Effect of Cochlear Hearing Loss on Tone Burst Evoked Stacked Auditory Brainstem Response

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Abstract

The auditory brainstem response (ABR) is one of the most useful clinical procedures for the examination of auditory sensitivity and integrity of auditory system. The conventional ABR is not sensitive in detecting small acoustic tumors and small intracanalicular tumors. Stacked tone burst ABR is a new method developed to increase the sensitivity of ABR in detecting small tumours. It has been reported that cochlear hearing loss affects conventional ABR measures. Hence, it is possible that cochlear hearing loss also affects stacked ABR. Also a separate normative data was established for stacked ABR obtained from adding different frequency specific ABRs. In the present study tone burst ABRs for 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz were recorded from 22 ears with cochlear hearing loss and thirty five ears with normal hearing. Stacked ABR was constructed from these tone burst ABRs. The results indicated there is an effect of number of frequencies used for stacking and amplitude of ABR is largest when ABRs for all the four frequencies are stacked. The results also revealed that cochlear hearing loss affects the amplitude of stacked ABR and the reduction in amplitude increases with increase in severity of hearing loss.

Key words: Frequency Specificity, amplitude, Synchronization.

Introduction

The auditory brainstem response (ABR) is one of the most useful clinical procedures for the examination of auditory sensitivity and integrity of auditory system. The auditory brainstem response (ABR) has been well accepted as a procedure to detect retrocochlear pathology (Selters & Brackmann, 1977; Chandrasekhar, Brackmann & Devgan, 1995; Selesnick & Jackler, 1992; Welling, Glasscock, Woods & Jackson, 1990; Jerger, Oliver, Chmiel & Rivera, 1986; Starr et al, 1996). However, the sensitivity of ABR in detection of acoustic neuroma, the most common space occupying lesion on the auditory nerve, depends on its size and location. There are reports indicating that conventional ABR is not sensitive in detecting small acoustic tumors and small intracanalicular tumors. Tumors of sizes less than 10 mm and small intracanalicular tumors are often missed by standard ABR methodology (Telian, Kileny, Niparko, Kemink & Graham, 1989; Wilson, Hodgson, Gustafson, Hogue & Mills, 1992; Eggermont, Don & Brackmann, 1980; Schmidt, Satallof, Newmann, Spiegel & Myers, 2001).

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Studies have reported an increase in incidence of small acoustic tumors over the years (Stangerup et al., 2004). Tos, Charabi and Thomasen (1999) investigated the distribution of diagnosed vestibular schwanomas (VS) of various sizes in Denmark from 1976 to 1995 and reported an increased incidence of intra-canalicular tumors (from 0.4 to 7.9 VS/million/year) and small tumors (from 13.3 to 29.0 VS/million/year). Similar findings have been reported in other parts of the world also (Nestor, Karol, Nutik & Smith, 1988; Moffat, Hardy, Irving, Beynon & Baguley, 1995). Therefore it is essential that audiological tests are developed to identify small acoustic tumors.

To overcome the disadvantage of standard ABR methodology, Don, Masuda, Nelson and Brackmann (1997) developed a new ABR measure, called the stacked ABR. The stacked ABR is a measure which reflects the overall neural activity from a wide frequency region of the cochlea in response to auditory stimulation. This overall neural activity is a result of synchronized activity from various regions of the auditory nerve and desynchronization resulting from compression of a small tumor may be evident in reduction of stacked ABR wave V amplitude (Don, Kwong, Tanaka, Brackmann & Nelson, 2005; Chandrasekhar, Brackmann & Devgan, 1995). Don, Kwong, Tanaka, Brackmann and Nelson (2005) reported that this method has demonstrated 95% sensitivity and 88% specificity in detecting small acoustic tumors. Philibert, Durrant, Ferber-Viart, Duclaux, Veuillet and Collet (2003) used tone burst of different frequencies instead of derived band technique and waveform obtained were added after aligning wave V. They reported similar enhancement of wave V amplitude as obtained using derived band method. They further reported reduced amplitude of the stacked ABR in patients with small tumors.

There is a dearth of literature on stacked ABR especially tone burst evoked stacked ABR. Limited research available on stacked ABR indicates that stacked ABR is sensitive in identification of small acoustic tumors. However, there is a need to standardize this procedure and also study the factors that can affect the amplitude of stacked ABR. Several investigators have reported that cochlear hearing loss affects various ABR measures such as absolute latencies, inter peak latencies, latency intensity function and amplitude measures (Watson, 1996; Oates & Stapells, 1992; Elberling & Parbo, 1987; Watson, 1999; Coats & Martin, 1977; Rosenhamer, Lindstrom & Lundborg, 1981; Keith & Greville, 1987). There are very few reports investigating effect of cochlear hearing loss on amplitude of wave V. The amplitude of the wave V for click evoked ABR might be smaller in subjects with cochlear hearing loss than in normal hearing subjects (Xu, Vinck, De Vel & Cauwenberge, 1998; Fowler & Durrant, 1994).

It can be hypothesized that any factor which affects conventional ABR will affect stacked ABR measure. So it can be hypothesized that cochlear hearing loss has an effect on the amplitude of stacked ABR. However, there is a dearth of studies in this area. It is essential to determine the effect of cochlear hearing loss on stacked ABR and consider the effect if any, while using stacked ABR for neurodiagnostic applications. ABR for five frequencies have been used to obtain stacked ABR to assess the neural integrity across different frequency regions

(Don, Kwong, Tanaka, Brackmann & Nelson, 2005; Philibert et al, 2003). However, using lesser number of frequencies may reduce the test time. Also in subjects with mild high frequency loss, ABR for tone bursts of 4000 Hz and/or 2000 Hz might be absent but present for tone bursts of other frequencies. At such time it will be useful if stacked ABR can be obtained from ABRs of only two or three frequencies. The amplitude of stacked ABR will depend on the number of waveforms stacked and the frequency of the stimuli used for recording frequency specific ABR. Don, Masuda, Nelson and Brackmann (1997) reported a reduction of 33% of amplitude of derived band stacked ABR when two bands of frequencies were removed in subjects with normal hearing. So a separate normative data needs to be established for stacked ABR obtained from adding different frequency specific ABRs. The present study was designed to investigate the following aims:

1. To investigate the effect of cochlear hearing loss on the tone burst evoked Stacked ABR.
2. To obtain separate normative data for amplitude of stacked ABR obtained from
   - ABR for 500 Hz, 1000Hz, 2000 Hz & 4000 Hz tone bursts.
   - ABR for 500 Hz, 1000 Hz & 2000 Hz tone bursts.
   - ABR for 500 Hz & 1000 Hz tone bursts.

Method

Participants: Participants of the present study were divided into two groups. Group 1 included thirty five ears of normal hearing individuals aged 15-50 years and hearing sensitivity within 15 dBHL. The group 2 included twenty two ears with cochlear hearing loss of subjects aged 15-50 years with hearing sensitivity within 55 dBHL. Speech identification scores of all 22 subjects were proportional to pure tone average of 500, 1000 and 2000 Hz and there was no abnormality indicated on click evoked ABR.

Instrumentation: A calibrated diagnostic audiometer was used for estimating the puretone thresholds and a calibrated middle ear analyzer to rule out middle ear pathology. Tone burst evoked stacked ABR was recorded using Intelligent Hearing Systems (Smart EP version 3.86) evoked potential systems.

Procedure:

Table 1: Test protocol to record Tone burst ABR

Type of stimuli	Tone bursts
Transducer	Insert ear phones ER-3A
Test frequency	500, 1000, 2000, 4000 Hz
Duration	4 cycles (2-0-2)
Envelope(Gating)	Blackmann
No. of stimuli	2000
Repetition rate	11.1/s
Test intensity	80dBnHL
Time window	20ms
Electrode montage	Single channel
Polarity	Alternate
Sensitivity	50uV
Filter settings	30Hz-3000Hz

Pure tone thresholds were obtained at octave frequencies between 250 Hz and 8000 Hz for air conduction stimuli and between 250 Hz to 4 KHz for bone conduction stimuli using modified Hughson-Westlake method (Carhart & Jerger, 1959). ABR was recorded for the tone bursts using the test protocol given in Table 1. The wave V was identified at all test frequencies. The wave V recorded at all frequencies was time aligned and these aligned waveforms were added to obtain stacked ABR. The peak-to-trough amplitude of the added waveform was measured.

Results

The participants of the cochlear hearing loss group were further divided into two groups. One group consisted of 12 ears with mild cochlear hearing loss (26 dBHL to 40 dBHL) and other group included 10 ears with moderate cochlear hearing loss (41 dBHL to 55 dBHL). Separate stacked ABRs were obtained by stacking ABRs for all four frequencies (hereafter called SA), stacking ABR for 500 Hz, 1000 Hz and 2000 Hz (hereafter called SA_3) and stacking ABR for 500 Hz and 1000 Hz (hereafter called SA_2). Table 2 shows the mean amplitude and standard deviation values of stacked ABR for 35 ears with normal hearing and 22 ears with cochlear hearing loss. The mean amplitude for stacked wave V was largest for SA followed by SA_3 and SA_2 in individuals with normal hearing whereas there was not much difference between mean values for amplitude for SA, SA_3 and SA_2 for individuals with cochlear hearing loss.

Table 2: Amplitude of stacked ABR for individuals with normal hearing for different stacked ABRs in micro volts (μV)

Stacked ABR	Normal hearing			Cochlear hearing loss		
	N	Mean	Std. Deviation	N	Mean	Std. Deviation
SA	35	0.54	0.09	19	0.30	0.11
SA_3	35	0.53	0.11	21	0.30	0.11
SA_2	35	0.50	0.14	22	0.30	0.12

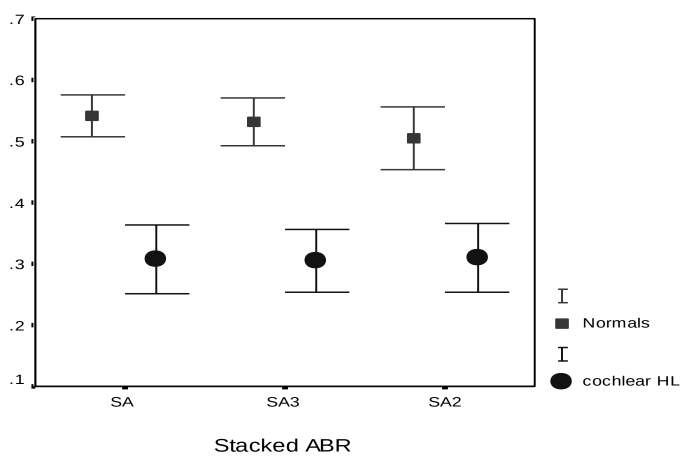

Figure 1: Error bars showing the upper and lower bounds of amplitude at 95% confidence interval at different stacked ABRs for two groups

Figure 1 shows error bars for the upper and lower bounds of amplitude at 95% confidence interval at different stacked ABRs for two groups and it can be observed from figure that there is no overlap between the range of 95% confidence interval for individuals with cochlear hearing loss and those with normal hearing for all stacked ABRs. There is a large gap between lower bound of normal hearing and upper bound for cochlear hearing loss group.

Table 3 shows the mean amplitude and standard deviation values of stacked ABR for 12 ears with mild cochlear hearing loss and 10 ears with moderate cochlear hearing loss. The mean amplitude for stacked wave V is largest for SA than other two stacked ABRs in individuals with mild cochlear hearing loss and the mean amplitude for stacked wave V was largest for SA_2 than other two stacked ABRs i.e. SA and SA_3 in individuals with moderate cochlear hearing loss.

Table 3: Amplitude of stacked ABR for individuals with mild hearing loss and moderate cochlear hearing loss for different stacked ABRs in micro volts (μV)

	Mild cochlear hearing loss			Moderate cochlear hearing loss		
Stacked ABR	N	Mean	Std. Deviation	N	Mean	Std. Deviation
SA	10	0.36	0.11	9	0.24	0.08
SA_3	12	0.34	0.09	9	0.25	0.11
SA_2	12	0.34	0.14	10	0.26	0.08

Results of Mann Whitney U test revealed that there is a significant difference ($p<0.01$) in mean amplitude of stacked wave V for all stacked ABRs between individuals with normal hearing and individuals with mild cochlear hearing loss and a significant difference was observed between amplitude of stacked wave V between individuals with normal hearing and individuals with moderate cochlear hearing loss for all stacked ABRs. Amplitude of stacked wave V differed significantly ($p<0.05$) between the individuals with mild hearing loss and individuals with moderate hearing loss for only SA.

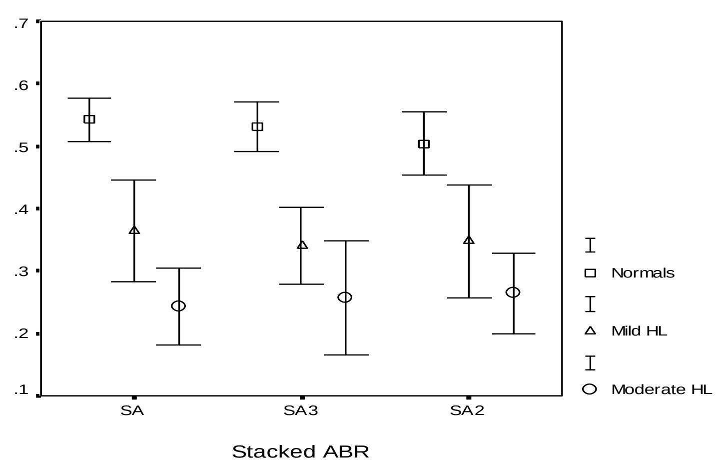

Figure 2: Error bars showing the upper and lower bounds of amplitude at 95% confidence interval at different stacked ABRs for three groups

It can be observed from Figure 2 that the range of 95% confidence interval for individuals with normal hearing loss is extremely different from range for individuals with mild cochlear hearing loss or moderate cochlear hearing at all frequencies. But the ranges of 95% confidence interval for mild hearing loss and moderate hearing loss are overlapping for all stacked ABRs.

Discussion

Amplitude of stacked wave V in individuals with normal hearing ranged from 0.50µV to 0.57µV for SA which is lesser than the range reported by Philibert et al (2003). This can be attributed to the differences in the methodology used in the two studies. Philibert et al (2003) tried to approximate the methodology of Don, Masuda, Eggermont and Nelson (1997) and hence used five frequencies to obtain frequency specific ABR. In the present study standard audiometric frequencies were used due to time constraints. Also the duration of the stimuli in the present study was 2-0-2 cycle as compared to 2-1-2 cycle used by Philibert et al (2003).

Results of the present study also showed an increase in stacked wave V amplitude with the increase in the number of frequencies included for stacking in individuals with normal hearing. This may be due to the increase in number of neural elements that contribute to the response (Don, Ponton, Eggermont & Masuda, 1994). So it was observed that SA had more amplitude as it involves four frequencies which results in more synchronization and higher amplitude in individuals with normal hearing. Don, Masuda, Nelson and Brackmann (1997) also reported similar results in which there were a reduction of 33% of amplitude of derived band evoked stacked ABR when two bands were removed and waveforms were stacked. The reduction in amplitude of stacked wave V with reduction in number of frequencies used in stacking could be because of lesser number of averages in the final stacked ABR. It has been reported in literature that the amplitude of wave V increases with increase in number of averages (Hall, 1992; Hood, 1998). However, studies also indicate that change in amplitude is not significant when the number of averages is increased beyond 2000 (Hall, 1992). In the present study at each frequency 2000 sweeps were averaged. Therefore the effect of number of sweeps on amplitude of ABR would be minimal. So the effect on amplitude of stacked ABR was due to cochlear hearing loss.

In individuals with cochlear hearing loss there was a significant reduction in stacked wave V amplitude for all the stacked ABRs when compared to those individuals with normal hearing. This may be attributed to the fact that cochlear hearing loss results in abnormal functioning of different neural elements across the cochlea. It is known that stacked ABR is a result of total synchronized neural activity from different neural elements (Don, Kwong, Tanaka, Brackmann & Nelson, 2005). So reduction in input to neural fibers due to cochlear hearing loss will result in a significant reduction in stacked ABR amplitude.

Though the amplitude values of stacked wave V of different stacked ABRs were not significantly different in individuals with mild and moderate cochlear hearing loss the amplitude was reduced in individuals with moderate hearing loss. This may be attributed to the fact that with the increase in hearing loss there will be more damaged regions in the cochlea which consequently reduces the number of neural fibers stimulated leading to reduced amplitude.

To summarize, the results of the present study indicate that the amplitude of stacked ABR depends on number of tone bursts evoked ABRs used for stacking. The results also revealed that cochlear hearing loss affects the amplitude of stacked ABR and the reduction in amplitude increases with increase in severity of hearing loss.

Conclusions

The results of the present study indicate that amplitude of ABR is largest when ABRs for all the four frequencies are stacked. There is a significant difference between mean amplitude of stacked ABR of individuals with normal hearing and individuals with cochlear hearing loss. The amplitude of stacked ABR for individuals with mild hearing loss as well as moderate hearing loss is significantly lesser than that of normal individuals. Though not statistically significant the amplitude of stacked ABR reduces with increase in degree of hearing loss.

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