Otoacoustic Emission in Tinnitus Patients
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The purpose of the study was to determine the effect of tinnitus and total effect of tinnitus and the hearing loss function on the distortion product otoacoustic emission. Tinnitus patients were selected to exhibit normal hearing and such tinnitus patients who exhibited the increasing or notch-like sensorineural hearing loss. It was found that the cochlear hearing activity expressed in terms of DPOAE response differed between tinnitus patients and normal-hearing subjects. The DPOAE levels in the tinnitus patients with normal hearing threshold have been lower than those in the nontinnitus subjects. The differences depended on the frequency and the age of the patients suggesting the effect of presbyacusis.

1 Introduction

There have been only a few, not always consistent reports on tinnitus and otoacoustic emissions (OAEs). For example, the distortion product otoacoustic emissions (DPOAEs) level in the tinnitus patients showing normal hearing have been reported to be lower or higher than those in normal-hearing (without tinnitus) [14, 15, 17]. Some authors suggest that in tinnitus patients with sensorineural hearing loss either a decrease or an increase in the DPOAE amplitudes may be found [10, 9]. It is known that increasing hearing loss in nontinnitus patients is usually associated with a decreasing magnitude of the DPOAE response, which tends to zero for large losses [6, 7, 11, 13]. But so far it is not well established what is a relation between tinnitus and DPOAEs and what is the effect of the shape of hearing loss function on the DPOAE response. Thus, the basic aim of the present study was to estimate the effect of tinnitus alone (Experiment I) and combined effect of tinnitus and hearing loss function on the DPOAE level (Experiment II).

2 Methodology

2.1 Patients

Tinnitus patients who exhibited normal hearing (TNH) according to ANSI standard [1] were selected for experiment I. Keeping in mind the effect of age on the DPOAE [12, 16] those patients were divided into two age groups: tinnitus normal hearing - age ≤50 years (TNH≤50) and tinnitus normal hearing - age ≥50 years (TNH>50). The age of the normal hearing subjects determined as a normal-hearing group ranged between 23 and 36 years. Tinnitus patients who exhibited sensorineural hearing losses, participated in Experiment II. Two classes of sensorineural hearing losses were distinguished: increasing and notch-like. All hearing losses were cochlear in origin and stable. Before DPOAEs data had been collected basic audiometric and middle-ear testing were performed. The audiometric testing comprised measurements of hearing thresholds and bone conduction thresholds. The middle-ear testing concerned the basic otology examination, immittance measurements and tympanometry.

2.2 Procedure

The DPOAE measurements for tinnitus ears were made with a Bio-logic System. The stimuli were delivered to the ear canal via Etymotic ER-2 transducers and the ear canal sound pressure was measured using an Etymotic ER-10B microphone. The DPOAE frequency functions (DPgrams) were collected in response to pairs of primary tones (f₁ and f₂; f₂/f₁ = 1.22), at one-eighth octave steps, in the f₂ frequency range from 1.5 to 10 kHz. DPOAE level was determined as the level of the 2f₁-f₂ component. Primary tones were presented at the sound pressure levels of L₁ = 65 dB SPL and L₂ = 55 dB SPL.

3 Experiment I. Tinnitus and DPOAE

Figure 1 presents averaged DPOAE responses in two age tested groups. The solid lines correspond to DPgrams for tinnitus patients, the broken lines to normal-hearing subjects (nontinnitus group) and thin dotted lines represent the levels of the noise floor. As can be seen despite the similarity in audiograms for the normal and TNH groups, differences in the DPOAE levels between those groups are seen within the whole frequency range. A clear level difference of the order of 6 dB SPL appears at 2; 3 and 5 kHz. To characterize the DPOAE decrease, the slope s=[DPOAE level]/[Δf] was calculated for frequency range (Δf). Between 1.5 and 3 kHz, the DPOAE level exhibited a continuous decrease from 5 to –6 dB, that is by 11 dB, which corresponds to the slope of about 0.007dB/Hz.
4 Experiment II. Tinnitus combined with hearing loss and the DPOAE response

Experiment II was undertaken to assess the effect of hearing loss on the DPOAE response in tinnitus ears. The effect of increasing hearing loss on the DPOAE revealed that the DP level decreases from about 4 to –16 dB (Fig. 2 B) within the range to 3 kHz, where hearing loss versus frequency systematically increases up to about 38 dB HL (Fig. 2 A). Further increase in hearing loss above 38 dB HL (up to 60 dB HL) does not cause a decrease in the DPOAE level, however, the DPOAE could still be recorded on the level around -16 dB SLP. According to Figs. 2 A and 2 B, hearing sensitivity and DPOAE level decrease within the frequency range ∆f =1.5 – 3 kHz about 17 and 20 dB, respectively. That corresponds to the slope s equal to 0.0113 and 0.0133 dB/Hz. The DPOAE slope is about 12% greater than the slope of hearing loss function. In this case the DPOAE slope is about 14% greater than the slope of the hearing loss function. These data show that for increasing hearing loss, if the slope of hearing loss function diminishes in the frequency range of interest, the slope s of the DPOAE response also decreases and is slightly steeper.

The DPOAE responses for tinnitus groups showing notch-like hearing loss are generally similar and reproduce quite well the hearing loss functions in the notch frequency region. The hearing sensitivity, starting from 1.5 kHz, systematically decreases versus frequency reaching at 4 kHz its minimum of 40 dB HL. Above 4 kHz up to 8 kHz, the hearing sensitivity increases by about 13 dB (Fig. 2 C). Similar courses are shown by the DPOAE responses. The DPOAE levels from 2 kHz systematically decrease reaching their minima about -17 dB, in the range 3-4 kHz. Next the DPOAE level increases by about 12 dB with frequency increasing to 8 kHz (Fig. 2 D). The slope calculation, similar as for increasing hearing loss was made for the left and right parts of the notch of hearing loss function and the DPOAE response. According to Fig. 2 C, the decrease in the left part of the notch (between 2-4 kHz) and an increase in the right part of the notch (between 4-7 kHz) of hearing loss function amounted to 23 and 12 dB HL. They correspond to the slope s of 0.0115 and 0.004 dB/Hz, respectively. It means that the slope of the notch on the low-frequency side is about three times greater than on the high-frequency side.

The calculation performed for the DPOAE notch have shown that for the left part of the notch, a level decrease (counted within the range of 1.5-3 kHz) is 18 dB and for the right part, a level increase (counted within the range of 4-7 kHz) is 12 dB SLP. The slopes s of the DPOAE notch branches correspond to 0.012 and 0.004 dB/Hz, thus almost the same values as for the hearing loss function. This indicates that the notch shape of the DPOAE reflects quite well the hearing loss notch.
Fig. 2. Two types of the hearing loss functions (audiograms): increasing and notch like (A, C) and the corresponding DP-grams (B, D) averaged across the tinnitus patients aged up to 50. Solid lines show the audiograms and DPgrams for the tinnitus patients and broken lines show the audiograms and DPgrams for the normal-hearing subjects (control group). The courses of noise floor are depicted with thin dotted lines. Vertical bars specify the standard deviation.

5 DISCUSSION

The data from Experiment I have shown that the DPOAE level decreases in the tinnitus ears with clinically normal-hearing when compared to the DPOAE level in normal-hearing (nontinnitus ears). These findings suggest that in ears without and with tinnitus some different cochlear signal processing might take place. For the tinnitus patients with clinically normal hearing, the DPOAE is found to be quite sensitive to the aging process. This is in agreement with [12, 2, 16] findings who also reported an age effect on the DPOAE response for the higher frequencies. The decrease in DPOAEs with increasing age of tinnitus patients is also in agreement with the effect of aging on the spontaneous otoacoustic emissions (SOAEs) and transiently evoked otoacoustic emissions (TOAEs) [4, 5]. Other reports, however, fail to support the DPOAE-age related dependence. For example, [18] found that DPOAEs were related to hearing sensitivity and frequency, but not to age.

The results of Experiment II clearly show a decrease in the DPOAEs in tinnitus ears exhibiting hearing losses. It is consistent with the general finding presented in other papers reporting that the DPOAE level is reduced in ears with hearing loss [6, 7, 8, 13, 19]. However, it is not in agreement with [9, 10] findings who show that in tinnitus patients with sensorineural hearing loss the DPOAE responses are nonuniform. In some tinnitus ears they tested, the DPOAE level decreased with increasing hearing loss. The other ears, however, exhibited a poor or even inverse relationship between the DPOAE level and the hearing loss, i.e., displayed a surprising increase in the DPOAE level with increasing hearing loss. They assumed that in those ears a reinforced mechanical distortion was generated by cochlear hypothetical hyperactivity being a source of the DPOAE and the tinnitus.

If one assume that a decrease in the DPOAE level with increasing hearing loss in tinnitus ears is caused by OHCs dysfunction, it implies that the OHCs are probably not the only source of tinnitus. Perhaps some contribution to tinnitus generation comes from the hyperactivity of the efferent neural system. Since this system affects cochlear function, its improper activity may lead to mechanical overstimulation of the cochlea resulting in tinnitus. Attias et al. [3] studying noise-induced tinnitus found that TEOAEs evoked by contralateral noise were less suppressible or even increased, what was interpreted as efferent dysfunction.

6 CONCLUSIONS

- The DPOAE level in the tinnitus patients with clinically normal hearing thresholds has been found lower than that in the normal-hearing subjects (without tinnitus). The level difference changes versus frequency and depends on the age of the patients.
- The DPOAE responses measured for the tinnitus ears with increasing and notch-like hearing losses reflect the shape of the hearing loss functions up to about 40 dB HL.

ACKNOWLEDGMENTS

This work was supported by grant from the State Committee for Scientific Research (KBN) No 2 P05D 122 26 and grant from A. Mickiewicz University.

References


