ORIGINAL ARTICLE

Assesment of Hearing Loss and Prognosis in Middle Ear Ventilation Disorders Based on Otoacoustic Emissions

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Objectives: Aims of the study was to establish the relationship between the hearing level (HL) and OAE's response in MEVDs. Further more to asses the prognosis of the disease by pretreatment and post treatment observations done at 1st and 2nd month.

Background: Because otoacoustic emissions (OAEs) are transmitted from the cochlea to the ear canal via the middle ear, OAEs are directly influenced by the transmission properties of the middle ear. In general, Middle ear ventilation disorders (MEVDs) reduce the measured emission amplitudes and sometimes eliminate the response entirely.

Material and Methods: A study group of 97 ears was formed which was divided further to controls and cases groups of 36 and 61 patients respectively, based on signs and symptoms along with otoscopy, tympanometry and pure tone audiometry (PTA) examination. Then OAE test with preset protocols was done for both DPOAE and TEOAE.

Results: A depressed level of OAE was found in the pretreatment study group, which improved with increased signal to noise ratio (SNR) level after the treatment.

Conclusion: The OAE (TEOAEs and DPOAEs) are highly reliable, objective and noninvasive useful tests for assessing HL, in predicting the course and monitoring changes in MEVDs.

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Introduction

Otoacoustic emissions (OAEs), that is, "sounds generated by the ear," have been scientifically researched since 1977, but clues to their existence in human ears can be traced back in the literature for decades before that. The case for there being a functional "sound-generating capability" in the healthy cochlea causing tonal tinnitus as a by-product of the hearing process had been made 23 years before Glanville's observations[1] by Gold [2]. The concept that led to the first recording of OAEs was physical standing waves occurring in the cochlea [3-5]. This led to the first stimulus frequency emission (SFOAE) recordings[6,7]. Zurek[8] confirmed spontaneous emissions and is credited with being the first to use the term otoacoustic emission. OAEs are divided into two general categories: spontaneous and evoked emissions. Spontaneous OAEs (SOAEs) appear without any sound stimulation at a few frequencies in a healthy cochlea and seem to be a direct consequence of the cellular force generation of outer hair cells (OHCs) [9,10]. Evoked OAEs are generated by external sounds, either by transient (clicks and tone bursts) or stationary stimuli (tones). Transient evoked OAEs (TEOAEs) represent the sum of the pulse responses of OHCs along the cochlea, whereas distortion product OAEs (DPOAEs) represent cubic distortions of OHCs when stimulated simultaneously by two tones f1 (lower frequency) and f2 (higher frequency). The 2f1–f2 distortion component yields the highest amplitude and

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is therefore primarily used in audiological diagnostics [11]. Dependence of OAE detection on robust middle-ear function has been demonstrated in a variety of human patient groups exhibiting a number of middle-ear disorders [12], and by experimental treatments of the middle ear by applying positive or negative air pressure to the outer ear canal in both humans [13]. Ears with type B and type C tympanogram patterns showed absent or markedly reduced OAE amplitudes, when compared with emissions measured in their control counterparts [14].

Material and Methods

Subjects: This study was performed on 97 ears of 50 patients, of different age, attending ENT OPD of JN Medical College Hospital, A.M.U., Aligarh, India. Procedures were in accordance with ethical standards of board for research and thesis work set in the JN Medical College, AMU and was passed in its meeting. Patients presented with major symptoms of otalgia, aural fullness, periodic popping or snapping sound in the ear, nasal stuffiness, severe snoring and complaints or history of hearing loss which may be associated with tinnitus or vertigo. Physical examination of the middle ear using an otoscope, tympanometry, pure tone audiometry (PTA), along with TEOAE and DPOAE test were performed. Of the total no. of ears examined 3 were excluded from the study (one had sensorineural hearing loss on PTA, other two had Ad and As type of curve on tympanometry). There were 34 males and 16 females; the age range was between 3yrs to 45 years with a mean age of 21.8 years (+9.35).

Procedures: For tympanometry MIACO Tympanometer (Middle ear analyzer) was used. Tympanograms were defined on the basis of static compliance (cc) and peak pressure (daPa). Type A (0.25-1.6 cc; -100 to +50 daPa), Type As (<0.25 cc; -100 to +50 daPa), Type Ad (>1.6 cc; -100 to +50 daPa), Type B (peak absent; extreme -ve pressure or >-250 daPa) and Type C (0.25-1.6 cc; -ve pressure or < -100 daPa). Experimental group as cases of 61 patients with tympanograms having features of middle ear ventilation disorder (i.e. type B, type C, or combined curves) were selected. Tympanograms of 36 patients having type A curve formed the control group. Two ears one with type As and other with type Ad curve were excluded from the study. Pure tone audiograms using an ARPHI 700 MK IV pure tone audiometer were obtained for both the air and bone conduction hearing thresholds. In our study we found significant difference in PTA value of controls and cases with mean of 24.88(SD+9.45) dB in cases group (i. e. patients having middle ear ventilation disorders) therefore 25 dB was considered to divide in two groups of <=25 and>=25.

The otoacoustic emission test was performed in a soundproof room using an Maico Ero-Scan OAE Test System and all of the tests were recorded by one person. Two types of OAE (DPOAE, TEOAE) were measured for each ear with a preset protocol for both. According to instrument specifications 4 or 6 frequencies settings can be used for testing. 6 frequencies settings were used for both TEOAE and DPOAE testing in our study. For TEOAE signal to noise ratio (SNR) of 4dB at any 3 out of 6-test frequencies drops the probability of passing an ear with a significant hearing loss to less than 1%. Therefore, SNR of at least 4dB was taken as passing criteria for a frequency in TEOAE. six frequencies (1.5, 2, 2.5, 3, 3.5, 4 kHz) were tested, and for an ear to pass the test (i.e. emissions to be present) no. of such passing frequencies should be at least three DPOAE signal to noise ratio (SNR) of 6dB at any 3 out of 4-test frequencies drops the probability of passing an ear with a significant hearing loss to less than 1% but as we used 6 test frequencies (1.5, 2, 3, 4, 5, 6 kHz) so 4 out of 6 test frequencies with SNR of 6 dB were taken for an ear to pass.

All of the patients were given treatment for the disease and again post-treatment tympanometry, PTA, DPOAE&TEOAE test were done at 1 month and same test were repeated after 2 months and results were recorded on the patient's Performa. Statistical analysis of the result was done with SPSS programme using z test, Pearson chi-square and t-test.

Results

Considering these tests as ideal for making diagnosis of middle ear ventilation disorders study group was divided into two control (36) and cases (61) groups. The average conductive hearing levels between control and cases were 12.05(SD+4.93) dB and 24.88(SD+9.45) dB respectively and were significantly different (p<0.01)

DPOAE in two groups of <25 and >=25 dB CHL, in 97 ears, were significantly different with p<0.001 (Figure 1)

TOAE in two groups of <25 and >=25 dB CHL, in 97 ears, were significantly different with p<0.001 (Figure 2)

Two groups of DPOAE and TEOAE in ears with <25 dB CHL were significantly different with p<0.05 (Figure 3)

Two groups of DPOAE AND TEOAE in ears with >=25 dB CHL were not significantly different with p>0.05 (Figure 4)

Pretreatment (Figure 5) and post treatment DPOAE at 1 month in cases are significantly different with p<0.001. Post treatment at 1month and post treatment DPOAE at 2 month were not significantly different p>0.05. (Figure 6)

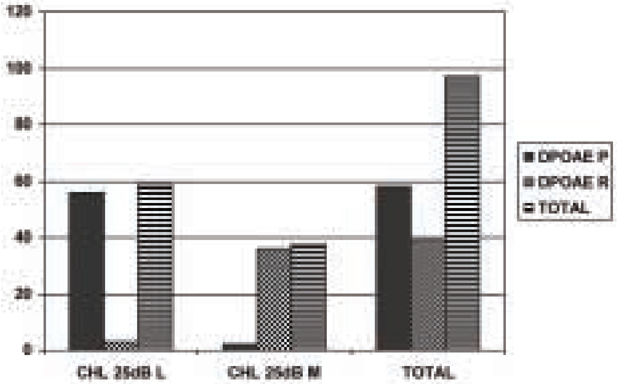

Figure 1. Status of pretreatment DPOAE in two groups of <AND>=25 dB CHL
L=less than 25dB CHL,
M= more than 25dB CHL,
P=pass, R= refer
The two groups of <25 and >=25 dB CHL are significantly different with p<0.001

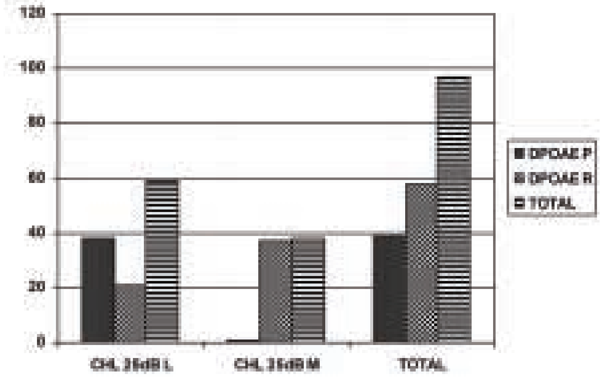

Figure 2. Status of pretreatment TEOAE in two groups of <AND>=25 dB CHL
L=less than 25dB CHL,
M= more than 25dB CHL,
P=pass, R= refer
The two groups of <25 and >=25 dB CHL are significantly different with p<0.001

Pretreatment and post treatment TEOAE at 1 month in

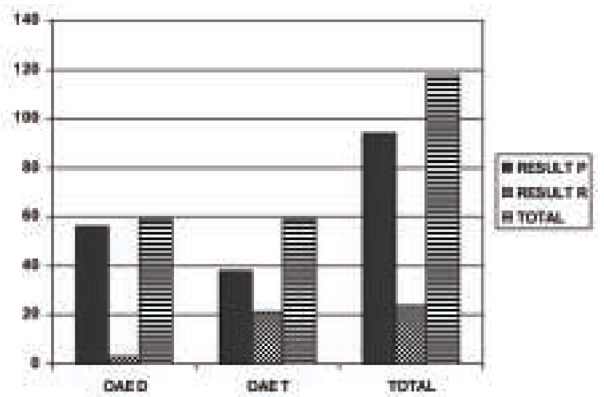

Figure 3. DPOAE compared with teoae in ears with <25 dB CHL in pretreatment study group D=DOAE, T=TEOAE,
P=no. of ears pass OAE test in <25 dB CHL,
R=no. of ears refer OAE test in <25 dB CHL
Two groups of DPOAE and TEOAE IN <25 dB CHL are significantly different with p<0.05

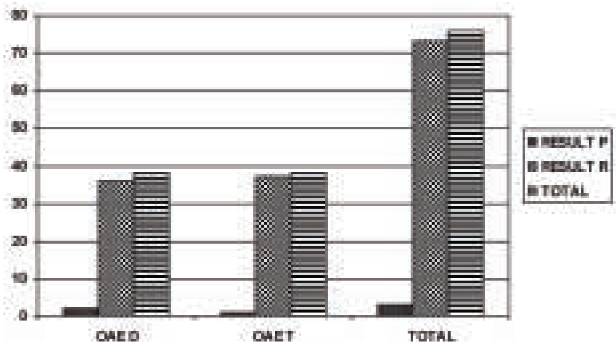

Figure 4. DPOAE compared with teoae in ears with >=25 dB CHL in pretreatment study group D=DOAE, T=TEOAE,
P=no. of ears pass OAE test in >=25 dB CHL,
R=no. of ears refer OAE test in >=25 dB CHL
Two groups of DPOAE and TEOAE IN >=25 dB CHL are NOT significantly different with p>0.05

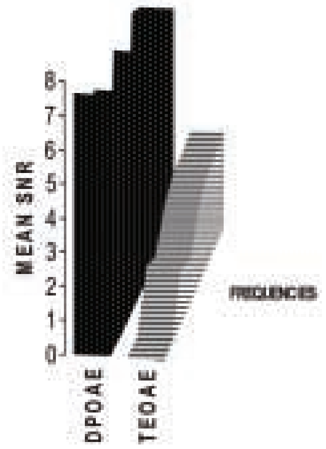

Figure 5. Pretreatment mean signal to noise ratio (SNR) for DPOAE and TEOAE.

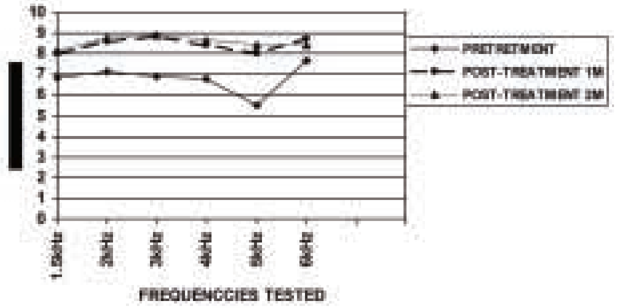

Figure 6. Mean DPOAE signal to noise ratio (SNR) for different frequencies in cases.
* Pretreatment and post treatment DPOAE at 1 month in cases are significantly different with p<0.001
* Post treatment at 1 month and post treatment DPOAE at 2 month are not significantly different p>0.05

cases are significantly different with p<0.001. Post treatment at 1month and post treatment TEOAE at 2 month were NOT significantly different p>0.05. (Figure 7)

Discussion

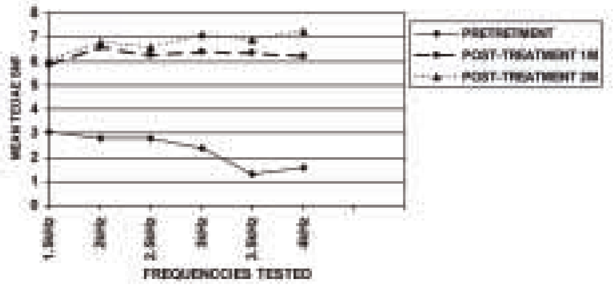

Figure 7. Mean teoae signal to noise ratio (SNR) for different frequencies in cases.
* Pretreatment and post treatment TEOAE at 1 month in cases are significantly different with p<0.001
* Post treatment at 1 month and post treatment TEOAE at 2 month are not significantly different p>0.05

Measurement of otoacoustic emissions is a noninvasive and objective procedure, and also saves time while determining the function of the cochlea[15-17]. Therefore can be used for many clinical purposes. All the otoacoustic emissions must pass through the middle ear before being measured in the external auditory canal, so any changes occurring in sound conduction properties of the middle ear can change the characteristics of OAEs. Therefore in our study, we can easily predict that measurement of various OAEs in the middle ear ventilation disorders group who show a type B and type C tympanogram with conductive hearing loss in PTA may be different from those showing normal type A tympanogram. TEOAEs fail to measure cochlear function above 4 kHz. In contrast, DPOAEs have the advantage of being capable of superior detection of a high-frequency hearing loss. This is due to the fact that stimulus (primary tones at f2 and f1) and response (2f1-f2) do not superimpose. So in our study with pretest protocols we have measured DPOAE at higher frequencies as compared with TEOAE. SNR limits for transients are lower than the corresponding limits of distortion products because the traditional noise calculation used in TEOAE measurements (and in the EROSCAN instrument) gives a 3 dB lower SNR than the calculations used for DPOAE (Figure 5). Environmental noise at the test room is an important limiting factor that affects the performance of both DPOAE&TEOAE tests. High noise levels make these tests unreliable at frequencies below 1 kHz.

In our study we found significant difference in PTA value of controls and cases with mean of 24.88(SD+9.45) dB in cases. Zhao et al examined TEOAE status as a function of hearing threshold and middle ear dynamic characteristics. Using both non-linear and linear stimulus modes, larger TEOAE responses were obtained when the hearing level was better than 20 dB HL, and there was moderately good middle ear mobility. Moreover, TEOAEs were absent using the non-linear mode when the hearing level was worse than 30 dB HL18 and therefore we formed two groups of <=25 and >=25

In <25dB HL group when DPOAE (94.9% pass) was compared with TEOAE (64.4% pass) then a significant difference was found ($p<0.05$) (Figure 3). While on comparing the same in >=25 dB HL group, DPOAE (5% pass) and TEOAE (2% pass), no significant difference was found (Figure 4). On the basis of above results and the study of TEOAE by Zhao et al[18] we can assume that more ears pass the test if hearing level is less than 25 dB for DPOAE. In other words if DPOAE test refers the ear it means that there is more chance of having a hearing loss of >=25 dB. Although this could be because of different frequencies being tested for DPOAE and TEOAE. Of all the 97 ears, in <25 dB HL group 94.9% pass DPOAE test with only 5% passing the same in >= 25 dB HL group and a significant difference was found between the two groups ($p<0.001$) (Figure 1). Same significant difference ($p<0.001$) was found in two groups on testing for TEOAE with 64.4% pass in <25 dB HL group and only 2% pass in >=25 dB HL group (Figure 2). Decreased emissions measurements are due to blockage of middle ear i.e. MEVD, which in turn is leading to hearing loss. Therefore, hearing loss was described as the conductive hearing loss due to middle ear ventilation disorders leading to decreased emissions measurements. According to Anges and Jean (2002) the sensitiveness of OAEs seemed better than the routinely used subjective 5dB step hearing thresholds. Audiograms using narrower threshold may yield more precise information but would also be more time consuming and are anyway less objective than OAEs [19]. A study result by Amedee RG (1995) refutes previous notions that OAEs are not measurable if the tympanogram is abnormal or fluid is present in the middle ear space i.e in MEVDs [20]. In our study also we also found that emissions are decreased with abnormal tympanometric finding depending upon the level of hearing loss and amount of hearing level can be assed on the basis of the DPOAE and TEOAE tests. A prospective observational study by Choi SS et al (1999) concluded that type B and C tympanograms and the presence of ME effusion (which reflect abnormal ME status) have an adverse effect on TEOAEs. However, the presence of hearing loss is the most significant predictor of TEOAE results[21]. Another study also supported that Middle ear effusion (MEE) results in a significant reduction in TEOAEs even when the effusion is nonmucoid (Koivunen P et al 2000)[22].

Yeo SW et al (2002) [23] concluded that SOAEs, TEOAEs and DPOAEs are highly reliable and useful tests for monitoring changes in middle-ear condition in children with OME and in predicting the course of OME. In DPOAE pretreatment cases mean SNR for different frequencies showed significant difference with post treatment SNR at 1month ($p<0.001$) while post treatment at 1 month was not significantly different with post treatment at 2month ($p>0.05$) (Figure 6.). Same significance level was found in TEOAE also (Figure 7). But the graph for TEOAE (Figure 7) showed upward curve for post treatment SNR level at 2 month as compared with DPOAE SNR level at 2 month (Figure 6) thereby emphasizing the need for prolonged and aggressive treatment if DPOAE test is referred in an ear. This could also be because of small sample size or different frequency testing for both and needs further evaluation. Yeo SW et al (2003) investigated prognostic value of otoacoustic emissions in children with MEE. Spontaneous otoacoustic emission, TEOAE, and DPOAE measurements were performed on each ear before medical treatment and were compared according to the responsiveness of medical treatment (medicine responder vs medicine no responder groups). They showed the high prognostic value of these tests in terms of predicting response to medical treatment in the patients with MEE24. From During treatment and post treatment monitoring of MEVD could be simply done by a noninvasive, objective OAE test only

Conclusion

This study suggests that MEVDs affects the expression rate of TEOAEs and DPOAEs depending upon the HL or the severity of the disease.

1. If TEOAE is referred then HL can be < or >=25 dB but if DPOAE is referred in the same ear then the probability of HL of being >=25dB is more i.e. the severity of the disease increases if DPOAE test is referred.
2. Persons with referred ear for DPOAE, in comparison with TEOAE need aggressive and prolonged treatment.
3. Monitoring treatment response by assessing hearing level during treatment can be done by a non-invasive and objective OAE test.
4. As tests in children need to be non-invasive and objective and MEVDs being common in them, during treatment and post treatment monitoring of MEVD and assessment of hearing level could be simply done by OAE test only.

Further attempts to co-relate OAEs with hearing threshold can fail because the mammalian OAE generation mechanism does not involve the inner hair cells that determine the local excitation threshold for activation of auditory fibers and future studies are needed.

References

1. Glanville JD, Coles RR, Sullivan BM (1971) A family with high-tonal objective tinnitus. J Laryngol Otol 85:1-10.

2. Gold T (1948) Hearing II. The physical basis of the action of the cochlea. Proc R Soc Lond B135:492-498.

3. Kemp DT (1979) The evoked cochlear mechanical response and the auditory microstructure-evidence for a new element in cochlear mechanics. Scand Audiol Suppl 9:35-47.

4. Kemp DT (1980) Towards a model for the origin of cochlear echoes. Hear Res 2:533-548.

5. Kemp DT (1998) Otoacoustic emissions: distorted echoes of the cochlea's traveling wave. In: Berlin C (ed), Otoacoustic Emissions-Basic Science and Clinical Applications. San Diego: Singular Press, pp. 1-59.

6. Kemp DT (2003) The OAE Story. Hatfield, UK: Otodynamics.

7. Kemp DT (2007) Otoacoustic emissions-the basics, the science and the future potential. In: Robinette M andGlattke TJ (eds) Otoacoustic Emisions: Clinical Applications, 3rd ed. New York: Theime, Chapter 1

8. Zurek PM (1981) Spontaneous narrowband acoustic signals emitted by human ears. J Acoust Soc Am 69:514-523.

9. Zwicker E, Schloth E (1984) Interrelation of different oto-acoustic emissions. J Acoust Soc Am 75:1148-1154.

10. Burns EM, Keefe DH, Ling R (1998) Energy reflectance in the ear canal can exceed unity near spontaneous otoacoustic emission frequencies. J Acoust Soc Am 103:462-474.

11. Gorga MP, Nelson K, Davis T, Dorn PA, Neely ST (2000a) Distortion product otoacoustic emission test performance when both 2f1-f2 and 2f2-f1 are used to predict auditory status. J Acoust Soc Am 107:2128-2135

12. Lonsbury-Martin BL, Martin GK, McCoy MJ, Whitehead ML (1994) Testing young children with otoacoustic emissions: middle-ear influences. Am J Otol 15, Suppl 1:13-20.

13. Kemp DT (1981) Physiologically active cochlear micromechanics-one source of tinnitus. In: Evered D, Lawrenson G (eds) Tinnitus. London: Pitman Books Ltd., pp. 54-81.

14. Owens JJ, McCoy MJ, Lonsbury-Martin BL, Martin GK(1993) Otoacoustic emissions in children with normal ears, middle ear dysfunction, and ventilating tubes. Am J Otol. 1993 Jan;14(1):34-40

15. Onur et al (2009) Protective effect of erdosteine against amikacin-induced ototoxicity: Int. Adv. Otol. 2009; 5:(2)

16. Ayudin et al (2009) Effect of Hypothermia on Distortion Product Otoacoustic Emission Findings in Children Undergoing Congenital Open Heart Surgery: Int. Adv. Otol. 2009; 5:(1)

17. Attanasio G., De Seta E., Musacchio A., Filipo R.(2005) Evaluation of distortion product otoacoustic emissions before and after stapes surgery: Mediterr J Otol 2005:1(2):55-58.

18. Zhao F et al (2003) Transient evoked otoacoustic emissions in patients with middle ear disorders: Int J Audiol. 2003 Apr; 42(3):117-31

19. Anges Job, Jean-Bertrand Nottet (2002) :DPOAEs in young normal hearing subjects with histories of otitis media; evidence of sub-clinical impairments; Hearing Research 167 (2002) 28-32.

20. Amedee RG (1995) The effects of chronic otitis media with effusion on the measurement of transiently evoked otoacoustic emissions. Laryngoscope. 1995 Jun; 105(6):589-95

21. Choi SS, Pafitis IA, Zalzal GH, Herer GR, Patel KM(1999) Clinical applications of transiently evoked otoacoustic emissions in the pediatric population. Ann Otol Rhinol Laryngol. 1999 Feb; 108(2):132-8

22. Koivunen P, Uhari M, Laitakari K, Alho OP, Luotonen J (2000) Otoacoustic emissions and tympanometry in children with otitis media. Ear Hear. 2000 Jun; 21(3):212-7.

23. Yeo SW, Park SN, Park YS, Suh BD (2002) Effect of middle-ear effusion on otoacoustic emissions. J Laryngol Otol. 2002 Oct; 116(10):794-9.

24. Yeo SW, Park SN, Park YS, Suh BD (2003) Prognostic value of otoacoustic emissions in children with middle ear effusion Otolaryngol Head Neck Surg. 2003 Jul; 129(1):136-40.