



DIAGNOSTIC MARKERS OF TONE BURST EVOKED AUDITORY BRAINSTEM RESPONSE IN ADULTS

¹Abhishek Sehta

²Ratul Dey

¹Consultant Neuro-Audiologist, SIEMENS Hearing Care, Dubai, UAE.

²Lecturer (Audiology), Guru Gobind Singh Medical College, Faridkot, India.

ABSTRACT

The auditory brainstem response (ABR) is a useful electrophysiological technique for assessing hearing sensitivity in patients whose age or handicaps rule out the use of conventional behavioral audiometric techniques. Tone burst ABR has great role to play as it offers frequency specific responses over that of click evoked ABR. To use tone-burst ABRs for site of lesion testing, it is necessary to have separate normative of absolute latency, inter-wave intervals, and amplitude ratio. The above study was taken up to find out the normative values of various parameters of tone burst ABR. Hundred adults with normal hearing were tested using tone burst stimuli to find out values of various parameters. It was found that all the parameters absolute latency, inter-wave latency differences, amplitude ratio differed in terms of their mean values from those with click evoked ABR. Findings of the present study will be useful as a normative and any deviation from these can be considered as being disordered.

Keywords: Auditory Brainstem Response, Tone Burst, Latency, Amplitude ratio.

INTRODUCTION

The electrical potentials generated by the nervous system to the auditory stimuli are known as auditory evoked potentials (AEPs) (Stapells, Picton, Perez-Abalo, Read & Smith, 1985). These evoked potentials have an important role in the clinical practice of Audiology. This is chiefly due to its ability to objectively assessing hearing thresholds without active participation of the subjects. The auditory brainstem response (ABR) is a useful electrophysiological technique for assessing hearing sensitivity in patients whose age or handicaps rule out the use of conventional behavioral audiometric techniques (Hood & Berlin, 1986; Kileny & Magathan, 1987; Hall, 1992; Weber, 1994; Oates & Stapells, 1998; Gorga, 1999). It is also used for detection, localization and monitoring of auditory and neurological deficits, involving lower auditory brainstem (Mahajan, 2007).

Click evoked ABR gives information about lower brainstem level integrity of auditory nerve fibers. However, its utility is limited in the presence of high frequency sensori-neural hearing loss as click-ABR is primarily contributed by high frequency nerve fibers (2000 Hz to 4000 Hz) which also is not frequency specific. In such instances, tone-burst evoked ABR may play a role to detect the presence and site of the space occupying lesion in the lower frequency regions of auditory nerve. Utilizing ABR to its maximum potential is primarily an exercise in identifying response patterns and knowing which value falls within the range of normal variation and which values have diagnostic significance for peripheral or brainstem dysfunctions (Thronton, 1975; Stockard, & Sharbrough, 1977; cited in Gerling & Fintzo-Hieber, 1983). To use tone-burst ABRs for site of lesion testing, it is necessary to have separate normative of absolute latency, inter-wave intervals, and amplitude ratio. Considering that travelling wave excitation is different for clicks and frequency specific tone bursts, these measures are expected to be different. The present study aims to develop normative of tone-burst evoked ABR, which will be useful in testing to detect site of lesion.

MATERIALS AND METHODS

The present study used normative research design to develop normative data of the tone-burst-evoked ABR to apply in the site of lesion testing. *Subjects:* Hundred adults in the age range of 18 to 25 years were taken as the subjects in the study. All the participants had normal hearing (hearing thresholds below or equal to 15dBHL) at octave frequencies between 250Hz and 8000Hz in both ears and normal middle ear function as assessed on immittance evaluation. There was no history of relevant otological or neurological dysfunction, and all of them were screened for auditory processing disorder by administering speech perception in noise (SPIN) test at 0dB SNR. Subjects with minimum score of 60% and above were included in the study. *Test Environment:* All the tests were done in sound treated rooms with noise levels as per the ANSI S 3.1 (1991) guidelines. Pure tone audiometry was done in double room setup while the immittance evaluation and recording of brainstem responses were carried out in a single room suite. *Recording of the Brainstem Responses:* Auditory brainstem responses (ABR) were recorded for the four frequencies using two repetition rates in a sound treated room where the noise levels were as per the guidelines in ANSI S 3.1 (1991). The subjects were seated comfortably in a reclining chair. The skin surface at the vertex (Cz), test ear mastoid (M1/M2), and lower forehead (Fpz) was cleaned with skin abrasive gel, to obtain the absolute electrode impedance of less than 5 k Ω and inter-electrode impedance of less than 2 k Ω . The electrodes were placed with the help of skin conduction paste and secured tightly in their respective places using surgical plaster. Testing was done monaurally in one of the ears. The ear to be tested within each subject was chosen randomly. The stimulus and acquisition parameters used for recording brainstem responses are given in Table 1.

Parameters	Target Settings
<i>Stimulus Parameters</i>	
Stimulus	Tone bursts of at 500 Hz, 1000 Hz, 2000 Hz and 4 kHz Blackman window (2-0-2)
Duration	Depended on the frequency
Polarity	Rarefaction and condensation
Stimulus Intensity	80 dB nHL
Repetition Rate	11.1Hz & 80.1 Hz
<i>Acquisition Parameters</i>	
Mode	Ipsilateral
Analysis Time	15 ms
Band Pass Filter	30 to 3000Hz
Electrode Montage	Vertical - Fpz, Cz, M1/M2
Sweeps	1500
Transducer	Insert ER-3A
Electrode Impedance	<5 k Ohms
No. of Channels	One
No. of Replications	Two

Table 1: Protocol for recording tone-burst auditory brainstem responses

RESULTS

In the present study, brainstem responses were elicited by tone-bursts of 4 frequencies: 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. At each frequency, responses were recorded by presenting the stimulus at 2 different rates: 11.1 and 80.1. For the comparison purpose, click evoked responses were also recorded at the 2 rates which was used as reference.

Percentage of occurrence of Jewett Waves

To consider tone-burst ABR for site of lesion, first of all it was important that the prevalence of wave I, III and V is high. Only then we could have measured absolute latency, inter-wave intervals, and amplitude ratio, which are considered to be sensitive parameters in click-evoked ABR. The prevalence in this study was assessed in terms of percentage. Table 2 gives the prevalence (in percentage) of wave I, III and V in the 4 stimulus frequencies at 11.1 and 80.1.

Wave	11.1 Hz					80.1 Hz				
	Clicks	500Hz	1000Hz	2000Hz	4000Hz	Clicks	500Hz	1000Hz	2000Hz	4000Hz
I	80.76	65.38	61.53	96.15	100	65.38	26.92	15.38	65.38	84.61
II	76.92	65.38	19.23	76.92	100	50	30.76	0	23.07	46.15
III	96.15	84.61	65.38	100	100	84.61	57.96	61.53	96.15	84.16
IV	50	88.46	11.53	46.15	88.46	53.84	42.3	0	30.76	26.92
V	100	100	100	100	100	100	96.15	100	100	100

Table 2: Percentage of occurrence of the waves elicited by click and tone bursts at 11.1 and 80.1 rates

The following observations were made from table 2.

1. Percentage of V peak was maximum (100 %) in all the frequencies and at both the rates (except 500 Hz at 80.1). Percentage of I and III wave was better than II and IV wave.
2. At 11.1, percentage of all the other waves was maximum at 4000 Hz followed by 2000 Hz, clicks, 500 Hz and 1000 Hz.
3. Percentage of occurrence of all the waves was more at 11.1 than 80.1 rate.

Absolute Latency of Tone-burst Evoked Brainstem Responses at 11.1

The mean and standard deviation (SD) of absolute latency of waves I, II, III, IV and V, at 11.1 repetition rate are given in Table 3.

Table 3: The mean and standard deviation (SD) of absolute latency of waves I, II, III, IV and V at different stimulus frequencies at 11.1 repetition rate

Wave	Clicks		500Hz		1000Hz		2000Hz		4000Hz	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
I	1.56	0.14	3.85	0.05	3.14	0.24	2.61	0.13	2.19	0.12
II	2.66	0.15	4.66	0.08	4.34	0.67	3.60	0.14	3.19	0.13
III	3.67	0.14	5.49	0.14	5.00	0.34	4.57	0.21	4.18	0.15
IV	4.77	0.10	6.34	0.19	6.15	0.18	5.62	0.11	5.30	0.17
V	5.46	0.24	7.14	0.27	6.80	0.25	6.33	0.19	6.03	0.16

Comparison of the mean absolute latency showed that the latency was prolonged in tone-burst ABR compared to click evoked ABR. Also, among the tone-burst ABRs, ABR elicited by 4000 Hz had minimum latency followed by that of 2000 Hz, 1000 Hz and 500 Hz. This was true for all the 5 waves. The data of confidence interval of absolute latency was obtained for 95% criteria.

Absolute Latency of Tone-burst Evoked Brainstem Responses at 80.1

Absolute latency of only wave V was analyzed as clinically only wave V is considered due to its high prevalence. The mean and standard deviation (SD) of absolute latency of waves V, at 80.1 repetition rate are given in Table 5.

Table 5: The mean and standard deviation (SD) of absolute latency of wave V at different stimulus frequencies at 80.1 repetition rate

Wave	clicks		500Hz		1000Hz		2000Hz		4000Hz	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
V	5.82	0.14	7.96	0.42	7.48	0.26	6.81	0.23	6.47	0.24

Comparison of the mean absolute latency showed that the latency was prolonged in tone-burst ABR compared to click evoked ABR. Also, among the tone-burst ABRs, ABR elicited by 4000 Hz had minimum latency followed by that of 2000 Hz, 1000 Hz and 500 Hz. With the increase of rate by 69 Hz (between 11.1 & 80.1), there was mean difference of 0.36, 0.82, 0.68, 0.48, and 0.44 for clicks, 500 Hz TB, 1000 Hz TB, 2000 Hz TB and 4000 Hz TB respectively.

Amplitude of Tone-burst Evoked Brainstem Responses at 11.1

The mean and standard deviation (SD) of amplitude of waves I, II, III, IV and V, at 11.1 repetition rate are given in Table 6.

Table 6: The mean and standard deviation (SD) of amplitude of waves I, II, III, IV and V at 4 different stimulus frequencies at 11.1 repetition rate

Wave	Clicks		500Hz		1000Hz		2000Hz		4000Hz	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
I	0.21	0.14	0.05	0.33	0.14	0.24	0.16	0.13	0.23	0.12
II	0.09	0.15	0.08	0.38	0.03	0.67	0.07	0.14	0.06	0.13
III	0.23	0.14	0.14	0.30	0.14	0.34	0.16	0.21	0.17	0.15
IV	0.23	0.10	0.19	0.36	0.15	0.18	0.13	0.11	0.16	0.17
V	0.23	0.24	0.27	0.34	0.25	0.25	0.18	0.19	0.19	0.16

Comparison of the mean amplitude showed that the amplitude was more for 4000Hz and 2000Hz and less for 500Hz and 1000Hz, whereas amplitude of click evoked responses similar to that of low frequencies. There was no clear trend in variation of amplitude across the responses evoked by different tone-bursts. This was true for all the 5 waves. For wave II and IV, at 1000 Hz, confidence intervals were not obtained due low prevalence.

Amplitude of peaks of Tone-burst Evoked Brainstem Responses at 80.1

The mean and standard deviation (SD) of amplitude of wave V, at 80.1 repetition rate are given in Table 7.

Table 7: The mean and standard deviation (SD) of amplitude of wave V at different stimulus frequencies at 80.1 repetition rate

Peak	clicks		500Hz		1000Hz		2000Hz		4000Hz	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
V	0.11	0.14	0.12	0.21	0.20	0.26	0.18	0.23	0.14	0.24

Comparison of the mean amplitude of wave V at 80.1 showed that there was no clear trend in variation of amplitude across frequencies.

Inter-peak interval of Tone-burst Evoked Brainstem Responses

The mean and standard deviation (SD) of inter-peak interval of I-III, III-V and I-V, at 11.1 repetition rate are given in Table 8.

Table 8: The mean and standard deviation (SD) of inter-peak interval of I-III, III-V and I-V at different stimulus frequencies at 11.1 repetition rate

Peak	Clicks		500Hz		1000Hz		2000Hz		4000Hz	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
I- III	2.09	0.15	1.64	0.12	1.85	0.22	1.96	0.15	1.98	0.10
III-V	1.79	0.52	1.65	0.25	1.70	0.23	1.74	0.13	1.84	0.11
I-V	3.85	0.28	3.37	0.27	3.56	0.19	3.72	0.18	3.83	0.15

Comparison of the mean inter-peak interval showed that the inter-peak interval was lesser for tone-burst ABR compared to click evoked ABR. Also, among the tone-burst ABRs, ABR elicited by 4000 Hz had higher interval for all the inter-peak intervals followed by that of 2000 Hz, 1000 Hz and 500 Hz. This was true for all the 3 inter-peak intervals.

V-I Amplitude Ratio of Tone-burst Evoked Brainstem Responses.

The mean and standard deviation (SD) of V-I amplitude ratio at 11.1 repetition rate are given in Table 9.

Table 9: The mean and standard deviation (SD) of V-I amplitude ratio at different stimulus frequencies at 11.1 repetition rate

Peak	Clicks		500Hz		1000Hz		2000Hz		4000Hz	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
V-I	1.21	2.04	4.11	2.91	2.20	1.35	1.52	1.22	0.70	3.01

Comparison of the mean amplitude ratio showed that the ratio was least for 4000Hz and maximum for 500 Hz. Ratio successively lesser from 2.20, 1.52 and 1.21 for 1000 Hz, 2000 Hz and clicks respectively.

DISCUSSION

The present study was taken up with the assumption that Tone-burst evoked responses may be clinically useful in the site of lesion testing in instances where click evoked brainstem responses are abnormal or absent due to high frequency cochlear hearing loss. Results showed that there was high prevalence of wave I, III and V in responses elicited from all the frequencies used. Hence, it is recordable in most of the individuals and at both the rates (11.1 & 80.1 per second) provided hearing sensitivity is normal. However, these results are true for the stimulus and acquisition parameters used in the present study. Results of the absolute latency of Jewett waves elicited by tone bursts showed increase in latency with decrease in the center frequency of the stimulus. This was true for all the waves at 11.1. Hz and even at 80.1 Hz for V peak. Brainstem responses to tone-bursts of different frequencies represent synchronous activity initiated from successive octave-wide regions across the cochlea. Hence, cochlear travelling wave velocity determines the latency of the tone-burst evoked responses. Because the nerve fibers responsible for low frequencies are connected to the apical part of the cochlea and the travelling reaches apical region later, the synchronous activity in the apical region of the cochlea has a prolonged latency with respect to the stimulus onset. On the other hand, because the excitation always starts from the basal end, the synchronous activity of the nerve fibers responsible for high frequencies will be earlier. Hence, progressively increasing latency in the tone-burst evoked responses ensured that the responses are from successive regions of the cochlea from base to apex. Also, the responses obtained from clicks, which is a broadband stimulus, have its latency closer to the latency obtained from the responses elicited 2 and 4 kHz tone-bursts. Therefore, it can be inferred that the click-evoked responses are primarily from high frequency nerve fibers innervating the basal region of the cochlea.

In the present study it was found that, as the repetition rate increased, there was a shift in the latency of V wave. This shift is attributed to the reduced inter-stimulus interval which affects the refractory period of the nerve. This notion was further supported by the difference in the shift across frequencies. Results showed that shift in latency increased with the decrease in stimulus frequency. This could be because of the difference in the duration of each sweep of tone burst. In a Blackman's window, each sweep will have 2 cycles of rise time, zero plateau and 2 cycles of fall time. In this pattern of sweep, a 4 kHz tone burst will have total duration of 1 ms while 500 Hz stimulus will be of 8 ms. Hence, at the same rate of stimulation, inter-stimulus interval

for low frequency bursts will be less than that for high frequency tone bursts. This means that the refractory period is affected at lower frequency to a greater extent than higher frequency tone bursts, thus leading to larger shift in latency.

Among the amplitude measures taken in the study, absolute amplitude showed that the amplitude of tone-bursts in general were lesser compared to click evoked responses. This is because, clicks elicit responses from a broader area of basilar membrane but tone-bursts evoke responses from a narrow range depending on the frequency of the stimulus. Otherwise, within tone-bursts of different frequencies, there was no trend seen either with 11.1 or with 80.1 stimulus rates.

However, V-I amplitude ratio had a clear trend with higher ratio at 500 Hz progressively decreasing with increase in stimulus frequency. An inspection of the absolute values of wave I and V showed that wave V remained relatively constant across frequencies while wave I was lesser at low frequencies. Because apical region contributes less for early waves (I & II) amplitude of wave I was lesser and in turn leading to higher amplitude ratio.

Results of inter-wave interval also can be justified through the same reason. Inter-wave intervals increased with decrease in stimulus frequency. An inspection of the absolute latencies of wave I and V showed that the shift in latency with decrease in stimulus frequency was lesser compared to wave I. Also, shift in wave I-V was more than that in wave I-III. All these findings support that the wave I is contributed more by higher frequency and wave V is contributed more by low frequencies.

Overall results showed that there were difference in the absolute latency, absolute amplitude, inter-wave interval and amplitude ratios obtained for tone bursts and clicks. Also normative data of the response parameters differed across tone-bursts of different frequencies. Therefore, it is proved that the normative developed for clicks cannot be used for tone burst-evoked responses.

SUMMARY AND CONCLUSION

The present study aimed to develop normative for tone-burst ABR to be used for site of lesion testing. In ears of acoustic neuroma associated with high frequency cochlear hearing loss, it is likely that click-evoked ABR is absent, or abnormal due to cochlear hearing loss. In those instances it was thought that tone-burst ABR would be help for site of lesion testing. Tone-Burst evoked ABRs were recorded from thirty adults, who were in the age range of 18 to 25 years, including both male and female participants. Responses were recorded for tone-bursts of 500Hz, 1000Hz, 2000Hz and 4000Hz center frequency. At each frequency, responses were recorded with 2 stimulus repetition rates: 11.1 and 80.1. The absolute peak latency, inter-wave intervals, the peak amplitude, and amplitude ratio were noted down from each response. Overall results showed that there were difference in the absolute latency, absolute amplitude, inter-wave interval and amplitude ratios obtained for tone bursts and clicks. Also normative data of the response parameters differed across tone-bursts of different frequencies. Therefore, it is proved that the normative developed for clicks cannot be used for tone burst-evoked responses. Also, there is a need to use the different normative for responses elicited for different frequencies.

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