TEOAE and DPOAE to evaluate the function of cochlear and outer hair cells.

Materials and Methods

This was a case–control study performed from March 2013 to April 2014 at the audiology clinic of Besat hospital of Hamedan University Medical Sciences & Health Services. The study group included 25 patients (13 males and 11 females) with the average age of 33/12 with tinnitus and normal hearing that time course of tinnitus was more than 30 days. The control group composed of 50 persons (26 males and 24 females) without tinnitus and with normal hearing. Two group matched by gender and age.

The followings are the exclusion criteria of the subjects in the present study: history of middle ear disease, acoustic trauma, vestibular problems and any previous otologic disease and using ototoxic drugs. A battery of audiological tests consist of otoscopic examination, pure tone audiometry and impedance audiometry was performed for inclusion.

In pure tone audiometry, only patients who had thresholds below 15 dB HL at 250–8,000 frequencies were included. Tympanometry as a test of middle ear function was carried out on each ear of subjects. Subjects with type A tympanometry and present stapedial muscle reflex were included.

The following parameters were considered for TEOAE: stimulus was click with intensity of 80 dB SPL, S/N 6 dB in at least 3 of 4 frequencies. DPOAE were performed at frequencies 1,000–8,000 Hz and I1 = 55 dB SPL, I2 = 65 dB SPL, S/N 6 dB at all frequencies. Noise level was less than 40 dB SPL.

Results

The result of this study showed 20 patients had tinnitus in one ear (11 patients in right ear and 9 patients in left ear) and five patients in both ears. Also females had greater amplitude in TEOAE and DPOAE but there was no significant difference regarding gender and age between the two groups. The TEOAE in 94 % control group and 76 % study group was normal with no significant difference between the two groups ($p = 0.024$). The DPOAE in 88 % control group and 64 % study group was normal and the difference statistically was significant ($p = 0.014$). According to our results, mean amplitude TEOAE and DPOAE in control group were greater than study group but this difference statistically was not significant. Table 1 shows that the difference in the amplitude of DPOAE in

Table 1 Mean and standard deviation of TEOAE and DPOAE in SG and CG in patients with tinnitus in RE

	Group	Mean	SD	P value
TEOAE1000right	Case	7.4545	5.17694	.945
	Normal	7.5864	5.04450	
TEOAE2000Right	Case	3.2545	5.56136	.363
	Normal	5.3227	6.28800	
TEOAE3000Right	Case	−0.4909	7.91018	.132
	Normal	3.4455	6.36080	
TEOAE4000Right	Case	−10.9455	5.23400	.070
	Normal	−6.8864	6.11838	
DPOAE988Right	Case	4.6336	7.56462	.998
	Normal	4.6391	6.64590	
DPOAE1481Right	Case	3.2836	11.05520	.362
	Normal	6.3027	7.55793	
DPOAE2222Right	Case	−0.4136	5.95799	.280
	Normal	2.6164	8.07786	
DPOAE2963Right	Case	0.0218	4.57976	.400
	Normal	2.3209	8.28098	
DPOAE44444Right	Case	0.6745	7.08978	.007
	Normal	9.0482	8.20577	
DPOAE5714Right	Case	−2.4009	9.17706	.165
	Normal	2.1868	8.51393	
DPOAE8000Right	Case	−7.6650	13.89904	.292
	Normal	−3.1559	9.51790	

Table 2 Mean amplitude and standard deviation of TEOAE and DPOAE in patients with tinnitus in RE

	Group	Mean	SD	P value
TEOAEright	Case	−0.7273	20.18733	.198
	Normal	9.4682	21.35022	
DPOAEright	Case	−5.2120	36.62119	.069
	Normal	23.9582	42.21113	

Table 3 Mean and standard deviation of TEOAE and DPOAE in SG and CG in patients with tinnitus in LE

	Group	Mean	SD	P value
TEOAE1000Left	Case	3.5222	4.2961	.208
	Normal	5.9522	4.73921	
TEOAE2000Left	Case	−.1111	4.80532	.228
	Normal	2.2056	4.49110	
TEOAE3000Left	Case	−2.7467	7.49277	.174
	Normal	0.8839	5.74766	
tTEOAE4000Left	Case	−11.0000	6.64336	.164
	Normal	−7.3278	5.74454	
DPOAE988Left	Case	−0.5800	9.26723	.015
	Normal	6.6344	5.25132	
DPOAE1481Left	Case	2.4078	6.09805	.110
	Normal	6.3656	5.73302	
DPOAE2222Left	Case	−2.6256	7.98444	.218
	Normal	0.8128	5.94960	
DPOAE2963Left	Case	−4.7944	7.50614	.379
	Normal	−2.1894	6.94698	
DPOAE4444Left	Case	2.0222	6.29958	.071
	Normal	7.1772	6.87581	
DPOAE5714Left	Case	−4.8556	9.82148	.278
	Normal	−.7328	8.74576	
DPOAE8000Left	Case	−9.3378	8.68786	.378
	Normal	−5.9872	9.34130	

Table 4 Mean amplitude and standard deviation of TEOAE and DPOAE in patients with tinnitus in LE

	Group	Mean	SD	P value
TEOAEleft	Case	−10.8900	22.07498	.095
	Normal	1.7139	14.52034	
DPOAEleft	Case	−17.7633	39.11941	.041
	Normal	12.0806	31.16974	

4,000 Hz and the mean amplitude of DPOAE in control group and study group patients with tinnitus in right ear is significant ($p = 0.004$). There was no significant difference regarding mean amplitude of TEOAE in this group. Also the mean amplitude of TEOAE and DPOAE in patients suffering from tinnitus in right ear was not significantly different (Table 2). In patients with tinnitus in left ear, amplitude of DPOAE in all frequencies was greater than control group but this difference was not statistically significant (Table 3). Mean amplitude of DPOAE in study group and control group was statistically significant in patients with tinnitus in left ear (Table 4). There was a significant difference between mean amplitude of TEOAE in left ear in patients who had tinnitus in both ears ($p = 0.008$) (Table 5).

Table 5 Mean amplitude and standard deviation of TEOAE and DPOAE in patients with tinnitus in both ears

	Group	Mean	SD	P value
TEOAEright	Case	−5.7600	17.40928	.075
	Normal	15.2730	20.82373	
TEOAEleft	Case	−23.0000	20.73741	.008
	Normal	8.7580	17.73077	
DPOAEright	Case	3.9560	17.26947	.460
	Normal	16.1950	33.32656	
DPOAEleft	Case	−19.1980	18.62808	.150
	Normal	10.1560	40.23637	

Discussion

Numerous hypotheses regarding mechanism of tinnitus generation have been suggested [19]. However, there is not an agreed upon model or hypothesis explains the presence of tinnitus in all patients. Therefore, multiple mechanisms may be present in a single individual with tinnitus [2–4]. The results of the present study revealed that there was normal TEOAE in 94 % control group and 76 % study group and DPOAE was normal in 88 % control group and 64 % study group. These differences were statistically significant.

These results were in agreement with Granjeiro, Thabet and Igna, reporting significant decrease in DPOAE amplitude of normal hearing tinnitus group when compared to the non tinnitus normal hearing [20–23]. The results of the present study revealed no significant difference regarding mean amplitude TEOAE and DPOAE in control group and study group, but mean amplitude TEOAE and DPOAE in control group were greater than study group.

Our results are in accordance with the results obtained by Granjeiro and Assaf in which the differences in distortion product of otoacoustic emissions amplitude at $P < 0.05$ between the study group and the control group were found to be significant [9, 24].

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 and internal hair cells. In contrast, our results do not agree with the results obtained by Sztuka and Gouveris that state greater amplitude of DPOAE at higher frequencies (4–6.3 kHz) and relatively decreased DPOAEs amplitudes at middle frequencies in patients with tinnitus in comparison to those without tinnitus [25]. The discrepancy between our results and the mentioned studies could be due to the existence of recruitment, which is the abnormal increase of the loudness as the intensity of sound, or any damage to the inner hair cells of the cochlea resulting in the

increased DPOAEs amplitudes. Increased mobility of outer hair cells may be induced by decreasing efferent fiber activity but not by outer hair cell failure.

According to the results of this study there was significant difference between mean amplitude of TEOAE and DPOAE in patients who had tinnitus in left ear and thus, there was significant difference about mean amplitude of TEOAE of left ear in subjects with tinnitus in both ears. It is recommended to investigate the correlation between location of tinnitus and amplitude of TEOAE and DPOAE in future studies.

Conclusion

In conclusion, our results could provide the evidence for an association between tinnitus and the reduced cochlear outer hair cells activity, which show that the outer hair cells of the cochlea are involved in the generation of tinnitus. Following the possible role of OHC damages or dysfunction of the cochlear efferent system in tinnitus subjects, detailed analyses on the effectiveness of tinnitus maskers used by this group of patients are necessary in future studies.

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