Effect of Short Duration Broad Band Noise on Transient Evoked Otoacoustic Emission Amplitude

Prawin Kumar · Kaushlendra Kumar ·
Animesh Barman

Received: 3 August 2012 / Accepted: 20 November 2012 / Published online: 30 November 2012
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Abstract Transient evoked otoacoustic emission (TEOAE) is being a non-invasive, objective technique and required less time to get administered can be easily used to find out effect of short duration broad band noise (BBN). However one must know the sensitivity of TEOAEs in predicting susceptibility of noise induced hearing loss. Thus the present study has taken up to find out the effect on TEOAE amplitude because of short duration exposure of BBN. Results indicated that there was statistically significant reduction in amplitude of TEOAE at all frequencies except 1 kHz ($p < 0.05$). It is also observed that the basal region of cochlea is more prone to noise exposure than apical region as revealed in the outcome of the study.

Keywords Transient evoked otoacoustic emission (TEOAE) · Broad band noise (BBN) · White noise · Temporary threshold shift · Permanent threshold shift

Introduction

Otoacoustic emissions (OAE) are generated by the cochlea and can be recorded by a small, sensitive microphone, placed in the external ear canal. OAEs are by-product of an active non-linear process involving the outer hair cells, which improves the hearing sensitivity and sharpens tuning by enhancing the vibration of a narrow region of the cochlear

partition. Transient evoked otoacoustic emissions (TEOAE) are recorded in response to transient stimuli and show a delay with respect to onset of the acoustic stimulus. Further, TEOAE are recorded in virtually all normal ears [1] but not in ears with hearing thresholds greater than 35 dBHL [2], except in rare occurrences of inner hair cells (IHCs) or retrocochlear disorders. The sensitivity of TEOAEs to separate hearing from hearing impaired ears reported to be as high as 90 % at frequencies of 2 and 4 kHz [3]. Thus, small changes in the biomechanical function of the cochlea can be monitored by measuring TEOAEs [4]. Noise exposure is believed to influence cochlear function and thus would alter the amplitude or frequency composition of OAEs [5].

Noise is probably the most frequent cause of sensorineural hearing loss in day-to-day life. Presence of high intensity noise occurring either continuously or intermittent impulses leads first to reversible temporary threshold shift (TTS) and later results in high frequency sensorineural hearing loss. It is well known that TTS can be changed into irreversible permanent threshold shift and has no known cure. Noise begins to stress the auditory system when sound levels exceed the 75–85 dBA range [6]. The chances of developing a TTS are considerable when the noise level is above the recommended limit of 85 dBA. However, individual susceptibility to noise exposure makes it difficult to predict temporary or, permanent damage to hearing sensitivity [6].

The effect of impulse noise on the cochlea differs considerably from that of continuous (steady-state) noise exposure [7, 8] in the way that impulse noise exerts a more direct mechanical effect, while steady state noise produces more metabolic changes. This difference may constitute a higher risk of damage from impulse noise than continuous noise of corresponding total sound energy. The hazard of impulse noise is more than continuous noise as former does not follow the ‘equal energy rule’ i.e. equal noise energy

P. Kumar (✉) · A. Barman
Department of Audiology, AIISH, Mysore 570006, India
e-mail: prawin_audio@rediffmail.com

K. Kumar
Kasturba Medical College, Mangalore 575 001, India

produces the same hearing loss [9]. In addition, histological studies in animals also suggest that impulse noise causes greater loss of the OHCs than IHCs loss [8, 10]. TEOAEs and DPOAEs are sensitive in detecting subtle changes in OHC even without a notable change in audiometric thresholds in individual following acute acoustic trauma [11] or after chronic noise exposure [12].

Thus, it is evident that the exposures to loud noise are likely to affect OHCs function and causing elevation of behavioral threshold. Test retest variability in behavioral threshold of an individual can be up to 10 dBHL. TTS due to short duration exposure of noise is usually obtained using pure-tone audiometry. This is known to be the good predictor of identifying individuals who are susceptible to hearing loss after exposure to noise. However the major factor, which can influence the test result using this method, is variation of, reducing the predictability of such effect. TEOAEs, which are also known to be generated by OHCs motility, thus can be an objective tool to predict such effect. Further, by recording TEOAEs, a subclinical cochlear lesion may be detected, and this is in agreement with the observation from animal studies that up to 30 % of the OHC population may be damaged prior to audiometric evidence [13].

Several authors tried to observe effect on TEOAEs amplitude due to short or long duration exposure to noise. However, the sensitivity of TEOAEs with noise and in predicting susceptibility of noise induced hearing loss (NIHL) has not been verified. Thus in the current study TEOAE is used in predicting susceptibility of NIHL. The same can be more useful as it is an objective test, which can be administered with in very short time.

Aim of the Study

The present study aimed to find out the effect on TEOAE amplitude after the exposure to short duration broad band noise (BBN). It also aimed to find out the efficiency of TEOAE to predict susceptibility of NIHL.

Method

Participants

A total of 40 ears from 20 adults in the age range from 18 to 30 years were taken for the study. Ten male and ten female were taken to minimize the gender effect and evaluated in random order so that order effects should not contaminate the results. The oral consent was taken from all the participants and they were explained in detail about the procedure of the study.

Participant Selection Criteria

Individual with pure tone threshold within 15 dBHL at octave and mid octave frequencies from 250 to 8,000 Hz were taken for the study. To evaluate the middle ear function GSI-TympStar was used. They had normal middle ear functioning as indicated by Immittance evaluation. It was ensure that all the subjects were in good health and no history of otological symptoms reported at the time of testing.

Instrumentation

A calibrated two channel clinical audiometer (OB-922) with TDH-39 headphones and bone vibrator BC-71 was used for pure tone audiometry. A calibrated immittance meter (GSI-TympStar) was used to assess the middle ear functioning of all the participants. TEOAE were measured using ILO 292 (software version 5) in standard default operational mode.

Test Environment

All the measurement was carried out in an acoustically treated double room situation. The ambient noise level was within the permissible level according to ANSI (1991) [14].

Test Procedure

Transient evoked otoacoustic emission were measured using non-linear click at 80 dB PeakSPL to estimate amplitude responses. A suitable probe with appropriate probe tip was used. Baseline TEOAEs amplitude was measured before exposure to noise with a good probe fit prior to recording. A total of 260 click stimuli were presented and the responses were averaged. Reproducibility of more than 50 % and an SNR of 3 dB or above was considered as a response. Overall TEOAE amplitude response and signal to noise ratio at 1000, 1500, 2000, 3000 and 4000 Hz were noted. After obtaining the baseline TEOAE response, all the subjects were exposed to 90-dBSPL white noise for 2 min through TDH-39 headphone. After the exposure of white noise all the subjects were given a gap of 2 min before measuring TEOAEs amplitude. This gap of 2 min was given as Hirsh and Ward [15] reported that TTS is more stable 2 min after the exposure of noise. Global TEOAE response and responses at 1,000–4,000 Hz were noted for comparison.

Results and Discussion

Data obtained from all the ears were subjected to statistical analysis using SPSS version 16. It includes descriptive

Table 1 Mean and standard deviation (SD) of pre and post-exposure TEOAE amplitude

Frequency (Hz)	Pre-exposure TEOAEs amplitude (SNR)		Post-exposure TEOAEs amplitude (SNR)	
	Mean	SD	Mean	SD
1,000	14.76	9.10	12.89	6.63
1,500	18.46	5.83	16.67	5.98
2,000	18.89	5.74	16.81	5.67
3,000	19.01	5.68	16.98	5.49
4,000	14.13	5.53	11.31	5.39
Global amplitude	12.47	4.68	9.97	4.13

Fig. 1 Mean and standard deviation (SD) of pre and post-exposure on TEOAE amplitude ** $p < 0.01$; *** $p < 0.001$

analysis to find out mean and standard deviation (SD) at each frequency and paired t test to find out whether any significant differences observed between pre and post-exposure of TEOAE amplitude responses at 1000, 1500, 2000, 3000 and 4000 Hz and global response exists.

From Table 1 and Fig. 1, it can be observed that there is gradual increase in TEOAE amplitude as frequency is increasing from 1,000 to 3,000 Hz including mid-octave frequencies (1,500 and 3,000 Hz) except 4,000 Hz for both before and after exposure of white noise. However, SD decreased as frequency increased from 1,000 to 4,000 Hz for both before and after exposure of white noise. The lesser SD at higher frequencies could be probably because of less variability among subject responses.

It is evident from the Table 2 that there is statistically significant reduction in TEOAE amplitude at all the frequencies except 1,000 Hz ($p > 0.55$) which also showed

marginal reduction in amplitude. Further, it is also observed that TEOAE amplitude is highly significant for global responses as well as at 3,000 and 4,000 Hz frequency.

In present study, there is significant difference between pre and post-exposure reduction in TEOAE amplitude. There were more shifts in TEOAE amplitude at higher frequencies i.e. above 1,500 Hz compare to low frequency. It is well establishes that the basal region of the cochlea is more susceptible to noise exposure and that lead to more reduction in TEOAE amplitude. The reduction in TEOAE suggests that OHCs are more prone to such effect as OAEs are generated by electro-motility of OHCs. This is also reported in chinchilla that the moderate levels of noise exposure, buckling of the supporting cells results in an uncoupling of the OHC stereocilia from the tectorial membrane, which results in a TTS [16]. Whereas moderate levels (105–110 dB SPL) of noise tends to induce more damage to the stereocilia of the IHCs than of OHCs.

The main drawback of present study could be that after every recording of TEOAE, probe was taken out, which would have lead to variation of the TEOAE amplitude. Every time the probe was inserted, there was a variation in the ear canal volume in spite of making effort to minimize the variation. However one can notice that TEOAE amplitude reduction is highly significant at 3,000 and 4,000 Hz ($p < 0.001$) which does justifies the sensitivity of the test to predict susceptibility of NIHL as noise induced damage of the cochlea starts predominately in the high frequency regions [17, 18].

Table 2 t Value and significance level between the pre and post-exposure TEOAE amplitude

Frequency (Hz)	t Value	Significance level
1,000	0.57	0.55
1,500	2.71	0.01
2,000	2.11	0.01
3,000	2.48	0.00
4,000	3.39	0.00
Global amplitude	6.13	0.00

Further, it is also claim that TEOAEs appears to be sensitive to the global cochlear state on the high frequency side rather than to the low frequency hearing threshold shift [19].

Conclusions

The present study showed that there were significant differences between the pre and post noise exposure reduction in TEOAE amplitude. Further, it is observed that highly significant reduction at higher frequencies (3,000 and 4,000 Hz) which indicates the effect of noise is more prone in basal region of cochlea. Thus, it can be considered that TEOAEs is sensitive enough to predict the susceptibility of NIHL. In addition, it can be suggested to use TEOAE to assess the susceptibility of cochlea, as it is an objective and non-invasive test and also can be assessed in a short time.

Acknowledgments The authors would like to thank the Director, AIISH, Mysore, for permitting to carry out this study. The authors also thank the staff of the department of audiology and the participants of the study.

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