mgr inż. Edyta Piłka

High-Frequency Distortion Product Otoacoustic Emissions

Summary

Introduction

At the current level of civilization development, hearing plays a key role in human communication. Due to excessive noise or disease conditions, the functions of the hearing organ may be disturbed, which may have a direct impact on the quality of information reception. Studies on changes of the cochlea in the inner ear show that areas of perception of the high frequencies are damaged first.

Standard diagnostics do not allow the detection of very small pathological changes in the hearing organ, because basic hearing tests often only cover the speech frequency band, i.e. frequencies from 0.125 kHz to 8 kHz. In contrast, the human ear can pick up sounds in the frequency band from about 0.016 kHz to 20 kHz. Extending hearing assessment above 8 kHz may be crucial in preventing early hearing damage due to noise or taking of ototoxic drugs.
It has also been shown that hearing at high frequencies can change, among others in people with chronic diseases such as diabetes or kidney failure, in patients with tinnitus or in children with middle ear dysfunction.

The basic diagnostic tool for objective assessment of the cochlea condition is the measurement of Otoacoustic Emissions (OAEs). The most commonly used are Distortion Products Otoacoustic Emissions (DPOAEs), typically measured in the 1-8 kHz range. Recently, however, devices are also available that make possible DPOAE testing for frequencies up to 16 kHz. To date, few papers have been published highlighting the diagnostic value of high frequency DPOAE responses.

Objective

The aim of the study is to assess the suitability of the distortion product otoacoustic emission method for the detection of preclinical changes in the organ of Corti in the high frequency range in a group of adult subjects with normal hearing in the frequency range from 0.125 kHz to 16 kHz. The main subject of interest were emissions for very high frequencies in the 8-16 kHz range. During the completion of the main objective, the following relationships were also studied:

1. influence of probe fitting mode on the size of DPOAE response levels. Three measurements were made – two in single probe fitting mode (without removing the probe from the ear canal) and one in multiple fitting mode (after reinserting the probe into the ear canal)
2. influence of the type of measuring equipment on the amplitude of the DPOAE signal
3. the influence of DPOAE by such factors as:
    a. external (excessive exposure to noise)
    b. internal (tinnitus)

Material

The data was collected from a group of 133 people, of which 231 ears with normal hearing in the range from 0.125 kHz to 16 kHz, and 4 ears with hearing loss were selected. Ears with hearing loss were used to depict some specific properties of DPOAEs. Additionally, to achieve the main objective and individual dependencies, the dataset was divided into subgroups:

I (goal 1 – the effect of the HearID Mimosa Acoustics, Inc., USA probe fit mode on DPOAE levels in adults) – 53 ears, normal hearing up to 16 kHz, average age of 26.16 with standard deviation of 6.76 years;

II (objective 2 – impact of the type of measuring equipment on the amplitude of the DPOAE signal) – 15 ears, average age of 26.66 with a standard deviation of 5.23 years;

III (objective 3a – impact of external factors on DPOAE parameters in a group of people with normal hearing) – 65 ears, average age of 21.8 with a standard deviation of 1.81 years.

People from group III had long-term exposure to noise – professional musicians and longtime music school students playing in orchestras. Before the battery of audiological tests, a questionnaire was completed in which, among other things, the time of exposure to noise was determined. All persons participating in the project were right-handed;

IV (objective 3b – impact of internal factors on DPOAE parameters in a group of people with normal hearing) – 27 ears, average age of 29.53 with a standard deviation of 6.5 years. Tinnitus occurring in this group was located throughout the head. Most often they were simple tones with higher frequencies with an average intensity of 15 dB SL. No hearing hypersensitivity was found in the persons participating in the project.

V (control group with normal hearing in the band from 0.125 kHz to 16 kHz, not exposed to noise, without tinnitus) –123 ears, the average age in the group was 25.48 with a standard deviation of 6.11 years.

Methods

The research was carried out at the Department of Experimental Audiology at the World Hearing Center of the Institute of Physiology and Pathology of Hearing. The testing procedure included introduction of the information about the study to the subject, signing the informed consent form, measuring impedance audiometry, test for assessing the functioning of the Eustachian tube, high frequency audiometry, and DPOAE registration.

DPOAE measurements were carried out according to various protocols and on different measuring equipment's depending on the type of analysis performed. Three DPOAE measuring systems were used: HearID Mimosa Acoustics, Inc., USA, SmartOAE Intelligent Hearing Systems, USA and Echoport ILO 292 Otodynamics Ltd, UK.

HearID Mimosa Acoustics, Inc., USA was used to evaluate the probe fit mode for the size of DPOAE levels (objective1). The influence of the type of measuring equipment on the DPOAE signal amplitude (objective 2) was assessed by recording DPOAE up to 16 kHz on two different commercial systems – HearID Mimosa Acoustics, Inc., USA and SmartOAE Intelligent Hearing Systems, USA. The reference device was the Echoport ILO 292 Otodynamics, UK system. HearID Mimosa Acoustics, Inc., USA was used to assess the impact of external (objective 3a) and internal (objective 3b) factors on DPOAE parameters.

Results

Analysis of the repeatability of DPOAE results was based on data measured on the HearID system in subjects with normal hearing in the frequency range from 0.125 kHz to 16 kHz and for two cases of specific types of hearing loss.

The results obtained in the group of people with normal hearing in the single probe fitting mode in the ear canal showed that a difference of close to 2 dB occurred only at 12 kHz. The analysis of the values in the multiple-fitting mode indicated that the fluctuations between the measurements exceeded the level of 1 dB for the frequencies of 8 kHz and 16 kHz and in the frequency band from 12 ($p = 0.01$) to 13 kHz. A statistically significant difference of up to 0.7 dB was obtained for a frequency of 0.5 kHz ($p = 0.03$).

Analysis of the results of repeatability of DPOAE measurements in a person with high-frequency hearing loss showed that in the single-fit probe mode in the external auditory canal the greatest variability was at 16 kHz and reached above 7 dB and at 12 kHz – around 6 dB. The smallest fluctuations were obtained for 1.5 kHz and 15 kHz (close to 0 dB). In the multiple probe fitting mode, the largest differences of up to 5 dB were recorded for 8 kHz and 15 kHz. The smallest was obtained in the band from 0.5 to 2 kHz and for frequencies 5, 6, 9 and 11 kHz. It is worth emphasizing that for many of the tested frequencies the difference between the measurements did not exceed 1 dB.

An analysis of the repeatability of DPOAE levels in a person with unilateral deafness was also made. The best repeatability of results in the healthy ear in single probe fit mode was obtained for a band from 2 to 4 kHz, while the worst, above 11 dB for the lowest frequencies and for 10 kHz reaching 9 dB. The highest fluctuations for 10 kHz (above 13 dB) and for 12 kHz (about 8 dB) were found for multiple probe matching. The smallest variability was obtained for the band from 1.5 to 6 kHz.

In the deaf ear in single probe fitting mode only for 8 kHz and 12 kHz, the differences were below 1 dB. Fluctuations usually did not exceed 5 dB, however in the 4 to 6 kHz band up to 20 dB of variation was recorded. In the multiple probe fitting mode, the largest differences above 10 dB were obtained for 0.75 kHz and for the band from 4 to 8 kHz, and the smallest for the frequency 1.5 kHz (about 1 dB) and 10 kHz (close to zero).

Unfortunately, it should be emphasized that the patient was anxious during the measurement, which could affect the recording.

The analysis of the influence of the type of equipment on the DPOAE response level was based on data measured on HearID and SmartOAE measuring systems in people with normal hearing in the frequency band from 0.125 kHz to 16 kHz. DPOAE responses registered on the HearID device had a higher level for 1.5 kHz and in the frequency band from 4 to 7 kHz, as well as for 9 and 12 kHz. The noise level was lower for SmartOAE for the range from 7 to 11 kHz and 12.5 kHz, and much higher for low frequencies and in the band from 14 to 16 kHz. Analyzes show that statistically significant differences for a single probe fit occurred at 0.5 kHz, in the 4-6 kHz band, as well as for 9 kHz. However, for multiple fit they were in the low frequency band and from 4 to 6 kHz and for 9. Higher values of differences between measurements made on different devices were obtained in the multiple probe fitting mode. The smallest differences between the fits were obtained for a frequencies of 0.75, 1.5, 3, 4, 7 and 16 kHz, the largest for 5 kHz.

The analysis of the influence of external factors on the parameters of DPOAE was made on the basis of data measured in orchestral musicians exposed to many hours of noise with normal hearing in the frequency range from 0.125 kHz to 16 kHz. The results obtained from the right ear showed that statistically significant differences between the subjects and the control group occurred at low frequencies. The largest difference between the measurements was obtained for the frequency of 16 kHz (above 4 dB) and the smallest for 4 kHz (0.12 dB). Analysis of the results from the left ear showed that statistically significant differences between the study group and the control group occurred only for 0.75 kHz. The largest difference was recorded for 12 kHz (4.79 dB) and the smallest for 0.5 kHz.

The analysis of the influence of internal factors on DPOAE parameters was made on the basis of data measured in people with tinnitus with normal hearing in the frequency band from 0.125 kHz to 16 kHz. Analysis of the results in the right ear did not show statistical significance between the measurements. The largest differences occurred for the frequency of 6 kHz (about 4 dB), while the smallest for 12 kHz. In the left ear for 0.5, 1 and 4 kHz, the differences between the measurements in people with tinnitus and the control group were statistically significant. The biggest difference between the groups was obtained for the frequency of 4 kHz – above 6 dB, and the smallest for 8 kHz. Bigger differences between the measurements in both groups were obtained for the left ear.

Conclusions

Based on the conducted research, the following conclusions were formulated:

1. In tests performed on the same device, no significant differences were found between measurements made without removing the probe from the ear canal and after removing and reinserting it into the ear canal.
2. Differences between the results obtained from different measuring devices were demonstrated – different level of DPOAE response and recorded noise under the same conditions – bigger differences in DPOAE response levels in the frequency band up to 8 kHz, bigger differences for multiple probe fitting in the ear.
3. In subjects with normal hearing exposed to noise, lower levels of DPOAE response in the left ear were observed.
4. In subjects with normal hearing with bilateral tinnitus, lower response levels in the frequency bands corresponding to tinnitus.
5. DPOAE measurement at higher frequencies seems reliable because the distance between the response level and the noise was significant.
6. The differences observed between the results presented in this work, and described in other papers may result from the size of the sample used, or use of other OAE measuring equipment.
7. When assessing the results of DPOAEs, it is worth considering the type of criterion for assessing the presence of OAE responses, because the deviations between measurements may result not only from pathological changes in the auditory system, but also from the variety of implemented assessment criteria for OAE recording
in a given device.
8. When monitoring the effect of various factors on the cochlea, such as noise or ototoxic drugs, it is therefore necessary to make measurements using the same device.