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Comparison of stacked tone-ABR and chirp ABR in individual with normal hearing and sensorineural hearing loss

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ABSTRACT

Background: There are no published studies that compared amplitude of stacked-Tone ABR and Chirp ABR in hearing impaired individuals with sensorineural hearing loss, which need to be investigated. Objective of the study was to know whether amplitude of standard chirp evoked ABR is same as tone burst evoked stacked ABR in individuals with normal hearing listeners and individuals with sensorineural hearing loss.
Methods: Present hospital based cross sectional study was carried out at Malla Reddy Institute of Medical Sciences, from January 2016 to December 2016. Two groups of subjects were taken. Group I consisted of 20 ears (14 males and 6 females) with normal hearing. Group II consisted of 20 ears (11 females and 9 males) with cochlear hearing loss.
Results: Wave V Amplitude of stacked tone ABR was higher than Chirp stimuli evoked ABR wave V in both the groups. Amplitude of stacked tone ABR and chirp was smaller for individuals with sensorineural hearing loss than normal hearing. Between the 2 chirp stimuli, standard Chirp ABR amplitude was higher than modified Chirp in normal hearing listeners and individual with sensorineural hearing loss. For modified chirp in individuals with normal hearing and cochlear hearing loss. Latency obtained by standard chirp was longer compared to latency obtained by modified chirp, which is seen in both the groups.
Conclusions: Chirp ABR may be opted over stacked tone ABR in neurological investigations due to its lesser variability in amplitude and shorter duration of testing.

Keywords: Stacked tone ABR, Chirp ABR, Sensorineural hearing loss

INTRODUCTION

Don et al developed a measure to record the sum of the neural activity across entire frequency region of the cochlea in response to auditory stimulation.[1] This is achieved by using derived band technique (applying high pass along with click), wherein, response corresponding to different frequency regions of the cochlea are recorded. These responses are added together by time aligning the wave V of the responses (stacked method). This procedure would provide an approximate of the total neural activity. So it is assumed that the final response would include the synchronized activity from essentially whole of the cochlea (output compensation).

Philibert et al reported that output compensation can also be achieved by using stacked tone-ABR.[2] It is assumed that using brief tone stimuli such as tone bursts for recording ABR; the responses are elicited from narrow region along the basilar membrane corresponding to the stimulus frequency. The tone bursts were synthesized at same center frequencies as derived noise band method by Don et al.[3] They demonstrated that stacked tone ABR method showed good approximation of the derived band

method in achieving stacked wave V amplitude enhancement.

Later ABR by Don et al used chirp stimuli that are designed to compensate for cochlear travelling wave delay to record ABR (input compensation).[4] The travelling wave in the cochlea in response to brief stimulus like click takes a considerable amount of time to reach from the base of the cochlea to the apex, thus individual areas along the cochlea partition will not be stimulated at the same time. Thus the compound neural response will be temporally smeared. This temporal dispersion can be counteracted by delaying the higher frequency relative to the lower frequency of the stimulus. Such a scheme has to be based on an appropriate model of the cochlear travelling wave delay and to eliminate such delay chirp stimulus has been develop to record ABR.

Different type of chirp stimuli were used for input compensation while recording ABR. They are namely A-chirp (Neely et al), M-chirp (Dau et al) and O-chirp (Shera & Guinan).[5-7] Among the chirp stimuli, A-chirp was developed based on the traveling wave delay derived from latencies of Tone-ABR (Gorga et al) and M-chirp was derived from De-Boers cochlear model.[8,9]

However, there are no published studies that compared amplitude of stacked-Tone ABR and Chirp ABR in hearing impaired individuals with sensorineural hearing loss, which need to be investigated. Hence present study was conducted to know whether amplitude of standard chirp evoked ABR is same as tone burst evoked stacked ABR in individuals with normal hearing listeners and individuals with sensorineural hearing loss.

METHODS

Present hospital based cross sectional study was carried out at Malla Reddy Institute of Medical Sciences, from January 2016 to December 2016.

Two groups of subjects were taken. Group I consisted of 20 ears (14 males and 6 females) with normal hearing. Group II consisted of 20 ears (11 females and 9 males) with cochlear hearing loss.

Subject selection criteria

Group I: Individuals with normal hearing

a) It was ascertained from a structured interview that none of these participants had difficulty in understanding speech in daily listening conditions.
b) None of them reported to have any physical or general weakness at the time of testing.

Group II: Individuals with sensorineural hearing loss

a) Individuals with mild to moderate degree of sensorineural hearing loss having air conduction thresholds between 26 dB HL to 55 dB HL were considered for the study.
b) None of them reported to have any physical or general weakness at the time of testing.

The following instruments were used for the study

a) A calibrated two channel diagnostic audiometer (GSI 61) with TDH 50 head phone and B-71 bone vibrator was used to obtain pure tone thresholds.
b) A calibrated Immitance meter (GSI tympstar) was used to assess the middle ear function.
c) TEOAEs were recorded using ILO-V6 instrument.
d) ABR recordings were done using intelligent hearing systems (IHS) smart evoked potential (version 2.390) with ER-3A insert phone.

Stimuli

To record ABR for the experiment, tone burst and two types of chirp stimuli were used.

Tone-burst

To obtain stacked tone ABR, tone ABR were obtained at multiple frequencies namely 0.25, 0.5, 1, 2, 4, 8 kHz. Tone burst stimulus of 2-0-2 cycles was used. All these stimuli were readily available in the instrument.

Standard Chirp (Dau Chirp)

Standard chirp stimuli with frequency range of 0.1 kHz to 10 kHz was generated to record chirp ABR. Chirp stimulus was generated using a program written in MATLAB (version 2010) using the method described by Dau et al.[6] The stimulus was generated with a sampling rate of 44100 Hz and 8 bit resolution and was then converted to the IHS software acceptable format. Duration of the chirp stimulus was 10 msec.

Modified chirp (250 Hz – 8 kHz)

The Modified chirp with a frequency range of 250 Hz to 8 kHz was generated using MATLAB software. The modified chirp was also generated based on the equation given by Dau et al.[6] The duration of the modified chirp was 6 msec which was less compared to standard chirp. Figure 1 shows temporal representation of modified chirp and standard chirp.

Test environment

All the tests were carried out in a well illuminated air conditioned acoustically treated rooms. The noise level in room was within the permissible levels as recommended by ANSI (S 3.1 - 1991).[9]

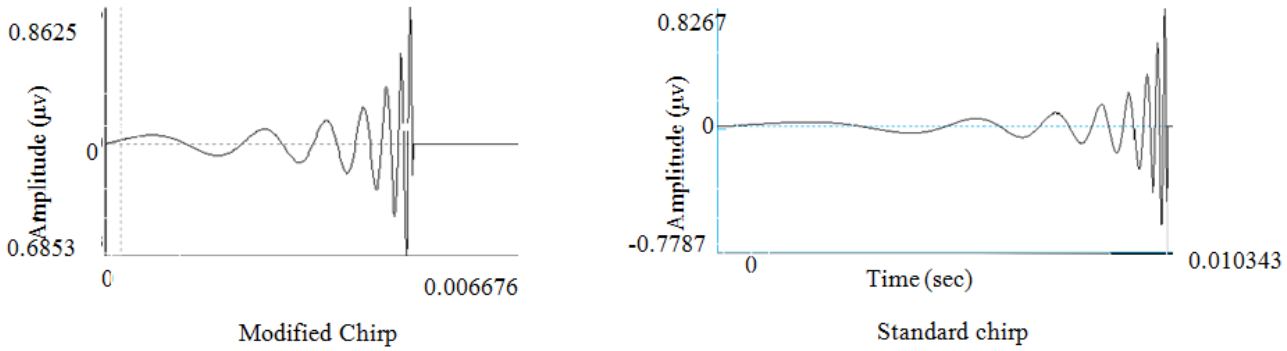

Figure: 1: Temporal representation of modified chirp and standard chirp.

Analysis

All the waveforms recorded were given to three qualified audiologists to mark wave V peak. If there was an agreement between all the audiologists, the waveforms were taken for further analysis. Wave V amplitude was measured for stacked tone ABR while amplitude and latency were noted for Chirp evoked ABR in Group I and Group II. Amplitude obtained from three different ABR wave forms elicited by three different stimuli was compared to see group and stimulus effect. Latency of wave V was also noted for standard chirp and modified chirp and was also compared to see group and stimulus effect.

RESULTS

It can be observed from Table 1 that the mean amplitude of stacked tone ABR and two different Chirp stimuli in both the groups are not the same. The mean amplitude was higher for stacked tone ABR compare to Chirp (standard & modified chirp) stimuli evoked ABR wave V in both groups. The mean amplitude of modified chirp was lesser than the standard Chirp evoked wave V amplitude in both groups.

Table 1: Mean and SD of amplitude of wave V obtained using stacked tone ABR method, standard chirp and modified chirp in Group I and Group II.

Stimuli	Subjects	Amplitude (Group I)		Amplitude (Group II)	
		Mean	SD	Mean	SD
Stacked Tone	20	2.18	0.60	1.32	0.28
Standard Chirp	20	0.67	0.08	0.39	0.07
Modified Chirp	20	0.51	0.06	0.35	0.09

Table 2: Bonferroni paired wise comparison between wave V amplitude elicited by stacked tone ABR and chirp (standard chirp & modified) evoked ABR.

Stimulus	Standard chirp	Modified chirp
Stacked tone	P<0.01	P<0.01
Standard chirp	-	P<0.01

Table 3: Mean and SD of wave V latency obtained using standard chirp and modified chirp in Group I and Group II.

Stimuli	Subjects	Latency (Group I)		Latency Group II	
		Mean	SD	Mean	SD
Standard chirp	20	12.94	1.12	13.99	0.94
Modified chirp	20	10.16	0.71	10.56	0.76

As the mixed ANOVA showed significant main effect of stimuli Bonferroni pair wise comparison was carried out to see the significance difference in amplitudes elicited between which two stimuli.

It can be seen in the Table 3 that the mean latency of modified Chirp evoked ABR was shorter than the standard Chirp evoked ABR in Group I and Group II.

DISCUSSION

The significant difference obtained between groups can be attributed to the following reason. In conditions of cochlear hearing loss, there would be lesser input to the neural elements due to sensitivity of hearing loss resulting in reduced amplitude of ABR peaks. It is known that stacked ABR is a result of total synchronized neural activity from different neural elements.[10] Therefore, reduction in input to neural fibers as a result of sensorineural hearing loss will cause significance decrease in Stacked ABR wave V amplitude.

Chirp (standard chirp & modified chirp) evoked ABR also showed higher amplitude in individuals with normal hearing than sensorineural hearing loss. This could be due to reduced signal information to the neural inputs because of structural or functional changes at level of cochlea due sensorineural hearing loss. This might have resulted in less number of neurons participated in generation of compound action potential in cochlear hearing loss and resulted in lesser amplitude.

Amplitude of stacked tone ABR in the present study was 2.1 µV, which is greater than that reported by Philibert et al.[3] The disparities in amplitude may be due to frequencies of tone burst used in the study. They have used 700 Hz, 1.4 kHz, 2.8 kHz, 5.7 kHz, and 11.3 kHz tone bursts to obtain stacked tone ABR wave V amplitude. However, in the current study 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz and 8 kHz frequencies of tone burst was used to obtain stacked tone ABR wave V.

Secondly, to obtain stacked tone ABR at various frequencies the duration of tone burst used was 2-1-2 by Philibert et al.[3] However, in the current study to obtain the stacked tone ABR wave V at various frequencies the duration of tone burst used was 2-0-2.

Amplitude obtained for stacked tone ABR was similar to those reported for stacked derived ABR by Dau et al. [6] Amplitude of stacked tone ABR in the present study was higher than that reported by Mahajan and Vanaja.[11] The disparities in amplitude may be due to frequencies of tone burst and filter settings used in both the studies. They have used 500 Hz, 1 kHz, 2 kHz, 4 kHz tone bursts and filter settings was 30 Hz- 3000 Hz to obtain stacked tone ABR wave V amplitude. However, in the current study 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz and 8 kHz frequencies of tone bursts and filter settings of 100-3000 Hz used to obtain stacked tone ABR wave V.

Amplitude obtained for the standard chirp in the present study was lower by 0.3 µV than that reported by Fobel and Dau.[12] This could be due to instrumental and procedural variations. In the present study ABR was recorded using IHS, whereas Fobel and Dau recorded ABR using TDT amplifier.[12] Further, they used a wider filter setting (30-3000 Hz) whereas in the present study filter setting was 100-3000 Hz, thus resulted in lower in wave V amplitude.

The mean amplitude of standard chirp and modified chirp evoked ABR was less than the stacked tone ABR in individuals with sensorineural hearing loss. To see whether the difference in amplitude between chirp-ABR's and stacked tone ABR wave V amplitude reaches significance level or not, a repeated measure ANOVA was carried out. The results revealed a highly significant main effect of stimuli [$F(2, 38)=172.85$, $p<0.01$] on wave V amplitude. To see the significant difference among the wave V amplitude elicited by different stimuli, Bonferroni paired wise comparison was performed. Results revealed that there was a highly significant difference ($p<0.001$) in amplitude of stacked tone wave V amplitude and chirp (standard chirp & modified chirp) wave V amplitude. However, no significance difference ($p>0.01$) in mean amplitude of standard chirp and modified chirp evoked ABR wave V amplitude.

Mean Amplitude of stacked tone ABR in the present study was 1.32 µv, which is higher than that reported by Mahajan and Vanaja in individuals with cochlear hearing loss.[11] The disparities in amplitude may be due to frequencies of tone burst and filter settings used. They have used 500 Hz, 1 kHz, 2 kHz, 4 kHz tone bursts and filter settings was 30 Hz- 3000 Hz to obtain stacked tone ABR wave V amplitude. However, in the current study 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz and 8 kHz frequencies of tone bursts and filter settings of 100-3000 Hz was used to obtain stacked tone ABR wave V.

A significant group difference was not seen for modified chirp evoked ABR wave V latency [$F(1, 38) = 39.581$, $p<0.01$].

It can be attributed to the following reason. Wave V latency of standard chirp ABR showed significantly longer in individuals with sensorineural hearing loss compared to normal hearing. This could be due to impaired cochlea response which leads to increase in latency in individuals with cochlear hearing loss.[1]

In Modified chirp evoked ABR there was no significant difference between individuals with normal hearing and cochlear hearing loss. This could be due to high variability in latency of Chirp evoked ABR than the amplitude.[13]

CONCLUSION

Keeping in view of all the above mentioned results of the present study, it can be concluded that, Chirp ABR may be opted over stacked tone ABR in neurological investigations due to its lesser variability in amplitude and shorter duration of testing.

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