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Otoacoustic emissions and effects of contralateral white noise stimulation on transient evoked otoacoustic emissions in diabetic children

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SUMMARY

Objective: In this study, our aim was to determine presence of dysfunction in the efferent auditory system of children with type-I diabetes mellitus (DM) presenting no evidence of symptomatic neuropathy.
Methods: Thirty children with type-I DM (DM group) and 31 age matched healthy children (control group) with normal hearing and middle ear function were entered to the study. Distortion product otoacoustic emissions (DPOAE), transiently evoked otoacoustic emissions (TEOAE), and spontaneous otoacoustic emissions (SOAE) measurements were performed. Then, the TEOAE recording was repeated while a continuous broadband white noise (bandwidth: 50–8000 Hz) presented at 40 dB SL was delivered to the contralateral ear for efferent auditory system suppression.
Results: We found that contralateral stimulation (CS) with white noise resulted in significantly more pronounced suppression of the TEOAE response amplitude in healthy controls compared to DM group at 2000 and 4000 Hz frequencies. Further, a relatively higher percentage of the controls had suppression in at least three frequencies compared to DM group. SOAE prevalence was found to be higher in the DM group.
Conclusions: Our findings suggest presence of a dysfunction in medial olivocochlear efferent system in diabetic children. This may be regarded as an early central manifestation of diabetic neuropathy.

1. Introduction

Otoacoustic emissions (OAE) are sounds recorded in the external ear, generated by the outer hair cells [1]. However, presentation of a sound ipsilateral or contralateral to a normal ear from which otoacoustic emissions are being recorded reduces or suppresses the amplitude of the OAE. Sound-induced suppression of OAE is a normal phenomenon mediated by the efferent auditory system [1]. Medial efferent fibers (medial olivocochlear bundle (MOCB)) originate in the medial nuclei of superior olivary complex. The large myelinated fibers of the bundle project mainly contralaterally to synapse at the base of the outer hair cells [1–4]. Activation of the bundle via contralateral acoustic stimulation results in inhibition of cochlear activity mostly via outer hair cells. Lack of contralateral suppression (CS) is a pathologic finding implicating dysfunction of the efferent auditory system [1].

Diabetes mellitus (DM) is a heterogeneous group of metabolic disorders characterized by chronic hyperglycemia with disturbances of carbohydrate, fat, and protein metabolism resulting from defects in insulin secretion, insulin action, or both. The effects of DM include long-term damage, dysfunction, and failure of various organs, especially the eyes, kidneys, heart, and blood vessels [5]. Although symptomatic neuropathy is uncommonly seen in children and adolescents with DM, sensory and autonomic motor nerve impairment can be demonstrated in young people [6].

In this study we aimed to determine whether there is a dysfunction in the efferent auditory system of the children with type-I DM presenting no evidence of symptomatic neuropathy.

2. Materials and methods

This study was performed in a prospective and blind manner, as the audiologist (the first author of the study) who performed the

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tests was blinded about whether the children were healthy or diabetic. Children with family history of hearing impairment, congenital defects of the ear and craniofacial skeleton, presence of otitis externa or otitis media, history of noise exposure, head trauma, ototoxic drugs, any medication currently known to affect cochlear, auditory afferent or efferent function, and any metabolic diseases other than DM were not referred to the audiology department.

Totally 61 children with normal hearing entered the study. The study group consisted of 30 (M/F: 11/19) children with type-I DM (60 ears; age range 6–16 years; mean age: 11.0 ± 2.8 years), which were diagnosed and in follow-up of pediatric endocrinology department. Control group included 31 (M/F: 15/16) age matched healthy children (62 ears; age range 6–16 years; mean age: 10.1 ± 2.2 years), which were recruited by the same doctors (the sixth and seventh authors).

After approval of the ethical committee of the hospital was obtained, a full verbal and written explanation of the study was given to all parents and children before entering the study group. All children had clear ear canals and normal tympanic membrane appearances prior to tests as determined by otoscopic evaluation.

First, tympanometry was performed using an Audio-med SAT 30 acoustic impedancemeter. The children with abnormal tympanograms according to the Jerger classification [7] were excluded from the study. Then, all audiologic tests were carried out in a double-walled sound-proof room. For the pure tone and speech audiometry tests, an 'Interacoustics AC 40 Clinical Audiometer' was used together with TDH–39 headphones between 125 and 6000 Hz. The subjects with pure tone audiometric thresholds (250, 500, 1000, 2000, 4000 and 6000 Hz) lower than 30 dB HL and speech discrimination scores better than 80% were included to the study.

Otodynamics ILO92 software (software Version 5, Otodynamics Ltd.), an IBM compatible PC, an ILO sound card with amplifier were used to generate the click stimulus for spontaneous otoacoustic emissions (SOAE) and transiently evoked otoacoustic emissions (TEOAE). Using a small probe (otodynamics) coupled to the ear by a soft plastic tip the stimulus was delivered to the ear. Presence of SOAE in the 500–6000 Hz frequency region as well as the number of SOAE peaks and the amplitude of the most prominent SOAE were sought and noted. Recordings were performed bilaterally using the SOAE mode of the ILO92 device. As the criterion for the objective detection of SOAE peaks, we used the method reported by Penner et al. [8]. According to these criteria a spectral line was considered to be a local maximum if it exceeded the level of the adjacent two points, i.e. one point on each side of the spectral line. A maximum was considered an SOAE if it exceeded, by 3 dB or more, all peaks of the noise floor within 196.8 Hz (98.4 Hz to the right and left of the maximum peak). SOAE measurements from a 2 cm^3 syringe were made for 10 times in order to test the validity of this criterion and we observed that there were not any peaks that exceeded the noise floor by 3 dB.

TEOAE were measured by standard techniques using 1–5 kHz TEOAE quick menu in the same device. Click stimuli were produced by 80 μs rectangular electric pulses presented at 50 s^{-1} in the nonlinear mode of stimulation of intensity 75–85 dB SPL. The measurements were averaged after 260 responses and were only accepted when stimulus stability was better than 70% [9,10]. Then a continuous broadband white noise (bandwidth: 50–8000 Hz) presented at 40 dB SL corresponding to 70 dB SPL was delivered to the contralateral ear for efferent auditory system suppression and TEOAE recording was repeated. Contralateral white noise stimulus was produced by the same audiometer and delivered by insert ear phones (ear tone 3A 10 Ω 410–3010). The mean TEOAE amplitude (dB SPL) and the amplitudes and reproducibility scores from 800 Hz width frequency bands centered at 1000, 1500, 2000, 3000, and 4000 Hz with and without contralateral white noise stimulus were used as TEOAE parameters in decibels for statistical analysis. The difference in dB SPL between two TEOAE recordings was calculated by subtracting the TEOAE value obtained in the presence of noise from the TEOAE waveform collected under the quiet condition. Therefore, suppression is indicated by positive values. When suppression was present in three or more frequencies, we accepted that TEOAE was suppressed by the given noise (full suppression ratio, FSR).

The distortion product otoacoustic emissions (DPOAE) measurements were performed by the same ILO device in the sound-proof room. Adequacy of probe fit was inspected prior to the commencement of data acquisition for DPOAE testing. A series of simultaneous pure tone pairs, of frequencies f1 and f2 (f2/f1 ratio: 1.22) at intensities of 70 dB SPL were delivered to the test ear to produce a DP-gram. The emission at 2f1–f2 was the distortion product measured. Distortion product response amplitude and noise floor across the range of frequencies corresponding to the following frequency values for f2: 1001, 2002, 3003, 4004, 5005, and 6006 Hz were recorded.

As clinical parameters related to DM, mean duration of disease, and *glycosylated* hemoglobin (HbA1c) blood levels were registered.

Chi-square test was used to compare DM and control groups regarding gender and the presence of SOAE. The normality of the emission and suppression variables was analyzed by Kolmogorov–Smirnov test. Student's *t*-test (in case of normal distribution) or Mann–Whitney *U* test (in case of non-normal distribution) was used to compare the emission and suppression parameters between the DM and control groups. Pearson correlation test was used to seek correlations of emissions and suppression variables with mean duration of disease and HbA1c blood levels. *P*-value lower than 0.05 was required for statistical significance.

3. Results

No significant difference regarding gender and age were found between the DM and control groups (χ^2 test, $P > 0.1$). In DM group, the mean duration of disease was 156 ± 130 weeks and HbA1c blood levels of children were 8.1 ± 1.5 units.

Pure tone audiometric thresholds in decibels of children with DM and the control group are presented in Table 1. The thresholds were marginally higher at all frequencies in DM than control group but the difference was not statistically significant ($P > 0.05$, Student's *t*-test). Thirty (M/F: 11/19) children with type-I DM control group included 31 (M/F: 15/16) SOAE were found in 27 out of 60 ears (45%) in the DM group and 20 out of 62 ears (32%) in control group ($P > 0.05$, Chi-square test). Although no difference was detected between males and females in the DM group regarding presence of SOAE, ears with SOAE were more frequently present in females than males in the control group ($P = 0.02$) (Table 2). The number of SOAE peaks and the mean amplitudes of the most prominent SOAE in children with diabetes (DM) and the controls are presented in Table 3. The total number of SOAE peaks

Table 1
Pure tone audiometric thresholds in decibels of children with DM and the control group.

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	6000 Hz
	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.
DM	13.6 ± 4.1	10.3 ± 3.8	7.3 ± 3.5	5.6 ± 3.7	7.5 ± 4.8	12.3 ± 7.0
Control	11.4 ± 5.4	9.0 ± 4.5	7.0 ± 4.2	4.9 ± 3.4	6.0 ± 4.3	11.8 ± 6.4
P^*	ns	ns	ns	ns	ns	ns

ns: nonsignificant.
* Student's *t*-test.