Comparison of Stacked tone-ABR with Chirp ABR in normal hearing listeners

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June - 2011

Dedicated

To

My grand father

CERTIFICATE

This is to certify that this Independent project entitled "**Comparison of Stacked tone ABR and Chirp ABR in normal hearing listeners**" is a bonafide work submitted in part of fulfilment for the degree of Post graduation diploma in Neuroaudiology of the student Registration No: 10DNA008. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

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CHAPTER-1

INTRODUCTION

The auditory brainstem response (ABR) remains one of the most useful clinical procedures for the examination of auditory sensitivity and auditory system integrity. The acoustical click also remains the most popular stimulus for neurodiagnostic-oriented ABR evaluations. The rapid onset of the click and its broad band frequency content results in the activation of a wide area of the basilar membrane and consequently, a robust response. Click evoked ABRs have been shown to be useful in a range of applications and are highly effective in site of lesion testing of the lower auditory pathway (Durrant and Ferraro, 1999).

The use of broadband click does not permit direct analysis by frequency (Oates and Stapells, 1997), yet the recorded response does not reflect response across the entire audible spectrum. The click evoked ABR reflects primarily the output of only the basal 1 1/2 turns or so of the cochlea (Hecox and Galambos,1978). And is best correlated sensitivity-wise with hearing in the 2000-4000 Hz region (Coats and Martin, 1977; Jerger and Mauldin, 1978). This may therefore limit the clinician's ability to detect cochlear nerve and brainstem dysfunction. Since the entire VIIIth nerve is not assessed effectively (Durrant and Ferraro, 1999). Although conventionally the click evoked ABR is less sensitive in detecting intracranial tumors (Wilson et al, 1999) .because of the recent advances in imaging (MRI). It is now possible to detect those very small tumors (Gordon et Cohen, 1995). However since MRI remains a relatively expensive test, there have been efforts to develop a new method that is Don and Eggermont(1978) demonstrated the applicability of the masking technique of Teas et al(1962) to ABR measurement to obtain frequency specific information.

Don et al., (1994) developed a measure to record the sum of the neural activity across entire frequency region of the cochlea in response to auditory stimulation. This is achieved by using derived band technique (applying high pass along with click), response corresponding to different frequency regions of the cochlea will be recorded. These responses will be added together by time aligning the V peak of the responses (stacked method), this procedure would provide an approximate the total neural activity. So it is assumed that the final response will include the synchronized activity from essentially whole of the cochlea (Output Compensation).

Philibert et al. (2003) reported that output compensation can also be achieved by using stacked tone-ABR. 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. (1997). They demonstrated that stacked tone ABR method show good approximation of the derived band method in achieving stacked wave v amplitude enhancement.

ABR were recorded by Dau et al. (2000) using chirp stimuli that are designed to compensate for cochlear traveling wave delay (input compensation).The traveling wave in the cochlear 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.

Different type of chirp stimuli were used for input compensation while recording ABR. They are namely A-chirp (Neely et al., 1988), M-chirp (Dau et al., 2000 and O-chirp (Shera and Guinan (2000). Among the chirp stimuli, A-chirp was developed based on the traveling wave delay derived from latencies of Tone-ABR (Gorga et al. 1988) and M-chirp was derived from De-Boers (1980) cochlear model. Dau et al. (2000) compared the amplitude of chirp-ABR and derived band ABR and showed that, amplitude of chirp-ABR is much lower than that of stacked derived band ABR. Don et al., (2009) has said that chirp ABR may be good tool identifying the small acoustic tumors. However, there no published studies that compared amplitude of stacked-Tone ABR, M-chirp ABR and A-chirp ABR.

Need of the Study

An aggregate neural activity across entire frequency region of the cochlea can be achieved using stacked ABR (output compensation) and chirp-ABR (input compensation). It has been demonstrated that stacked-ABR obtained either using derived band method or tone-ABR are equally efficient in identifying the "small vestibular schwannoma". The response amplitude of the chirp-ABR should be similar to stacked-ABR. Because, the latency adjustment was done the stimulus for chirp whereas in stacked ABR the latency adjustment is done on the basis of the derived narrow-band responses. Then both methods would be equally appropriate in identifying the "small vestibular schwannoma". If the stacked tone-ABR is similar to the chirp ABR with respect to amplitude and variability in amplitude then chirp-ABR can be used instead of stacked tone ABR. Using the chirp will dramatically reduce the test time and discomfort to client. The present study is aimed investigating comparing the stacked –tone ABR with M-chirp and A-chirp-ABR in normal hearing listeners.

Aim of the study

To investigate the difference in amplitude parameter of ABR obtained using staked tone technique and chirp stimuli.

Objectives

1. Compare amplitude of the stacked-tone ABR with M-chirp and A-chirp ABR
2. Compare amplitude of the M-chirp with A-chirp ABR
3. Compare the variability in amplitude for stacked-tone ABR, M-chirp and A-chirp ABR

CHAPTER-2

REVIEW OF LITERATURE

The auditory brainstem response (ABR) remains one of the most useful clinical procedures for the examination of auditory sensitivity and auditory system integrity. The acoustical click also remains the most popular stimulus for neurodiagnostic-oriented ABR evaluations. The rapid onset of the click and its broad band frequency content results in the activation of a wide area of the basilar membrane and consequently, a robust response. Click –evoked ABRs have been shown to be useful in a range of applications and are highly effective in site of lesion testing of the lower auditory pathway (Durrant & Ferraro, 1999).

The stacked ABR as described by Don, pontoon, Eggermont and Masuda (1994) is a measure which records the sum of the neural activity across entire frequency region of the cochlea in response to auditory stimulation. Using appropriate technique the responses from the different frequency regions of the cochlea will be recorded. These responses will then be added together to approximate the total neural activity (stacking method). So it is assumed that the final response will include the synchronized activity from essentially whole of the cochlea. It also hypothesized that the stacked ABR reduced background residual noise in the ABR wave form and hence reduces the variability seen in the amplitude measures of the ABR (Don et al, 1994).

Methods to record stacked ABR

Primarily two methods have been used to record stacked ABR. They are derived band technique and tone burst method.

A) **Derived band technique**:

This technique has been used to record frequency specific responses from the cochlea. The first major study of the use of derived band masking methods is generating frequency specific auditory evoked responses is that of (Teas et al (1962)) on an animal model, with the derived band response method, an ABR is generated a sound that includes the stimulus (generally clicks) plus a masker (narrow band noise or pure tone masker) that has contribution from portions of cochlea other than those underlying the stimulus. The ABR waveform for clicks is subtracted from the ABR waveform for the noise plus click condition. Theoretically during the subtraction process, the contribution of the masker to the wave form (and non stimulus frequency regions of the cochlea) is removed leaving only the ABR for the spectrally constrained stimulus (Hall, 1992).

Don, Ponton, Eggermont and Masuda (1994) were the first to record stacked ABR, they obtained frequency specific ABR using derived band technique and summed these responses after temporally aligning wave V in each response. They used stacked ABR to investigate whether variability in cochlear response times would also lead to variability in click evoked ABR amplitude, they compared stacked ABR recording with un masked ABR recordings and concluded that variability in amplitude related to temporal aspects of cochlear activation and response times and not related to the central conduction time. Stacked ABR reduces the residual noise and hence reduces the variability of amplitude of ABR peak between runs.

Don, et al. (1997) was the first to use derived band technique to record stacked ABR to detect small acoustic tumors. They adopted the technique given by Don and

Eggermont (1978) in which derived ABRs are obtained using ipsilateral pink noise masking, the noise was presented at a level sufficient to mask the ABR to the clicks presented alone and clicks presented with ipsilateral noise high pass filtered at 8,4,2,1and 0.5kHz. This procedure resulted at five derived band ABRs representing activity initiated from regions of the cochlea ~1 octave wide. The stacked ABR was constructed by time shifting the wave forms so that peak latencies of wave V in each derived band coincide, and then adding the shifted derived band waveforms.

The amplitude of the stacked ABR wave V reflects more directly the total amount of cochlear activity. The ABR amplitude for the wave V increases with derived band temporally aligned responses (stacked ABR) as compared to summed natural derived band responses in individual with normal hearing (Don et al, 1994), the derived band method require a masking technique that may not be readily available to the clinicians. Furthermore, relatively high level noise required for masking may be annoying to the patient.

Tone burst method:

Philibert et al. (2003) developed an alternative method called stacked tone burst evoked ABR to overcome the disadvantages of the derived band stacked ABR. It is assumed that, using brief tone stimuli such as tone bursts for recording ABR the responses elicited from narrow region along the basilar membrane corresponding to the stimulus frequency. Bekesy (1960) demonstrated that the higher frequencies in the sound will vibrate only the basal region of the basilar membrane and lower frequencies will vibrate apical regions. However several investigations have reported that when using low frequency stimuli at suprathreshold level the responses are mediated by high frequency regions of the cochlea (Oates & Stapells, 1997). But when stimulus intensity is decreased, tone evokes a response through the region of cochlea specific to its frequency (Stapells & Picton 1994).

Stacked ABR as constructed by temporally aligning the ABR wave forms recorded from different frequencies and subsequently adding them. Wave V was marked in the final summed wave form and its peak to peak amplitude was measured. It was concluded that TB method shows good approximation of the derived band method in achieving staked wave V amplitude enhancement. There was no significant difference between ABRs obtained using the two methods and tone burst method demonstrated similar enhancement of wave V as that of the derived band method. The morphologies differed between two methods are relatively high reproducibility was noted with tone burst evoked ABR particularly at lower frequencies. This may be due to more basal ward spread excitation potentially gives a more synchronous response to low frequency tone burst than the derived band ABR.

The chirp stimulus

The traveling wave in the basilar membrane in response to brief stimulus like click takes a considerable amount of time to reach from the base of the cochlea to the apex i.e., from the highest to the lower frequency areas, thus individual areas along the cochlea partition and corresponding hair cells and nerve fibers of the auditory nerve 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 and the functional relationship between stimulus frequency and place of maximum displacement (Grennwood, 1990). De Boer (1980) developed linear cochlear model in which he assumed that all viscosity effects were negligible. All movements were assumed to be so small that the fluid as well as the BM operates linearity.

A chirp stimulus was developed which theoretically produces synchronous discharges of VIIIth-nerve fibers along the length of the human cochlear partition. The concept of the chirp was applied to auditory electrophysiology by Shore and Nuttall (1985), and since has been studied intensively for its use within the auditory field. A chirp stimulus or more specifically an upward chirp is designed to compensate for the temporal dispersion in the cochlea related to the traveling wave delay, e.g., (Shore & Nuttall 1985). The equations defining the chirp were calculated to be the inverse of the delay-line characteristic of the cochlear partition on the basis of the linear cochlea model by de Boer (1980). ABR were recorded by shore and Nuttall (1985) and Dau et al, (2000) using chirp stimuli that are designed to compensate for cochlear traveling wave delay.

Types of chirp stimuli

Different studies done using rising chirp stimuli had used different models and formulas to generate rising chirp stimuli.

Different types of rising chirps

1) A-chirp: is ABR based chirp stimuli which was developed based on the tone –burst evoked ABR data by Gorga et al (1988). They used tone bursts at ten frequencies (0.25,

0.5, 1, 1.5, 2, 3, 4, 6, and 8 KHZ) and nine intensities (20 to 100 db SPL in 10 db steps) and obtained this stimulus.

2) O-chirp: also called as OAE based chirp stimulus was developed based on the experimental SFOAE data by Shera and Guinan (2000). They did experiments for stimulus frequencies in the range from 0.5 to 10 KHZ in humans. At a level of 40 db SPL and from his data they formulated the chirp stimulus.

3) Exact chirp stimuli: this stimulus was generated by Dau et al, (2000) using Deboer's cochlear model. In this stimulus spectral weightege to higher frequencies was not given thus the spectrum of the chirp stimuli was not flat.

4) M – chirp: also called as modified chirp was developed by Dau et al (2000). They developed chirp with flat magnitude spectrum and denoted it as the flat spectrum chirp. Since this chirp based on de Boers model (1980). It is also referred to as the M-chirp. The same Corse of the chirp developed and used in the study by Dau et al (2000) was determined by the travelling wave velocity along the partition is derived by the Boer(1980).

Out of these chirp stimuli most commonly used chirp was A-chirp (Don et al, 2000; Wegan &Dau, 2002, Feobel & Dau , 2004)

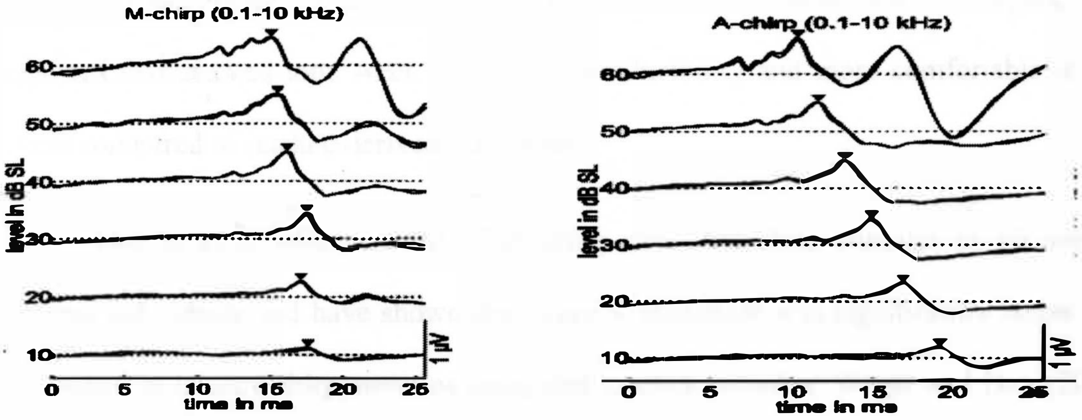

Figure 2.1.wvaeforms for A-chirp and M-chirp (fobel, Dau., 2000).

Chirp and stacked tone ABR

The stacked ABR and chirp ABR are the two amiable tools compensate delay in the cochlea and gives robust amplitude with less variance. Hence these tools were used to detect small acoustic neuroma (<1cm) by few investigators philibert et al, (2003), Don et al,(2009).This section of the review compares the parameters of stacked tone-ABR and Chirp ABR.

Mahajan & Vanaja (2006) has recorded stacked tone ABR in 5 ears with normal hearing listeners and 22 ears with cochlear pathology cases. They demonstrated that there is a significant difference in amplitude between normal hearing listeners and cochlear pathology cases and also reported that decrease in amplitude as increase severity of hearing loss. These results suggest that caution should be taken while interpreting data of stacked ABR in individuals with hearing loss. Philibert et al (2003) has recorded stacked tone ABR and stacked derived band ABR in 10 normal hearing listeners as well as in small in 10 unilateral vestibular schwannoma. Results demonstrated that there is no significant difference in amplitude and latency between these two techniques, and reported that stacked tone ABR has good reproducibility and more comfortable to the client compared to stacked derived band ABR.

Dau et al (2000) recorded ABR using click and chirp stimulus in 10 normal hearing individuals and have shown that wave V amplitude was significantly larger and prolonged in latency chirp stimulus compared to click stimulus. Weger and Dau (2002) has recorded ABR responses evoked by click and chirp stimuli in the presence of high masking noise with cut off frequencies of 0.5, 1, 2, 4, 8KHz from 9 normal hearing subjects. Results have demonstrated chirp evoked larger wave V amplitude in all the masking conditions than click.

Feobel & Dau (2004) recorded chirp ABR for three different types of chirps, they are namely A-chirp, M-chirp and O-chirp (disruption of them is given above), in 9 normal hearing listeners. They reported a wave V amplitude and latency of differences between different types of chirps they are A-chirp, M-chirp and O-chirp. Their resulst showed that the A-chirp amplitude was doubled than the M-chirp at low sensation levels, but at high sensation levels the amplitude was similar for both of the stimuli. Among these chirps A-chirp derived responses has good reproducibility and constant wave V latency measures.

Vignesh & Barman (2008) recorded click evoked ABR and chirp evoked ABR in30 ears with normal hearing listeners. Results demonstrated that the latency was prolonged with compared to click on normal hearing listeners, and amplitude is twice higher in chirp ABR compared to click ABR. Similar results were also demonstrated by many other investigators (Dau et al., 2000).

Elberling et al (2008) compared chirp amplitude ratio (amplitude of chirp/ amplitude of click) with the stacked amplitude ratio, and results demonstrated that stacked ABR has larger amplitude than the chirp ABR. Further they also demonstrate that amplitude ratio also higher for stacked ABR than the chirp ABR, however, more variation in the data was noticed for stacked ABR amplitude ratio than chirp ABR amplitude ratio. Based on the results obtained in Elberling et al (2008), Don et al., (2009) has said that chirp ABR may be good tool identifying the small acoustic tumors.

Overall, the above studies indicate that, stacked ABR is currently available tool for identifying the small acoustic tumors, as it has very good amplitude and less variability compared to click ABR. Further, it is noted that obtaining stacked ABR takes long time and causes discomfort for clients. A newly developed Chirp stimulus also has higher amplitude than click, so chirp can also be used as tool for detecting small acoustic tumors. However, there no published studies that compared amplitude of stacked-Tone ABR, M-chirp ABR and A-chirp ABR.

CHAPTER-3

METHOD

The following method was adopted to investigate the amplitude difference between stacked tone burst evoked ABR in normal hearing listeners and chirp.

Participants

10 normal hearing subjects in the age range of 20-50 years with mean age of 22 years participated in the present study. It was ascertained from a structured interview that none of these participants had difficulty in understanding speech in daily listening conditions, and that they did not have any history of neurologic or otologic disorder. All the participants had pure-tone thresholds of less than 15 dB HL (ANSI S3. 1-1991) at octave frequencies between 250 Hz to 8000 Hz and a speech identification score of greater than 90 % at 40 dB SL (ref: pure-tone average at 500 Hz, 1000 Hz, 2000 Hz and 4000Hz). Immittance evaluation and recording of as well as transient Otoacoustic emissions revealed normal findings in all the participants.

Instrumentation

The following instruments were used for the study

a) A calibrated two channel diagnostic audiometer (AC40) with TDH 39 head phone and B-71 bone vibrator was used to obtain pure tone thresholds.

b) A calibrated immittance meter (GSI tympstar) was used to assess the middle ear function.

c) A TEOAE were recording using ILO292 dB echo port instrument.

d) ABR recordings were done using intelligent hearing systems (HIS) smart evoked potential systems (version 2.390) with Insert ER-3A.

Stimuli

a. Tone-burst

To obtain stacked tone ABR, tone ABR was obtained at multiple frequencies namely 0.5, 1, 2, 4 kHz. Tone burst stimulus was of 2-0-2 cycles with 70 dBnHL. They are inbuilt stimuli within IHS systems. Figure-1 shows the 500 Hz and 1kHz tone-burst waveforms long with their spectrum.

b. Chirp Stimuli

Rising chirp stimuli with frequency range of 0.1 kHz to10 kHz and 70dBnHL intensity was generated to record chirp ABR. Two types of chirp stimuli were generated. They are as follows:

1. ABR-based chirp stimulus (A-chirp)

This chirp stimulus developed in this study based on the tone-ABR data by Gorga et al., (1988). They used tone-burst at ten frequencies (0.25, 0.5, 0.75, 1, 1.5, 2, 3, 4, 6 and 8 kHz) and nine intensities (20 to 100 dB at 10dB SPL steps). Neely et al., (1988) developed power law relation to latency to stimulus frequency. From the power law Neely described the BM group delay. Based equation described by Neely et al., (1988) and Feobel & Dau, (2004) described the instantaneous phase and amplitude and amplitude of chirp stimulus. Based on the above described equations by Fobel & Dau, (2004), A-chirp was developed for 50dB SL at 44.1 kHz sampling rate.

2. Model Based Chirp stimulus (M-chirp)

Dau et al., (2000) derived chirp stimulus from linear cochlear model described by de Boer's (1980) from which they developed equations for BM-group delay and instantaneous phase. Based these described equations by Dau et al., (2000), M-chirp was generated at 44.1 kHz sampling rate. Figure 2 shows stimulus waveform and the corresponding spectrum. These stimuli were further loaded in HIS system and were converted to the IHS software acceptable format. The output of these stimuli is calibrated using to 70 dB SPL using SLM.

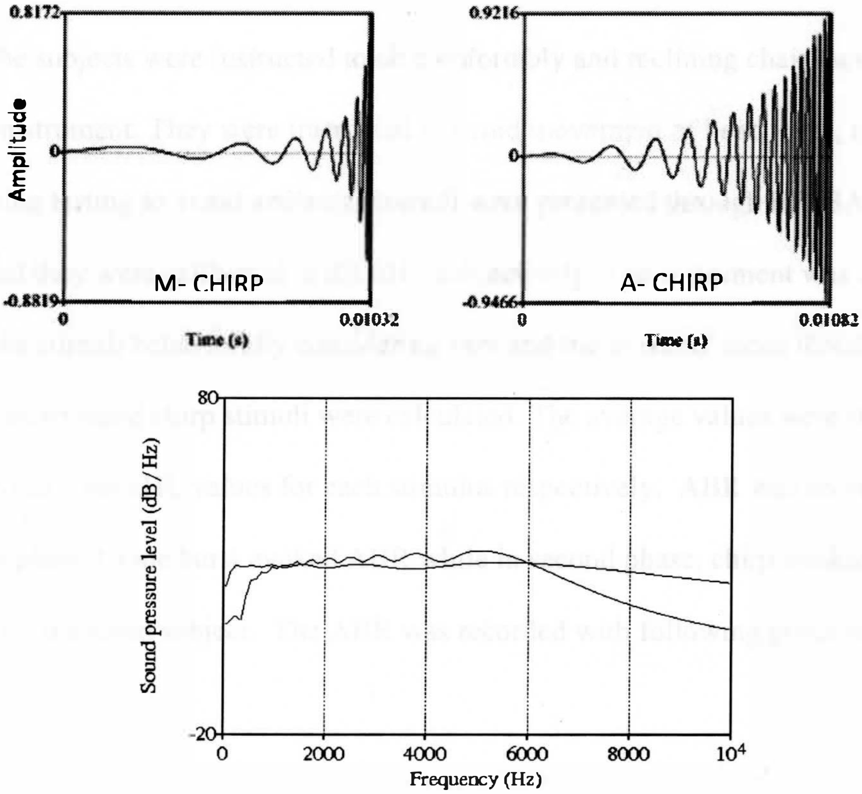

Figure: 3.1. Temporal and Spectral representation of M-CHIRP and A-CHIRP

Test environment

All the tests were carried out in a well illuminated air conditioned rooms which were acoustically treated. The noise levels were within permissible levels as recommended by ANSI (1996)

Procedure

Pure tone thresholds were obtained using modified Hughson and Westlake procedure (Carhart & Jerger , 1959), across octave frequencies from 250 to 8000Hz for air conduction and 250 to 4000Hz for bone conduction. Tympanometery and reflexometery was carried out to rule any middle ear pathology.

Recording procedure for AEP's

The subjects were instructed to sit comfortably and reclining chair facing away from the instrument. They were instructed to avoid movement of head, eyes, neck and limbs during testing to avoid artifacts. Stimuli were presented through ER -3A insert ear phones and they were calibrated in dB nHL subjectively. The instrument was calibrated for both the stimuli behaviorally considering ears and the average/ mean threshold for both tone burst stand chirp stimuli were calculated. The average values were than considered as 0 dB nHL values for each stimulus respectively. ABR was recorded in 2 phases. In phase 1 tone burst evoked ABR while in second phase, chirp evoked ABR was recorded for the same subject. The ABR was recorded with following given in the table.

Electrode placement:

Responses will be differentially recorded from AgCl electrodes with each electrode impedance < 5 kΩ. inverting electrode will be placed on test ear mastoid. Non Inverting electrode will be placed on the upper forehead and common electrode will be placed on the non test ear mastoid

Table 3.1. *Stimulus parameters used to record stacked tone- ABR and Chirp ABR*

Stimuli	Tone burst(0.5,1,2,4KHz)	Chirp (A-chrip and M-chrip) (0.5-10kHz)
Duration of stimuli	2-0-2	10msec
Polarity	Rarefraction	Rarefraction
Stimuli level	70dBnHL	70dBnHL
Repetition rate	11.1/sec	11.1/sec
Filter settings	100-3000HZ	100-3000HZ
Number of averages	1600	1600
Notch filter	OFF	OFF
Gain	10000	10000

Analysis

All the waveforms recorded were given to two qualified audiologists to mark wave 1 iii v peaks. If there is an agreement between the audiologists, the waveforms were taken for the further analysis. Absolute latencies and peak to peak amplitude were measured for each of the identified peaks.

- Descriptive stastics(mean and standard deviation) for latency and amplitude parameters were computed for stacked tone burst and chirp evoked ABR wave v obtained at one intensity level (70 db nHL)
- Paired t-test were applied to compare the stacked tone ABR and chirp evoked ABR wave v amplitude and latency at 70 db nHL.

Phasel : The wave v was identified at all presence of tone ABR was determined by replicating the wave v vertex. The change in latency with change in frequency of the stimuli was also used to confirm the presence of response. The wave v recorded at all frequencies were time aligned and these aligned waveforms were added the peak to amplitude of the added waveform was measured

Phase2: chirp evoked ABR were also recorded at 11.1/sec repetition rates for the intensity levels of t70 dBnHL. The procedure adopted to estimate ABR thresholds using click stimulus was used establish chirp evoked ABR thresholds.

CHAPTER-4

RESULTS AND DISCUSSION

The present study compares the amplitude between stacked tone ABR and chirp evoked ABR. To investigate the aim of the study ABR was obtained for tone burst at different frequencies to obtain stacked tone ABR and for two different chirp stimuli. ABR waveforms were analyzed for latency and amplitude. The obtained data was tabulated and subjected to statistical analysis using SPSS software (version, 10.0).

Stacked tone ABR

Table 4.1 show the mean latencies and amplitude of ABR obtained for different frequencies. The mean latency was longer for 500 Hz and shorter for 4 k Hz tone-burst, whereas, amplitude of tone ABR was higher for 500 Hz and lower for 4 KHz. The latencies and amplitude observed in the present study were similar to those reported by earlier investigators (Gorga et al., 1988). The wave V latencies were longer for 500 Hz compared to 4000 Hz, this effect is due to delay in the travelling wave (Don & Eggermont, 1978).

Table 4.1 : *Mean and SD of amplitude and latency for tone-ABR at different frequencies and stacked tone ABR.*

TONE BURST Frequency	**AMPLITUDE**		**LATENCY**	
	Mean	**SD**	**MEAN**	**SD**
500Hz	0.51	0.074	7.78	0.66
1000Hz	0.44	0.096	6.75	0.43
2000Hz	0.33	0.093	6.31	0.29
4000Hz	0.27	0.051	5.91	0.20
Stacked ABR	**1.4**	**0.25**	**5.95**	**0.4**

The obtained wave forms at all the frequencies for each subject was aligned to mean latency and added to obtain the Stacked tone ABR. For comparison of tone-ABR and stacked tone ABR, example of waveforms for tone-ABR at different frequencies and stacked tone ABR is presented in the Figure 1. The obtained stacked tone ABR waveforms were analyzed for peak to peak amplitude. From the Table 1 it can be ascertained that mean amplitude of the staked tone ABR is much higher than the individual amplitude of all the frequencies.

Similar to present study Phlibert et al (2003) and Don et al., (1994) also reported that ABR amplitude for individual's frequencies is much smaller than stacked ABR amplitude. Amplitude of stacked tone ABR in the present study was 1.4, which is similar to that reported by Phlibert et al (2003). Amplitude obtained for stacked tone ABR was similar to those reported for stacked derived ABR by Dau et al., (2000; 1994). Despite of procedural and stimulus differences between stacked tone-ABR and derived band stacked ABR, amplitude obtained was similar. Which suggest that either of two procedures may be used in the diagnosis of the small tumors.

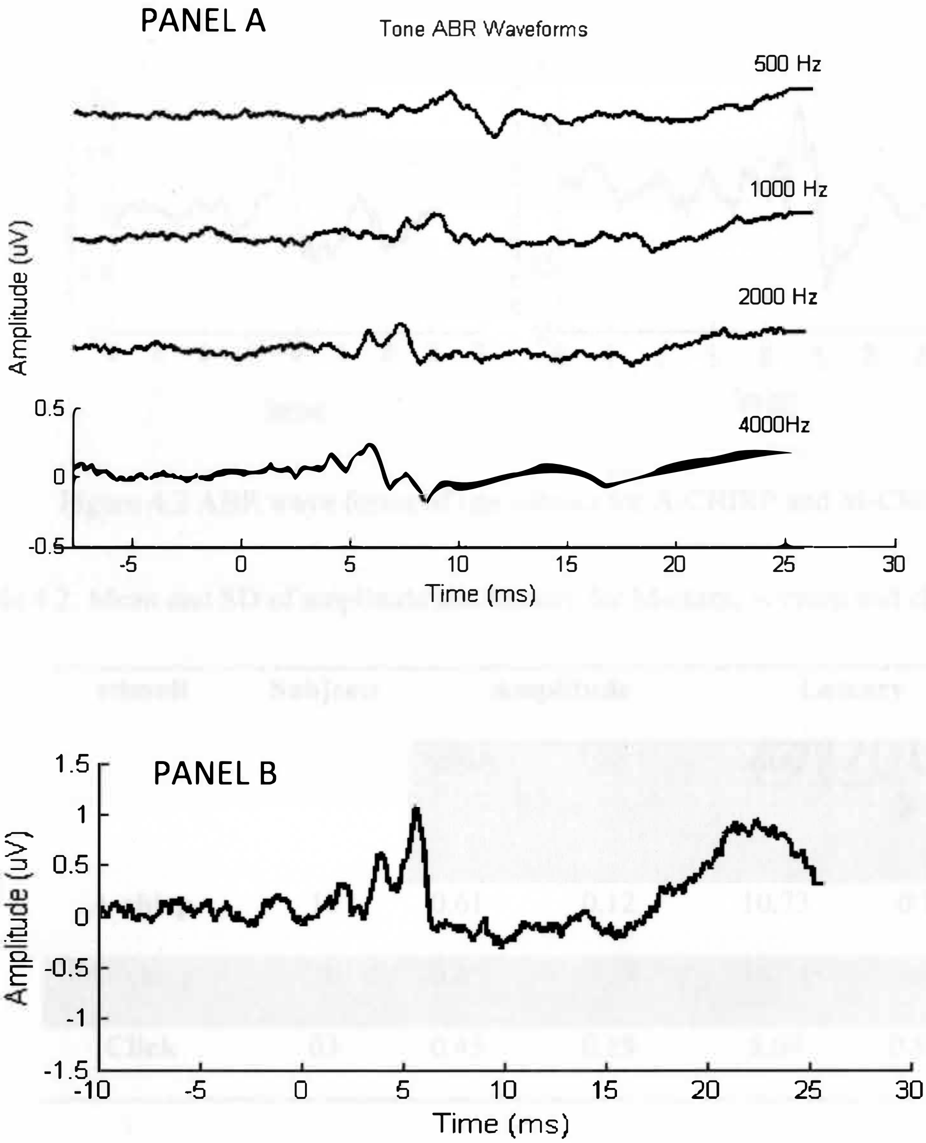

Figure 4.1: ABR waveforms for one subject. Panel A: The responses are shown for 500 Hz, 1kHz , 2kHz and 4 kHz at 70 dB nHL. Panel B: Stacked tone-ABR, obtained by aligning for mean latency and adding the waveforms.

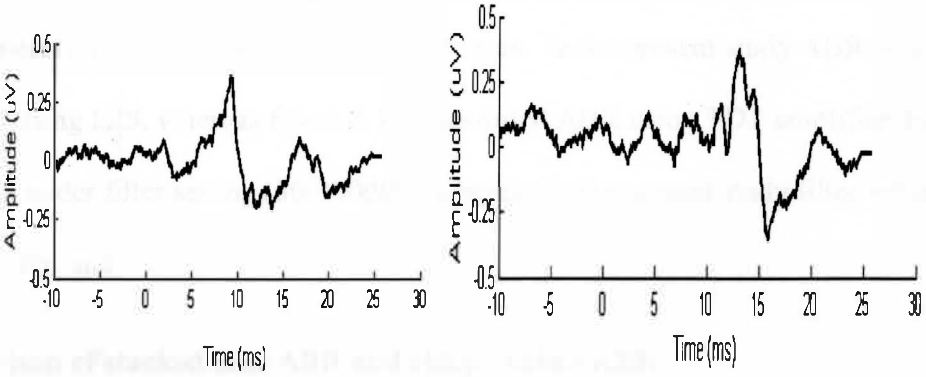

Figure 4.2 ABR wave forms of one subject for A-CHIRP and M-CHIRP.

Table 4.2. Mean and SD of amplitude and latency for M-chirp, A-chirp and click.

stimuli	**Subjects**	**Amplitude**		**Latency**	
		Mean	SD	Mean	SD
A-chirp	10	0.61	0.12	10.73	0.7
M-chirp	10	0.65	0.13	14.54	0.4
Click	03	0.43	0.19	5.64	0.89

From the Table 4.2 one read that latency for M-chirp was longer compared to A-chirp. Similar results were reported by Fobel & Dau, (2004). The latency values observed in the present study were approximately similar to that reported by Fobel & Dau, (2004) at 50 dB SL (approx 65-70 dB SPL). Figure 2&3 presents the waveforms of 1 subject for M-chirp and A-chirp. Amplitude of the ABR for both the chirp stimuli was similar in the present study. However, Fobel & Dau, (2004) reported that the ABR amplitude obtained with A-chirp was higher than M-chirp at lower SL's and approximately equal at 50 dB SL. However, amplitude obtained in the present was lower by 0.3µV than that reported by Fobel & Dau (2004). The difference in amplitude may be due to instrumentation and procedural differences. In the present study ABR was recorded using HIS, whereas Fobel & Dau recorded ABR using TDT amplifier. Further, they used wider filter setting (30-3000Hz) whereas in the present study filter setting was 100-3000Hz. and

Comparison of stacked tone ABR and chirp evoked ABR

From the Figure 4.3 one can observe that amplitude of chirp ABR for both A-Chirp and M-chirp was one half of the stacked tone-ABR. To see whether the difference in amplitude between chirp-ABR's and stacked ABR reaches significance, an independent sample 't' was performed. Results of independent sample t test revealed that there was a significant difference ($p<0.001$) in mean amplitude of stacked tone wave V amplitude and chirp (M-chirp and A-chirp) wave V amplitude. This amplitude of chirp ABR compared to Stacked tone ABR can be attributed to two reasons.

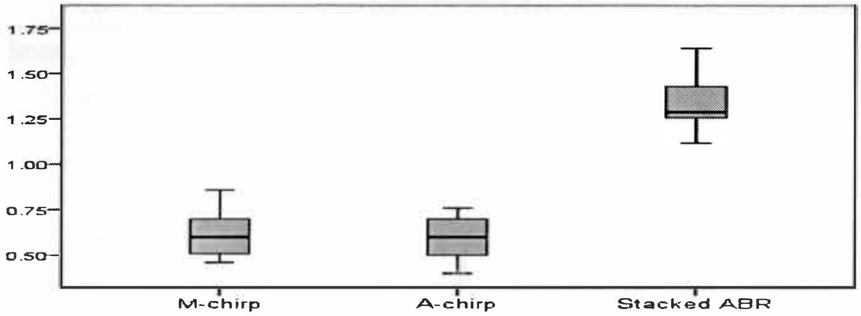

Figure4.3: Comparison of amplitude of stacked ABR and CHIRP ABR

Firstly, Amplitude of chirp ABR is assumed to be the sum of responses of all the neurons of VIII cranial nerve, stacked ABR amplitude is derived by adding responses of neurons for different frequencies obtained individually. While using tone ABR, there is some spread of excitation at each frequency, hence there is high possibility of a group of same neurons responding again for another tone burst though not of same amplitude. In stacked ABR a multiple compound potentials of different groups of neurons (some overlapping neurons) to different stimuli will be added. Hence, a summation of multiple compound potentials (stacked ABR) would always give a higher value than a single compound potential (Chirp ABR). In Chirp ABR it is the compound action potential recorded for a single stimulus which is been aligned temporally to give summed response of all the auditory neurons in a single compound potential.

Secondly, for a chirp at lower levels of stimulation, each frequency component excitation by the individual frequency component excites only a restricted area of the cochlea, but at higher levels the excitation spreads-especially towards the base of the cochlea (upward spread of excitation) leading to desynchronization, because each location will now be excited by a broader range of frequency components each arriving at a different point in time. Hence chirp is more sensitive and yields greater amplitudes at lower intensity levels whereas stacked ABR amplitude increases linearly with the stimulus level.

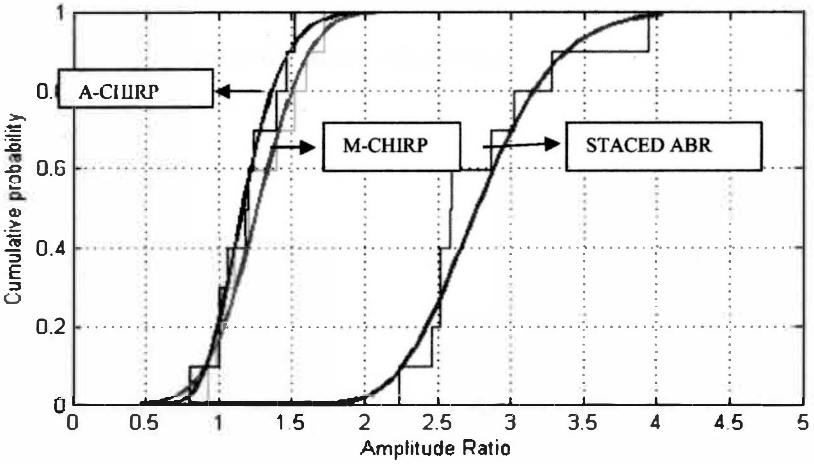

Figure 4.4: Cumulative distribution of amplitude ratio for stacked ABR, M-CHIRP and A-CHIRP.

To compare the stacked tone-ABR and chirp ABR, the amplitude ratio was derived by dividing the chirp ABR amplitude by click ABR amplitude. Similarly for stacked tone ABR, stacked tone ABR amplitude ratio was derived. The mean amplitude ratio of chirp ABR, that is, A-chirp was 1.18 (0.24) and M-chirp was 1.27 (0.27). Whereas for stacked tone ABR mean amplitude ratio was 2.43 (0.5). It can be noted that even the amplitude ratio is much higher for stacked tone ABR than chirp ABR for two stimuli. However, standard deviation of amplitude was higher for stacked ABR compared to chirp ABR. The observed amplitude ratio data points in different conditions were fitted with cumulative distribution function. It can be observed that the distribution function is much steeper for chirp amplitude compared to amplitude of stacked ABR. From the standard deviation values of both chirp and stacked ABR amplitudes mentioned in table 1 & 2, viability indicates was noted in stacked ABR. Results of the present study were similar to those reported by earlier investigators (Elberling and don 2004). They reported that at 50 and 60dBnHL levels, cumulative function was steeper for chirp than stacked ABR. Results of the present study and previous studies clearly demonstrate that chirp may also be a good measure for neuro-diagnosis.

CHAPTER-5

SUMMARY AND CONCLUSION

The present study aimed at investigating the amplitude differences in ABR elicited using stacked tone technique and chirp stimulus, where both the techniques have been assumed to be involving whole nerve response. Although both the techniques give information about the whole nerve, technique that gives more robust response and that gives less variable amplitude is essential to apply on clinical population. ABR was recorded for 10 normal hearing subjects using two kinds of chirp stimuli and a stacked tone technique. The results of the present study are summarized as follows.

When compared between amplitudes of two types chirp stimuli i.e. A-chirp and M-chirp, there is no significant difference found between the A-chirp ABR amplitude and M-chirp ABR amplitude. Hence the current study suggests that any of the type of chirp stimuli would yield approximately same results in terms of amplitude of ABR.

When compared with amplitudes of ABR elicited using chirp and stacked tone technique, response of stacked tone ABR is more robust than the chirp evoked ABR. Since, this difference in amplitude is attributed to the differences in stimulus and analysis of response and not the physiological difference, any of these techniques can be used to estimate whole nerve response at the level of brainstem.

When compared between the variation of ABR amplitudes in a given population elicited by chirp stimulus and derived by stacked tone technique, using probability distribution function and standard deviation values, it can be inferred that amplitude of chirp ABR is less variable compared to amplitude of staked tone ABR.

Keeping in view of all the above mentioned results of the present study, it can be concluded that, there is no strong evidence of choice established in selecting A-chirp over M-chirp or the other way round to estimate the ABR amplitude. Inspite of stacked tone ABR producing more robust ABRs, Chirp ABR may be opted over stacked tone ABR in neurological investigations due to its lesser variability in amplitude and shorter duration of testing. However, before considering results of the current study, an optimist should be aware of the following limitations of this study

- A large sample data would yielded much more comprehensive results
- Study was performed only in normal subjects hence results cannot be directly generalized to clinical population
- Comparison of ABR amplitudes to chirp and stacked tone techniques across the intensity levels would have shown a better indication of choice of technique to be applied in audiology clinics
- Study has not considered one of the proved techniques i.e. derived band stacked ABR

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