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TONEBURST-EVOKED ABR: NORMS AND GENDER DIFFERENCES

ENT

Sanjay K Munjal*	Additional Professor, Speech & Hearing Unit, Dept. of Otolaryngology, PGIMER, Chandigarh.*Corresponding Author
Rawish Kumar	Jr. Speech Therapist, Speech & Hearing Unit, Dept. of Otolaryngology, PGIMER, Chandigarh.
Anuradha Sharma	Lecturer, Speech & Hearing Unit, Dept. of Otolaryngology, PGIMER, Chandigarh.
Naresh K Panda	Professor and Head, PGIMER, Chandigarh.

ABSTRACT

Background: The ABR procedure has become a powerful non-invasive technique to assess the integrity of the auditory processing system particularly in infants and difficult-to-test subjects. The inability of click stimulus in frequency selectivity the tone burst makes it possible to obtain relatively narrow frequency range responses, particularly at lower frequencies. However, the click-evoked ABR does not provide frequency-specific information of the auditory system. The lack of normative data and the potential usefulness of the toneburst-evoked ABR, the present study aimed to establish gender-specific norms for the same at the octave frequencies. **Methods:** Twenty normal hearing subjects within the age range 18 to 25 years were examined followed by tympanometry, puretone audiometry and toneburst ABR for 500Hz, 1000Hz, 2000Hz and 8000Hz in each ear.**Results:** Wave-V was identified till 20 dBnHL for all tested frequencies with a decrease in mean absolute latency of waves with increase in frequency. Mean absolute latency of each wave was shorter in female than male for the tested frequencies. The difference in mean of puretone and TB-ABR thresholds ranged between 8-11.25 dBnHL for different frequencies. **Conclusion:** TB-ABR can be reliably used as an excellent tool to achieve frequency-specific information for difficult-to-test population.

KEYWORDS

Toneburst-evoked ABR, Frequency - Specific, Puretone, Gender Difference,

INTRODUCTION

The Auditory Brainstem Evoked Response (ABR) test procedure has undergone relatively minor modifications described in the late 1960s and early 1970s. Although the MRI is more effective at identifying smaller tumours or as a neurological assessment instrument, the cost of such procedures is typically higher than the ABR screening [1,2]. But, recent achievement in ABR procedure advancement during the last three decades enabled the test clinically more sensitive to the standard ABR routine.The recent improvement in recording ABR, a powerful non-invasive technique, is being used to assess the integrity of the auditory processing system and also hearing particularly in infants and who fails in psychoacoustic methods of hearing assessment.

Varieties of acoustic stimuli may be used to obtain electrical responses from the brainstem. Clicks(broadband stimulus of frequency range 2000-3000 Hz) are the most frequently used, and it is capable of activating a large portion of the basilar membrane. Its wide frequency range finds greater clinical importance in hearing screening, site-of-lesion testing and intraoperative monitoring.[3] On the other hand, click stimulus does not find importance in frequency-specific threshold estimation because it has broad-spectrum and short duration results in greater energy splatter. Hence, the inability of frequency selectivity is a significant drawback of click.

A better alternative to broadband stimuli is the tone burst and tone pips with their frequency specificity and less energy splatter due to their longer duration. Tone bursts make it possible to obtain relativelynarrow frequency range responses, particularly at lowerfrequencies[4]. Frequency specificity of an audiological response is clinically desirable for rational audiological management. Behavioural responses are not always obtained reliably while testing infants, children, individuals with mental retardations and individuals with functional hearing loss. This creates an even greater need for a frequency-specific objective test for assessment of thresholds. ABR measurements using tone burst are an excellent alternative to achieve this end.

The use of tone bursts in ABR testing provides precision and clinical usefulnesswhen estimating auditory sensitivity at 500 to 4,000 Hz in children and adults. Electrophysiological thresholds obtained with tone bursts are similar to pure tone thresholds, although higher at 500 Hz than at 4,000 Hz[6].Hayes and Jergeralso reported good agreement between ABRs and behavioural thresholds for 2000 Hz tone burst stimuli with less comparability at 500 Hz [7].

On the other hand, various studies have reported the poor quality of tone bursts ABR responses, particularly at 500 Hz, where waves are complex, challenging to see and with significantly variable responses [8,9,10,11]. Studies also suggested that the clinical use of tone bursts is questionable below 70 dBnHL[8,10].

The ABR to brief tones has been used successfully for threshold assessment for more than 30 years, since the first publications in the 1970s [12, 13,14,15]. Despite this early success, and the many subsequent studies supporting the use of the ABR to brief tones to estimate behavioural hearing thresholds in adults, children and infants with normal or hearing impaired, there remains an impression commonly held by audiologists that the tone-evoked ABR poorly predicts pure tone behavioural threshold, especially for low frequencies.

NEED FOR THE STUDY:

Various researchers have attempted to establish normative data for click-evoked ABRs. As compared, tone burst-evoked ABRs have received little attention, and normative data is unavailable despite the frequency specificity of the toneburst. Due to the lack of normative data and the potential usefulness of this technique as an objective measure to establish frequency-specific thresholds in the difficult to test population, the present study was undertaken.

AIM AND OBJECTIVES OF THE STUDY

1. To establish normative data for toneburst-evoked ABRs at the octave frequencies (including 500Hz, 1000Hz, 2000Hz and 8000Hz) and to assess their validity using puretone audiometry.
2. To compare the gender differences in absolute latencies of the waves obtained at different frequencies.

MATERIALS AND METHODS

Subjects:

Twenty normal-hearing subjects (including 10 males and 10 females i.e. 40 ears) within the age range 18 to 25 years were enrolled in the present study.The main inclusion criteria were- normal middle ear status, no history of noise exposure, no signs of retro-cochlear pathology and no complaint of hearing loss. Subjects who had one or more of the following conditions were also excluded from this study: medical or neurological problems known to affect the auditory system, family history of hearing impairment, ototoxic drug intake and noise exposure. Subjects with no history of chronic middle ear pathology or otoscopic evidence of ear-drum abnormalities, other otological complaints such as hard of hearing, tinnitus, vertigo and ear surgery were included in the study.

Instrumentation & Stimuli:

All participants underwent an otoscopic examination and tympanometry before enrolment in the present study. All audiological evaluations were carried out in a sound-treated chamber. The hearing assessment was performed on **Interacoustics AC40** two-channel diagnostic audiometer using TDH-39 headphone at conventional test frequencies viz., 0.25, 0.5, 1, 2, 4 and 8 kHz.

Followed by this, participants underwent ABR testing. ABR testing was carried out on Intelligent Hearing System (IHS) Smart EP using the 2-Channel tone burst ABR settings specified by IHS using insert earphone (ER 3A). To obtain response waveform in ABR, 2048 sweeps were presented across each toneburst frequency 500Hz, 1000Hz, 2000Hz and 8000Hz with the subject lying down in supine position using following recording parameters shown in table 1 below.

Table 1: Toneburst ABR Recording Parameters

Stimulus:	**Tonebursts**
Envelop:	Blackman gated
Duration:	500Hz- 8000µs 1000Hz- 4000µs 2000Hz- 4000µs 8000Hz- 2000µs
Rate:	27.7/sec
Polarity:	Alternating (to decrease the stimulus artefacts)
Transducers:	Insert Earphone (ER 3A, 10Ω)
Intensity:	- 90dBnHL, 70dBnHL, 50dBnHL,30dBnHL and 20dBnHL (for 500Hz, 1000Hz and 2000Hz) - 78dBnHL, 58dBnHL, 38dBnHL and 18dBnHL (for 8000Hz)
Filters:	High pass filter: 30Hz Low pass filter: 1500Hz
Notch Filter:	Off
Amplification:	100X
Analysis time:	0 – 25.6msecs (for 500Hz and 1000Hz) 0 – 12.8msecs (for 2000Hz and 8000Hz)
Sweeps:	2048
Electrode Montage:	Non-inverting electrode (+): Vertex; Inverted electrode (-): ipsilateral mastoid; Reference or Ground electrode: Lower forehead

Starting at 90dBnHL (for 500Hz, 1000Hz and 2000Hz) stimulus level presentation, the intensity level was decreased in 20dB step till 30dBnHL and 10dB thereafter to obtain the response waveform. The test was started at maximum recommended intensity level 78dBnHL for 8000Hz by the instrument used was tested till 18dBnHL in 20dB stepdown.

A waveform was considered to be present only if it was replicable (present for at least two acquisitions of response waveform). A wave was rejected from the analysis if the number of artefacts exceeded 100. It served to provide information about the reliability with which the waves were obtained.

Wave-V was defined as the largest vertex positive peak that was followed by a rapid negative-going slope using responses to high-level conditions to help guide its identification [16].

RESULTS

Tympanometry and puretone audiometry (a psychoacoustic evaluation)was done prior to enrolment for the electrophysiologic test in all subjects. Results showed that the mean of pure tone thresholds for 500Hz, 1000Hz, 2000Hz and 8000Hz were 18.75dBHL, 17dBHL, 10.5dBHL and 9.38dBHL respectively. Auditory thresholds were within normal hearing range (between 0 to 25dBHL) for all the subjects with a mean 18dBHL of puretone average (average of 500Hz, 1000Hz & 2000Hz).

The results reveal that wave-V (that is response waveform) was present for all subjects at 90dBnHL and 70dBnHL, but it was absent in one ear at 50dBnHL for 500Hz. Table 2 shows the wave identification percentage for a total of 20 subjects (40ears). Wave-V identification was found in all the subjects(100%) at intensity level 78dBnHL, 58dBnHL and 38dBnHL however 92.5% of the subjects at 18dBnHL for 8000Hz toneburst. Also, for 500Hz, 1000Hz and 2000Hz the wave-v identification was 100% at 90dBnHL and 70dBnHL. However, comparatively, the wave-V identification was less i.e, 42.5% and 60% at20dBnHL for 1000Hz and 2000Hz respectively. Wave morphology was good for all the frequencies with 8000Hz exhibiting all three major cardinal waves (V, III and I) at a high-intensity level. Specifically, 500Hz exhibited poor waveform morphology with least identification (17.5%) of waves at 20dBnHL intensity level. Hence, results revealed that identification of waves and its morphology decrease with a decrease in frequency and intensity and it's poorest for 500Hz as shown in table2.

Table 2: Wave Identification Percentages

Toneburst Frequency	**Wave**	**Intensity Level**				
		90dBnHL	**70dBnHL**	**50dBnHL**	**30dBnHL**	**20dBnHL**
500Hz	V	100%	100%	97.5%	87.5%	17.5%
	III	25%	15%	7.5%	-	-
	I	20%	5%	-	-	-
1000Hz	V	100%	100%	100%	95%	42.5%
	III	70%	52.5%	-	-	-
	I	57.5%	10%	-	-	-
2000Hz	V	100%	100%	100%	92.5%	60%
	III	95%	90%	52.5%	7.5%	-
	I	92.5%	65%	10%	-	-
8000Hz	**Wave**	**78dBnHL**	**58dBnHL**	**38dBnHL**	**18dBnHL**	
	V	100%	100%	100%	92.5%	
	III	97.5%	87.5%	65%	40%	
	I	97.5%	85%	47.5%	27.5%	

Table 3 shows the mean of absolute latencies, inter-peak latencies with standard deviation (SD) of wave V, III and I for 500 Hz, 1000 Hz and 2000 Hz toneburst at intensity level tested. The obtained mean absolute latency of wave-V at 90dBnHL was 7.80ms for 500Hz; 7.43ms for 1000Hz; and 6.74ms for 2000Hz. However, it was 12.81ms at 30dBnHL for 500Hz; 11.97ms for 1000Hz; and 10.09ms for 2000Hz at 20dBnHL. Wave-I and III were observed only at 90dBnHL and 70dBnHL in the majority of the subjects. Mean wave I absolute latency at 90dBnHL was 3.57ms, 3.42ms, and 2.91ms for 500 Hz,1000Hz and 2000Hz respectively. However, the mean latency of wave-III was 5.67ms for 500Hz; 5.57ms for 1000Hz; and 4.97ms for 2000Hz.

Table 3: Mean Absolute Latency and Interpeak Latency (IPL) for 500Hz, 1000Hz & 2000Hz

Intensity Level	**Frequency**	**Wave-V (Mean±SD in msec)**	**Wave-III (Mean±SD in msec)**	**Wave-I (Mean±SD in msec)**	**IPL V-I (Mean±SD in msec)**	**IPL III-I (Mean±SD in msec)**	**IPL V-III (Mean±SD in msec)**
90dBnHL	500Hz	7.80±0.52	5.67±0.69	3.57±0.70	3.92±0.44	2.02±0.42	1.87±0.20
	1000Hz	7.43±0.36	5.57±0.30	3.42±0.33	3.76±0.24	1.98±0.18	1.78±0.17
	2000Hz	6.74±0.33	4.97±0.29	2.91±0.34	3.81±0.31	2.05±0.26	1.80±0.29
70dBnHL	500Hz	8.72±0.56	6.5±0.10	-	-	-	1.77±0.05
	1000Hz	7.97±0.40	6.33±0.34	4.18±0.28	3.63±0.16	2.08±0.12	1.68±0.16
	2000Hz	7.32±0.35	5.55±0.34	3.43±0.33	3.83±0.34	2.05±0.25	1.75±0.17

50dBnHL	500Hz	10.39±0.97	-	-	-	-	-
	1000Hz	9.02±0.41	-	-	-	-	-
	2000Hz	8.21±0.52	6.18±0.33	-	-	-	1.87±0.27
30dBnHL	500Hz	12.81±1.25	-	-	-	-	-
	1000Hz	11.16±0.77	-	-	-	-	-
	2000Hz	9.39±0.49	-	-	-	-	-
20dBnHL	500Hz	-	-	-	-	-	-
	1000Hz	11.97±0.72	-	-	-	-	-
	2000Hz	10.09±0.48	-	-	-	-	-

Table 4 shows the mean of absolute latencies, inter-peak latencies with standard deviation (SD) of wave V, III and I at intensity level tested for 8000Hz toneburst. The mean latency value was 6.01ms of wave-V; 4.12ms of wave-III; and 1.94ms of wave-I at 78dBnHL. At 18dBnHL, mean of absolute latency was 7.35ms and 5.49ms of wave-V and III, respectively.

Table 4: Absolute Latency and Inter-peak Latency (IPL) For 8000Hz

Intensity	Wave-V	Wave-III	Wave-I	IPL V-I	IPL III-I	IPL V-III
78dBnHL	6.01±0.29	4.12±0.22	1.94±0.20	4.10±0.27	2.20±0.20	1.90±0.21
58dBnHL	6.27±0.34	4.43±0.34	2.20±0.26	4.07±0.36	2.23±0.34	1.84±0.23
38dBnHL	6.76±0.40	5.03±0.33	2.75±0.21	3.86±0.23	2.17±0.30	1.77±0.23
18dBnHL	7.35±0.44	5.49±0.21	-	-	-	1.80±0.20

Table 5 shows the comparison of absolute latency between female and male for wave-V at two highest intensity level viz., 90dBnHL and 70dBnHLusing unpaired t-test. The result showed statistically significant difference (p>0.05) in the mean of absolute latency between male and female at 90dBnHL for 1000Hz and 2000Hz; however, no significant difference (p>0.05) at 90dBnHL for 500Hz and 8000Hz. Results also showed significant (p<0.05) difference between the mean absolute latency of wave-V between female and male at 70dBnHL for all tested frequencies viz., 500Hz, 1000Hz, 2000Hz and 8000Hz. (as shown in table 5).

Table 5: Comparisons of Mean of Absolute Latency of wave-V between Male and Female

Toneburst Frequency	Latency at 90 dBnHL (Mean±SD in msec)		t-value	p-value	Latency at 70 dBnHL (Mean±SD in msec)		t-value	p-value
	Female	Male			Female	Male		
500Hz	7.86±0.45	7.92±0.56	1.522	0.138	8.49±0.36	8.95±0.63	4.713	0.009*
1000Hz	7.17±0.27	7.51±0.37	1.725	0.003*	7.787±0.26	8.152±0.42	6.331	0.003*
2000Hz	6.562±0.23	6.913±0.32	3.247	0.000*	7.128±0.25	7.503±0.33	1.707	0.000*
Toneburst Frequency	**Latency at 78 dBnHL (Mean±SD in msec)**		**f-value**	**p-value**	**Latency at 58dBnHL (Mean±SD in msec)**		**f-value**	**p-value**
	Female	**Male**			**Female**	**Male**		
8000Hz	5.952±0.31	6.058±0.26	0.687	0.255	6.140±0.26	6.407±0.34	0.990	0.010*

***Significant ifp≤0.05**

The puretone threshold obtained during pure tone audiometry for the same subjects was 18.75dB at 500Hz; 12dB at1000Hz;10.5dB at 2000Hz; and 9.38dB at 8000Hz. In ABR testing Wave-V could be traced till 20dBnHL for 1000Hz and 2000Hz toneburst and 18dBnHL for 8000Hz. At 500Hz wave-V was traced till 30dBnHL in most subjects; however, in a few subjects, it was traced at 20dBnHL.

Pearson's correlation test was performed to observe the correlation between the obtained behavioural threshold of pure tone audiometry and the toneburst-evoked threshold for all tested frequencies. The result showed statistically significant (p<0.05) correlation between the puretone and TB-ABR threshold levels for all frequencies. Strong correlation (r=0.963, p=0.007 at 2000Hz; r=0.788, p=0.044 at 8000Hz) was seen at high frequencies. However, weak correlation (r=0.324, p=0.042 at 500Hz; r=0.429, p=0.006 at 1000Hz) was observed at low frequency (as shown in table 7).

Table 6: Correlation Between ABR and Puretone Thresholds for Different Frequencies

Frequency	Pearson Correlation (r)	Sig. (2-tailed)
500Hz	0.324	0.042*
1000Hz	0.429	0.006*
2000Hz	0.963	0.007*
8000Hz	0.788	0.044*

Table 7: Mean Difference between Puretone and ABR thresholds

Tests	Frequency			
	500Hz	**1000Hz**	**2000Hz**	**8000Hz**
ABR	30	20	20	18
PTA	18.75	12	10.5	9.38
Difference	11.25	8	10.5	8.62

Table 7 shows the difference between the mean thresholds of puretone, and the lowest intensity level at which wave-V was obtained at tested frequencies viz., 500Hz, 1000Hz, 2000Hz and 8000Hz. The mean threshold difference obtained between puretone and ABR was 11.25dB at 500Hz; 8dB at 1000Hz; 10.5dB at 2000Hz; and 8.62dB at 8000Hz.

DISCUSSION:

There was a proportional difference in the percentage of wave identification at various intensity level across frequencies being tested. Identification of wave-V was 100% for all the frequencies at the high-intensity level but not for wave-III and I (as shown in Table 2). Probably, the rapid rise time at high frequency may be a factor in provoking the auditory nerves to discharge impulses in a greater synchronous manner, which might have resulted in the greater amplitude of response relative to the background noise [16]. Despite interferences of noise and the baseline on-going EEG activities, 500Hz exhibited wave-V, with least identification (17.5%) at 20dBnHL.In concordance, Jerger and Hyes had also reported wave-V identification in less than 50% in normal-hearing adult subjects at the low-intensity level [17]. Gorga et al., have also reported that there was a difference in identification of waves across frequency at the lower levels. As the frequency and intensity are lowered, responses start merging with noise and EEG floor, which affect the waveform and identification of waves [16]. Hence, results revealed that identification of waves and its morphology decrease with a decrease in frequency and intensity, and it is poorest for 500Hz.

Data computed in table 3 and 4 shows that there is a decrease in the mean absolute latency of wave V, III and I with the increase in frequency (500Hz, 1000Hz, 2000Hz and 8000Hz). Furthermore, there is an orderly pattern of latency, dependent on frequency and intensity level. The latency value of wave-V decreased as the frequency increased and it is a known fact that low frequencies cover more distance as compared to high frequencies, which results in a delay of auditory evoked potential waves at low frequencies. It explains higher wave V latency at low frequencies compared to middle and high frequencies. Greater nerve fibre density per unit distance on the basilar membrane at the basal turn of the cochlea and rapid rise time at high frequencies simultaneously result in a greater synchronous discharge of auditory nerve fibres. However, this synchronous discharge of nerve fibres decreases with a decrease in frequency and with the lowering of intensity. This pattern change of synchronous nerve firing may result in a shift in wave latency with lowering of frequency and intensity [18]. Also, the rapid travelling-wave velocity at the basal end of the cochlea with high frequency results in nerve fibres to fire in greater synchronous which may yield early latency at high frequency, i.e. at 8000Hz compared to low frequency situated at the apical end of the basilar membrane [19].

The present study showed statistically significant (p<0.05) difference for the mean absolute latency of wave-V between male and female, at 90dBnHL for 1000Hz and 2000Hz.However, no statistically significant (p>0.05) gender differences were observed for 500Hz and 8000Hz at 90dBnHL (shown in Table 5). The mean wave-V latency was higher in male than female subjects. In concordance, Pinto and Matas had also reported similar findings except for 8000Hz [20]. A significant difference was also observed in the current study at 70dBnHL between male and female across all tested frequencies. Don et al., had also found the significant difference in mean of absolute latency tested at 93dBpeSPL, 83dBpeSPL and 73dBpeSPL between male and female across frequencies between 5700Hz to 700Hz. They stated that comparative longer latency in males might relate to the head size since males have typically larger skull size. Additionally, the rapid cochlear responses in female may explain these findings [21].

Pearson's correlation showed a strong positive correlation between puretone and TB-ABR thresholds for high frequencies and a weak correlation for low frequency (shown in table 6). In concordance with the current findings, van der DJF et al., and Bellman et al., also found a better correlation at high frequency [22, 23].

The difference in mean puretone and TB-ABR thresholds ranged between 8 – 11.25 dBnHLfor different frequencies (as shown in table 7). Similar findings have been reported by Stapell'set al., who confirmed that reliable responses could be elicited from low-mid frequency also [24]. Canale A et al., also noted that the mean threshold difference was larger at low frequency compared to high frequency [25].

CONCLUSION:

TB-ABR can be reliably used to achieve frequency-specific information across different frequencies. A good agreement exists between puretone thresholds and TB-ABR thresholds. Hence, TB-ABR can be an excellent tool to get frequency-specific information for difficult-to-test populations and further audiological management.

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