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Unveiling the Cochlear Physiology Behind Hidden Hearing Loss

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Purpose: The study is aimed at identifying the cochlear physiology behind hearing impairment at extended high frequencies (EHF) despite having a normal threshold in conventional audiogram. Secondly, it is compared with the levels of Distortion Product Oto Acoustic Emissions (DPOAE).

Methods: A total of 21 participants were included in the study, who have EHF loss with normal Pure tone Audiometry (PTA) thresholds. EHF testing was performed exclusively at 10 kHz, 12.5 kHz, 14 kHz, and 16 kHz using Modified Hughson-Westlake procedure. Distortion Product OAE levels were also estimated at 2 kHz, 4 kHz, and 5 kHz.

Results: Significant correlation between EHF loss and DPOAE levels was seen in 10 out of the 21 participants (47.6% of the total) for one or more of the standard frequencies and ears. Whereas DPOAE's were present in the remaining participants.

Conclusions: Reduced or absent DPOAE levels with EHF loss in spite normal audiogram results reveal the potential aetiology as Cochlear Synaptopathy leading to Hidden Hearing Loss. This demands the inclusion of EHF audiometry for unveiling Hidden Hearing Loss in assessing young and adult population. It brings forth a significant change in the outcomes of Early Intervention.

Keywords: Hidden hearing ioss, Oto Acoustic Emissions, DPOAE, Cochlear physiology

INTRODUCTION

As behavioural tests are known as the gold standards of hearing assessment, the most commonly used method to assess an adult's hearing ability is pure tone audiometry. Which is one of the routinely used test in the test battery approach. A frequency range of 250 Hz-8,000 Hz are used in testing across intensity levels from -10 dB HL to 120 dB HL, as it covers almost all the sounds included in the speech spectrum required to carry out a conversation. This method evaluates the whole hearing pathway from external ear to the hearing cortex [1]. Recently, some other methods have been proposed to detect the probability of hearing loss in an earlier time. One of the proposed methods for early diagnosis of hearing loss is extended HFA which evaluates hearing thresholds at frequencies higher than 8,000 Hz (i.e., 10,000, 12,000, 14,000, 16,000, 18,000, and 20,000 Hz). It is believed that these frequencies are affected earlier than conventional frequencies due to exposure to noise [2-4]. It provides information regarding the nature, origin and extent of the hearing loss in terms of degree of hearing loss which serves as a basis for choosing appropriate management options like amplificatory de-

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vices. A normal hearing sensitivity audiogram shows the Pure tone average of thresholds obtained within 15 dB HL as a strict criterion [5,6].

It is quite common for a clinical audiologist to come across patients self-reported having hearing difficulty despite a normal audiogram result in routine PTA. There are several research results also supports this condition [7,8]. Extended high frequency audiogram has to be done in such patients to rule out hearing loss in frequencies above 8,000 Hz which is called as extended high frequency hearing impairment or hidden hearing loss (HHL) as this cannot be detected using conventional pure tone audiometry testing. Some evidences suggest that subjects with complaints of difficulty in speech understanding with the presence of noise may have poor thresholds at extended higher frequencies [9].

Cochlear physiology behind human auditory perception of frequencies from 20 Hz to 20 kHz is based on travelling wave theory were the movement of Basilar membrane, hair cells and the generation of action potentials at the neural level plays major role. Cochlear synaptopathy is the degeneration of synaptic contacts between inner hair cells and auditory nerve fibers [10]. In contrast, HHL has been defined inconsistently between studies and is often used colloquially. HHL has been described as auditory dysfunction that hides underneath the standard audiogram and is thought to be associated with perceptual deficits, including speech understanding in noisy backgrounds. From a clinical standpoint, it is unclear how HHL differs from myriad terms for listening difficulties with a normal audiogram, e.g., King-Kopetzky syndrome, obscure auditory dysfunction, idiopathic discriminatory dysfunction, hidden auditory neuropathy and (arguably) certain forms of auditory processing disorder. Perhaps, HHL was originally intended for referring to the perceptual consequences of cochlear synaptopathy, although this is not explicit in the relevant literature [10,11].

There is few research results suggests Outer hair cells (OHC) dysfunction as the potential mechanism behind extended high frequency impairment [4]. For the first time in 1978, Kemp recognized acoustic emissions due to the movement of outer hair cells in the cochlea [12]. OAE is an objective and quick examination easily performed and does not need acoustic conditions, so it was recommended as a surrogate for audiometry [13]. High-frequency audiometry is believed also to find hearing loss due to ototoxic drugs or substances sooner than conventional audiometry [14,15].

Aim

The present study is aimed at identifying the correlation between hearing impairment at extended high frequencies and DPOAE levels despite having a normal conventional audiogram in young adults.

METHODS

This study was carried out in the Department of Audiology, MAA Institute of speech and hearing, Hyderabad as part of the routine biological calibration of instruments using daily listening checks. Conventional pure tone audiometry along with extended high frequency testing is also part of this. A total of 21 students, aged between 18 to 29 years (10 males & 11 females) were included in the present study who were having normal conventional audiogram results (thresholds are within 15 dB HL from 250 Hz to 8,000 Hz) with extended high frequency hearing impairment which is considered as thresholds obtained at any of the following frequencies in any ear is 20 dB HL or above. Extended high frequencies included in the present study are 10 kHz, 12.5 kHz, 14 kHz, and 16 kHz. The subjects were not reported any complaints related to hearing sensitivity and they were not having any other co morbid conditions.

The conventional audiometry and extended high frequency audiometry were carried out in a soundproof room using a clinical audiometer (Maico MA 42-Dual channel digital audiometer) and Senheiser HDA 2000 Circum aural headphones. The air-conduction thresholds at 10 kHz, 12.5 kHz, 14 kHz, and 16 kHz were detected for Right ear and Left ear separately using Modified Hughson-Westlake method and plotted on a high frequency audiogram and routine audiometry results were plotted on the pure tone audiogram.

Followed by this, DPOAE test was carried out using Neurosoft Diagnostic OAE instrument. Distortion product OAE's were tested for all 21 subjects' right and left ears separately. 2f1-f2 DPOAE's were obtained for F2 frequencies at 2 kHz, 3 kHz, 4 kHz, and 5 kHz. Approximates of OAE, noise floor and SNR were acquired. DPOAE's were considered as normal if the emission level is above the noise floor by at least 6 dB for the four f2 frequencies. Statistical analysis was done using paired t test to determine level of significance between EHF hearing impairment and levels of DPOAE's.

RESULTS

All the participants included in the study were having ex-

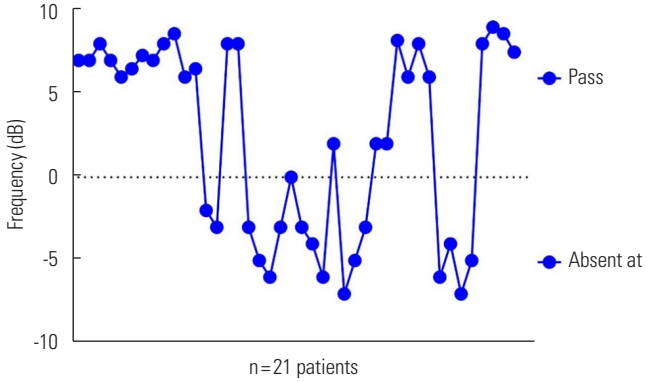

Figure 1. A scattered line graph representing the OAE status with the Frequency range in n=21 patients.

tended high frequency impairment in atleast one frequency among 10 kHz, 12.5 kHz, 14 kHz, 16 kHz either in one ear or in both ears. Among the total 21 participants with extended high frequency hearing impairment, DP emission levels were absent in 10 of them (47.6% of the total participants) for at least one or more of the standard frequencies in either one ear or in both ears. DPOAE's were present in rest of the 11 participants (Figure 1), followed by Table 1 shows the results of statistical analysis.

Statistical analysis also revealed that there is a statistically significant relationship ($p<0.01$) between absent DPOAE levels and extended high frequency hearing loss.

DISCUSSION

The results of this small group study indicates that there is a strong correlation between hearing impairment at extended high frequencies and DPOAE levels even after controlling the factor of aging in this study (age range of participants are between 18 to 29 years) similar to other research results in this area [1].

One can correlate results of this study with the two following possibilities of physiology behind this. First, the generation of DPOAEs are dependent on the status of far basal components along the cochlear partition may be one of the reasons for absent DPOAE's in participants with extended high frequency impairment despite having a normal standard audiogram. Another possibility could be DPOAEs are sensitive to various cochlear insults even when behavioural thresholds are unaffected [2]. The absent DPOAEs may suggest that EHF hearing is an early marker for cochlear damage.

Hence, results of this study indicate the presence of a HHL

Table 1. Paired t test analysis showing the OAE status in n=21 patients

Frequency	N	N%	OAE status	Paired t test analysis		
				T	Df	Level of significance
0 to < ±6 dB	10	47.6	OAE absent	4.71	2	$p<0.01$
>6 dB	11	52.4	OAE present			

$p<0.05$ is considered as the level of significance.

which cannot be identified based on routine audiogram and the participants may face difficulties in perception of speech in the presence of background noise as well. The major causative factor behind this phenomenon could be cochlear damage/cochlear synaptopathy where there is a potential damage to the basal portions of the cochlea.

CONCLUSIONS

Reduced or absent DPOAE levels in conjunction with extended high frequency impairment despite having a normal routine audiogram result necessitates the revision of tests included in the test battery approach for early detection, monitoring and prevention of hearing impairment even for young adults. The results also demand more research activities in this area to better understand the physiology behind HHL and for the differential diagnosis of the same with other sensorineural hearing loss conditions where OHC's are affected.

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