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FACULTY OF SPECIAL EDUCATION
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THE ROLE OF OTOACOUSTIC EMISSIONS IN AUDIOLOGICAL ASSESSMENT OF CHILDREN WITH SUSPECTED HEARING LOSS

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Introduction: *Otoacoustic emissions are sounds that result from energy generated in the cochlea. The otoacoustic emissions test helps to confirm outer hair cell function.*

Aim: *The objective of the study was to evaluate the expression of distortion product otoacoustic emissions in children with suspected hearing loss.*

Method: *This retrospective study included 115 children, 65 males (56.5%) and 50 females (43.5%), aged 0 to 14 years (mean age of 6.9±3.5 years), examined during the period from January 2017 to March 2021. The audiological assessment included Distortion product otoacoustic emissions test, tympanometry, and pure-tone audiometry in children older than 4 years. Distortion product otoacoustic emissions were recorded in the form of DP-gram elicited by two primary tone stimuli L1=65 dB SPL and L2=55 dB SPL. Levels of the 2f1-f2 distortion product otoacoustic emissions were registered at frequencies from 1000 Hz to 8000 Hz at four points per octave. For statistical data analysis we used Chi-square test with level of significance p<.05.*

Results: *From the total of 81 children with tonal audiogram, 13 children (16%) had sensorineural hearing loss with mean distortion product otoacoustic emissions amplitude -7.4 dB SPL, and 68 children (84%) had normal hearing with mean DPOAE amplitude 9.9 dB SPL. In children without tonal audiogram, distortion product otoacoustic emissions were present in 23 children (67.6%) at control examination after absence during middle ear pathology and 9 children (26.5%) at first examination. Otoacoustic emissions were absent in 2 children (5.9%) without middle ear pathology. They were mostly absent at frequency of 4000 Hz (p=.036).*

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Conclusion: *The otoacoustic emissions test is good cross-check for pure-tone audiometry. In children with sensorineural hearing loss, the otoacoustic emissions are absent in the range of hearing loss. In young children not cooperative for pure-tone audiometry, expression of otoacoustic emissions after previous absence during middle ear pathology would indicate that there is no coexistent sensorineural hearing loss.*

Keywords: *otoacoustic emissions, children, hearing loss*

INTRODUCTION

Otoacoustic emissions (OAEs) are sounds that result from energy generated in the cochlea that are propagated through the middle ear and into the ear canal where they can be measured using a sensitive microphone (Prieve & Fitzgerald, 2015). Two primary methods of eliciting otoacoustic emissions are used clinically: distortion-product (DPOAE) and transient-evoked (TEOAE). In DPOAE, two tones are presented at different levels and frequencies. The relationship between their frequencies is selected to elicit a response in the cochlea at a third frequency, where the DPOAE occurs. Different combinations of frequencies prompt responses from different frequency regions of the cochlea (McCreery, 2013). TEOAEs are elicited by brief stimuli such as clicks and provide information about outer hair cell integrity across a broad range of frequencies (Mertes & Goodman, 2013).

OAE test is employed as initial screening method in newborn screening programs (Akinpelu et al., 2014). Both DPOAEs and TEOAEs can be considered also as a procedure of choice for hearing screening in school-aged children (Vasconcelos et al., 2008). Whereas TEOAEs more qualitatively assess cochlear function, DPOAEs provide quantitative information about the range and operational characteristics of the cochlear amplifier, i.e. sensitivity, compression, and frequency selectivity (Janssen et al., 2006).

The presence of robust evokeable OAEs across the key speech frequency range indicates a useful degree of normal function in both the middle ear and cochlea. The absence of OAEs without middle ear pathology or acoustic obstruction strongly indicates sensory transmissive hearing loss. Depending on the type and intensity of stimulation, OAEs can reveal threshold elevation as small as 20 dB HL (Kemp, 2002). In an absent OAE response, there is less than 6 dB of separation between the OAE response and the noise, which is measured at an acceptably low level (Smith & Wolfe, 2013).

Expression of DPOAEs is significantly affected not only with presence of middle ear fluid, but also in cases of negative middle ear pressure without hearing loss (Ristovska et al., 2017). Pathologies that alter the impedance of the middle ear consecutively modify the OAE amplitude (Campos et al., 2016). Even when the middle ear departs only slightly from its optimal transmission, in the absence of any detectable conductive hearing loss, OAE can reflect middle ear impedance changes (Avan et al., 2000).

AIM

The objective of the study was to evaluate the expression of DPOAEs in children with suspected hearing loss, both children cooperative and not cooperative for pure tone audiometry.

METHOD

This retrospective study included a sample of 115 children, 65 males (56.5%) and 50 females (43.5%), aged 0 to 14 years (mean age of 6.9±3.5 years), examined at the Department of Otorhinolaryngology, Division of audiology, City General Hospital "8th September", Skopje, Macedonia, during the period from January 2017 to March 2021. The audiological assessment included DPOAE test, tympanometry, and pure-tone audiometry in children older than 4 years. DPOAEs were recorded with OAE device MADSEN Capella[2] (GN Otometrics, Denmark) in the form of distortion product audiograms (DP-gram) elicited by two primary tone stimuli L1=65 dB sound pressure level (SPL) and L2=55 dB SPL. The frequency ratio was adjusted to f1/f2=1.22. Levels of the 2f1-f2 DPOAEs were registered at frequencies from 1,000 Hz to 8,000 Hz at four points per octave. A total of 13 points were recorded in each ear. DPOAE was considered to be measurable if its amplitude was at least 6 dB above the noise level and minimum -5 dB SPL. Pure tone audiometry was performed with MADSEN Astera[2] audiometer (GN Otometrics, Denmark) and Senheiser HDA 300 circum-aural headphones (Senheiser, Germany) in sound proof booth. Tympanometry was performed with Amplaid A756 tympanometer (Amplifon, Italy). For statistical data analysis we used Chi-square testwith level of significance $p<.05$. The Protocol number of Ethical approval is 1360-2/2021.

RESULTS

The total number of children surveyed in our study was 115, 65 males and 50 females. Pure-tone audiometry was performed in 81 children (70.4%). Thirteen children (16%) in this group had sensorineural hearing loss, 10 children had unilateral and 3 children had bilateral hearing loss. We displayed degree of hearing loss in children with tonal audiogram. A total of 162 ears were analyzed (Table 1).

Table 1

Degree of hearing loss in children with tonal audiogram

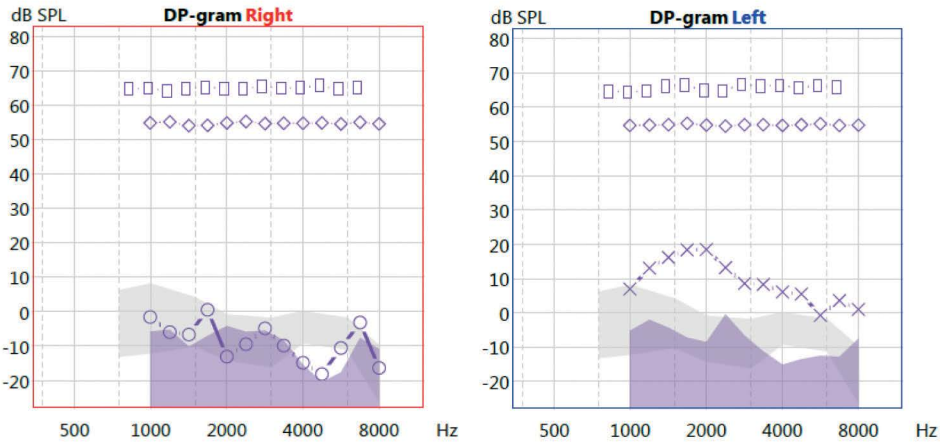
Degree of hearing loss	Males No (%)	Females No (%)	Total No (%)
0-20 dB HL	86 (53.1)	60 (37)	146 (90.1)
20-40 dB HL	2 (1.2)	/(0)	2 (1.2)
40-60 dB HL	2 (1.2)	5 (3.1)	7 (4.3)
60-95 dB HL	3 (1.9)	3 (1.9)	6 (3.7)
>95 dB HL	1 (0.6)	/ (0)	1 (0.6)
Total	94 (58)	68 (42)	162 (100)

Legend: dB HL = decibels hearing level

In children with sensorineural hearing loss, the OAEs were absent in the range of hearing loss. We displayed the example DP-gram of a child with right ear hearing loss (Figure 1).

Figure 1

DP-gram of child with absent OAEs in the right ear and present OAEs in the left ear



We calculated the mean DPOAE amplitude and mean signal-to noise ratio (SNR) in children with normal hearing and children with sensorineural hearing loss (Table 2).

Table 2

Mean DPOAE amplitude and mean SNR in children with tonal audiogram

Hearing in children	DPOAE amplitude (dB)	SNR (dB)
Normal hearing	9.9	18.2
Hearing loss	-7.4	3.4

A total of 34 children (29.6%) were younger than 4 years or not cooperative for pure-tone audiometry. In this study group, DPOAEs were present in 23 children (67.6%) at control examination after absence during middle ear pathology and 9 children (26.5%) at first examination. They were absent in 2 children (5.9%) with normal middle ear function (Table 3).

Table 3

Presence of DPOAEs in children without tonal audiogram

Middle ear function	Present No (%)	Absent No (%)	Total No (%)
Normal	9 (26.5)	2 (5.9%)	11 (32.4%)
Normal after pathology	23 (67.6%)	/ (0)	23 (67.6%)
Total	32 (94.1)	2 (5.9%)	34 (100)

We analyzed the acceptance of DPOAE amplitude at different frequencies in children with overall absent OAEs (Table 4).

Table 4
Acceptance of DPOAE amplitude at different frequencies

Frequency (Hz)	Accepted No (%)	Rejected No (%)	Total No (%)	p*
1000	8 (10)	12 (15)	20 (25)	.036
2000	10 (12.5)	10 (12.5)	20 (25)	
4000	2 (2.5)	18 (22.5)	20 (25)	
8000	5 (6.3)	15 (18.8)	20 (25)	
Total	25 (31.3)	55 (68.8)	80 (100)	

*Chi-square test

We included 16 cases of sensorineural hearing loss and 4 ears of two children younger than 4 years with absent OAEs despite normal middle ear function. There is statistically significant difference between acceptance of DPOAE amplitude and tested frequency (χ^2=8.553, df=3, p=.036). DPOAE amplitude was mostly rejected at frequency of 4000 Hz.

DISCUSSION

We evaluated the role of otoacoustic emissions in audiologic assessment of children with suspected hearing loss. Tympanometry was performed in all children, except in the youngest patient, 5-months old girl, but she had present otoacoustic emissions, so we can assume normal middle ear function. DPOAEs were recorded as distortion product audiograms. Typically, the DPOAE amplitude or level is displayed as a function of stimulus frequency. The plot id called a DP-gram (Zelle et al., 2017).

In children with sensorineural hearing loss, the OAEs were absent in the range of hearing loss. Putterman et al. (2017) also concluded that OAE test is a potential objective tool to identify patients with cochlear hearing loss. OAE test may be necessary outside of screening programs because children may pass the hearing test, but can develop hearing loss (Rowe et al., 2016).

In present study mean DPOAE amplitude in children with normal hearing was 9.9 dB. A previous study showed mean DPOAE amplitude 10.8 dB in children with normal hearing and type A timpanogram (Ristovska et al., 2017). A clearly present and normal outcome must show a DPOAE with SNR greater than 3-6 dB at approximately 70% of the collected data points and appropriate absolute amplitude for the patient's age (Abdala & Visser-Dumont, 2014).

In children not cooperative for pure-tone audiometry, DPOAEs were present in 26.5% of children at first examination, and 67.6% of the children at control examination after absence during middle ear pathology. We found absent DPOAEs in 5.9% of the children without middle ear pathology. In a study of prevalence of hearing loss, the authors concluded that the majority of 3-5-year olds with absent DPOAEs likely had conductive hearing loss (Feder et al., 2017).

Most of the children with middle ear pathology in our study had otitis media with effusion (OME). Measurement of DPOAEs helps in evaluating middle ear condition during the treatment (Akdogan & Özkan, 2006; Yeo et al., 2002) It has been known that negative middle-ear pressure (<100 daPa) negatively impacts the ability to record DPOAE (Beck et al., 2016). Sanfins et al. (2020) concluded that a history of repeated otitis media interferes with the generation and transmission of DPOAEs.

CONCLUSION

The OAE test is good cross-check for pure-tone audiometry. In children with sensorineural hearing loss the OAEs are absent in the range of hearing loss. In young children not cooperative for pure-tone audiometry, expression of OAEs after previous absence during middle ear pathology would indicate that there is no coexistent sensorineural hearing loss.

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