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Distortion products of otoacoustic emissions and their role in assessing hearing loss in young children

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Abstract

Background: Hearing loss in children is far beyond the scope of otology, since audition is the basis of developing speech and cognitive abilities, as well as the child's personality. Due to its incidence and severe consequences that often lead to disability, hearing loss remains an acute issue for scholars and specialists of various fields.

Material and methods: There have been studied distortion products otoacoustic emissions in children from two groups: the control group included 30 children, aged between 1-36 months, with normal hearing; whereas the study group consisted of 110 children aged between 1-36 months with sensorineural deafness.

Rezults: We studied auditory distortion products (ADP) in the control group of children, where prior impedance had excluded any middle ear pathology, whereas the medical history data regarding the functional development of the auditory system and behavioral audiometry showed normal hearing. We studied ADP at frequencies of 500; 750; 1000; 1500; 2000; 3000; 4000 and 6000 Hz. The analysis of the obtained results revealed some particularities of the ADPs according to the tested frequencies. Thus, ADPs recording that explores 1000 Hz; 1500Hz; 2000Hz; 3000Hz; 4000Hz and 6000Hz frequencies showed no difficulty, being 100% recorded in all children within the control group. The background noise varied from – 10 dB SPL to – 20 dB SPL. Low frequencies were difficult to assess due to a significant environmental noise which in some cases was higher than the ADP amplitude.

Conclusions: As a result of ADP recording carried out in examined children, we conclude: the ADP recording, namely the "ADP audiogram" test, is an objective method with high sensitivity, which can be used in hearing screening in early childhood. The criterion for impaired hearing based on the "ADP audiogram" is the spectral interruption for frequencies higher than 1000 Hz.

Key words: distortion products, otoacoustic emissions, hearing loss, children.

Introduction

Hearing loss in children is far beyond the scope of otology, since audition is the basis of developing speech and cognitive abilities, as well as the child's personality. Due to its incidence and severe consequences that often lead to disability, hearing loss remains an acute issue for scholars and specialists of various fields. According to worldwide-specialized literature, the occurrence of this disorder remains quite common and differs from one source to another. Statistical data provided by the National Institute of Deafness and Other Communication Disorders (NIDaOCD) show that deafness occurs in 1-3 cases per 1,000 healthy newborns and in 2-4 cases per 100 newborns admitted to Neonatal Intensive Care Unit.

Distortion product otoacoustic emissions (DPOAEs) or auditory distortion products (ADP) reflect outer hair cell integrity and cochlear function. When used appropriately in the audiology clinic, they are an effective diagnostic tool and can detect hearing loss with accuracy. DPOAEs are easily and rapidly recorded in newborns and children, and provide basic hearing screening information as well as detailed diagnostic information in cases of suspected hearing loss. In the past decade, solid guidelines have been established to select the most effective recording parameters, thereby optimizing the DPOAE's diagnostic potential [1,2,3,4].

DPOAEs can be used effectively to diagnose or detect hearing loss in infants and children. Although they are technically not a measure of "hearing," they are correlated with hearing. As such, they are useful in the audiology clinic. Under good-to-excellent test conditions, the correlation is fairly straightforward: When DPOAEs are present and normal in amplitude and configuration, their presence indicates that the cochlear amplifier is normally functional. In the absence of neurological or isolated inner hair cell dysfunction, this result is consistent with normal hearing. When DPOAEs are absent, their absence indicates that there is some dysfunction in the cochlea, though the level of dysfunction and, thus, degree of the hearing loss is not clear. This reliable correlation between DPOAEs and hearing allows for the effective clinical application of this easily recorded response [5,6].

Purpose of the study is aimed at studying major characteristics of acoustic distortion products in children with normal hearing, as well as the diagnostic values of this method in assessing the hearing function in young children.

Material and methods

There have been studied distortion products otoacoustic emissions in children from two groups: the control group included 30 children, aged between 1-36 months, with normal hearing; whereas the study group consisted of 110 children aged between 1-36 months with sensorineural deafness (tab. 1).

Table 1

Distribution of patients by groups

The study group	The control group
110 children	30 children
With sensorineural hearing loss	With normal hearing
Age 1-36 months	Age 1-36 months

The distribution of patients by gender: 59.3% boys and 40.7% girls (tab. 2). Distortion products otoacoustic emissions have been studied on the following frequencies: 500; 750; 1000; 1500; 2000; 3000; 4000 and 6000 Hz.

Table 2

Distribution of patients by gender and age

Patients	%
Boys	59.3%
Girls	40.7%
Age (years)	1-36 months

Results

Our task was to highlight two main aspects: 1) basic properties of acoustic distortion products in children with normal hearing and "normal hearing" criteria based on ADPs; 2) diagnostic value of this method in assessment of hearing function in early childhood.

First, we studied ADPs in the control group of children, where prior impedance had excluded any middle ear pathology, whereas the medical history data regarding the functional development of the auditory system and behavioral audiometry showed normal hearing. We studied ADPs at frequencies of 500; 750; 1000; 1500; 2000; 3000; 4000 and 6000 Hz. The analysis of the obtained results revealed some particularities of the ADPs according to the tested frequencies (tab. 3).

Thus, ADPs recording that explores 1000 Hz; 1500Hz; 2000Hz; 3000Hz; 4000Hz and 6000Hz frequencies showed no difficulty, being 100% recorded in all children within the control group. The background noise varied from – 10 dB SPL to – 20 dB SPL. Low frequencies were difficult to assess due to a significant environmental noise which in some cases was higher than the ADP amplitude. This explains ADP recording that explores 500 Hz frequencies in only 29% and at 750 Hz in 70% of testing. ADPs that explore 500 Hz frequencies exhibited both a significant background noise and a lack of ADP (negative amplitude). The obtained results correspond to the data from P. Bonfils [7], which claim that ADP low frequency testing is not feasible due to a high background noise.

Table 3

Recording acoustic distortion products in tested children

DP 2 $F_1 - F_2$	Geometric mean of primary frequencies Hz	Incidence %		X^2	P
		Control Lot n=60	Basic Lot n=220		
353	500	20.00	23.64	0.354	> 0.05
529	750	70.00	47.73	9.378	<0.05
1058	1000	100.00	3.,64	238.075	<0.001
1413	1500	100.00	0.00	274.087	<0.001
1779	2000	100.00	0.00	274.087	<0.001
2116	3000	100.00	0.00	274.087	<0.001
2824	4000	100.00	0.00	280.000	<0.001
4232	6000	100.00	0.00	274.087	<0.001

The result analysis of the ADP amplitude indicates some of its properties depending on the tested frequencies (tab. 4). Thus, for 500 Hz; 750 Hz 4000 Hz; 6000 Hz frequencies, the PDA's amplitude was higher, and decrease to 1000 Hz showing the lowest value. Frequencies of 1500 Hz; 2000 Hz and 3000 Hz are close, due to their amplitude values.

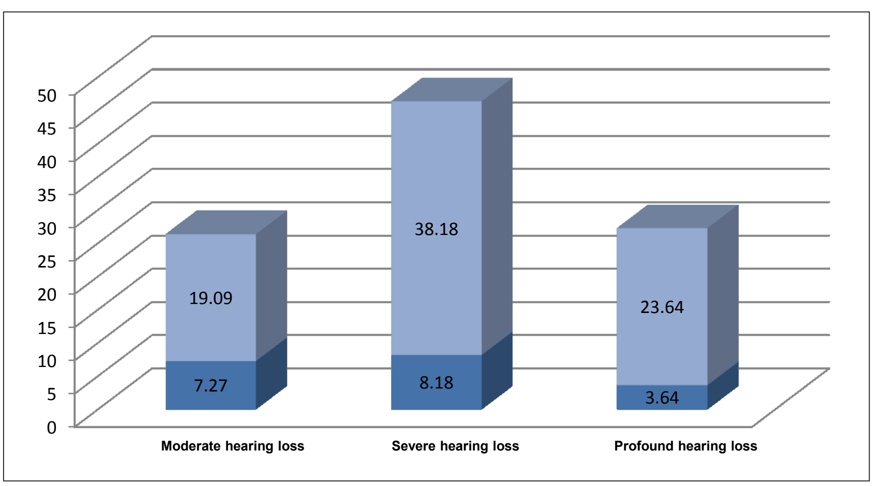

Fig. 1. Distribution of children by degree of deafness.

Table 4

Amplitude of acoustic distortion products in children with normal hearing

N/o	DP $2F_1 - F_2$	Geometric mean of F1 and F2 Hz	M	±m
1	353	500	15.83	1.63
2	529	750	10.48	0.55
3	1058	1000	6.93	0.48
4	1413	1500	9.93	0.48
5	1779	2000	9.27	0.46
6	2116	3000	8.16	0.52
7	2824	4000	11.91	0.51
8	4232	6000	14.61	0.65

Therefore, an "ADP audiogram" with positive amplitude values at frequencies of 750; 1000; 1500; 2000; 3000; 4000 and 6000 Hz indicates a normal hearing. The predominant background noise over the ADPs at frequencies of 500Hz and, in some cases of 750Hz, is not a criterion for impaired hearing. In our opinion, the lack of ADPs at low frequencies, if they are present on the frequency route of 1000; 1500; 2000; 3000; 4000 and 6000 Hz, is more related to some technical difficulties, since the ADPs cannot be selected from the environmental noise.

The ADP's amplitude revealed higher values at 500 Hz, 750 Hz, 4000 Hz and 6000 Hz frequencies, and a decrease up to 1000 Hz, showing minor significance. 1500 Hz; 2000 Hz and 3000 Hz frequencies remain almost the same in their amplitude values. An ADP "audiogram" with positive amplitude values at 750, 1000; 1500; 2000; 3000; 4000 and 6000 Hz frequencies indicates normal hearing.

ADP recording results in children from the control group reveal an ADP absence at frequencies above 1000 Hz, which graphically appears as an amplitude spectrum within the ADP "audiogram" (negative values of amplitude) – scotoma (fig. 2).

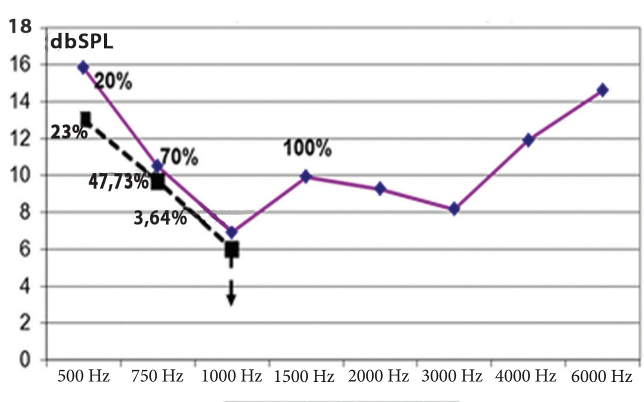

Fig. 2. The PD-gram (the mean amplitude and incidence recording).

The obtained data showed 100% absence of ADP at 1500; 2000; 3000; 4000 and 6000 Hz frequencies. ADPs which assess 750 Hz frequencies were present in 47.73% of cases; and 500 Hz in 23.67% of cases. ADP was even detected in assessing 1000 Hz frequencies in 3.64% of minimum cases. Therefore, the analysis of the obtained results in the ADP "audiograms" recording in the control group reveals lack of ADP in all children with sensorineural deafness.

Thus, ADP recording can be used to test hearing function in children since the early days of their lives. According to our research, sensitivity of ADP recording method is 81.9% and specificity is 99.5%.

Once the ADP properties and the basic criteria for the normal hearing based on the "ADP audiogram" recording had been determined in children from the control group, the ADP study was carried out in deaf children. The results of ADP recording in children from the basic group show the lack of ADPs at higher frequencies of 1000 Hz. The "DP audiogram" is displayed graphically as a spectral interruption (negative amplitude values) – scotoma.

According to the obtained data, ADPs at 1500; 2000; 3000; 4000 and 6000 Hz frequencies were absent in 100% (220 ears). However, it is worth mentioning that low frequency testing was possible in some deaf children. Thus, ADPs exploring at 750 Hz frequencies were present in 47.73% (105 ears), at 500 Hz in 23.67% (52 ears), and even at frequencies of 1000 Hz in 3, 64% (8 ears).

This could be explained by a better hearing condition at frequencies where ADPs are present, as in our cases – at the lowest frequencies, which is normal for sensorineural deafness. Therefore, the obtained result analysis based on the "ADP audiogram" recording in the basic group shows lack of ADPs in all children with sensorineural hearing loss.

Our research data confirm the existing literature findings that acoustic distortion products are present in all cases of normal hearing and absent in cases of sensorineural deafness [8,9,10,11,12,13].

Therefore, based on the ADP recording, we can identify if the child hears or not, even from the first months of life. According to our data, sensitivity of the ADP recording method is 81.9% and specificity is 99.5%.

Conclusions

As a result of ADP recording carried out in examined children, we conclude that the ADP recording, namely the "ADP audiogram" test, is an objective method with high sensitivity, which can be used in hearing screening in early childhood. The criterion for impaired hearing based on the "ADP audiogram" is the spectral interruption for frequencies higher than 1000 Hz.

Acoustic distortion products are present in all cases of normal hearing, whereas the "ADP audiogram" is being marked at frequencies of 750; 1000; 1500; 2000; 3000; 4000; 6000 Hz. In case of hearing loss, the "ADP audiogram" shows a high-frequency scotoma. As an objective method with a 81.9% sensitivity and 99.5% specificity, the "ADP audiogram" recording can be used in pediatric audiology as a screening method.

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