

# Binaural Recordings of Auditory Brainstem Response for Establishment of Normative Data and its Application in Screening Patients with Symmetrical Hearing Loss

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## ABSTRACT

**Background:** This article presents clinically important details of recording and evaluating ABR details that will eventually be helpful in standardization of our neurophysiology lab, so that ABR recordings on a routine basis will produce better and meaningful results for interpretation.

**Aims & Objective:** To establish normative data required for recording Auditory Brainstem Response (ABR) using binaural stimulations in children with normal hearing.

**Materials and Methods:** This study was conducted on 40 apparently healthy children with normal hearing. Database was collected following assessment with otological questionnaire, otoscopic examination. BERA was used as a tool for establishment of normative data. Standard test protocol given by Hall was followed for ABR recordings.

**Results:** The Interaural latency difference was less than 0.2 ms (milliseconds) and was found to be in normal limit. Normative data was obtained and the mean values of absolute latencies for left ear were 1.77 ms, 3.73 ms and 5.70 ms respectively and for right ear these were 1.77 ms, 3.76 ms and 5.56 ms respectively. Mean values for amplitude of wave I and V for left ear were 0.36 uV and 0.56 uV respectively. For right values were 0.31 uV and 0.52 uV respectively. Mean values of amplitude ratio (V/I) for left and right ears were 3.06 and 1.80 respectively. Mean values of interpeak latencies of wave I-III, III-V, I-V were 2.01 ms, 2.03 ms and 3.89 ms respectively for left ear and for right ear values were 1.98 ms, 2.02 ms and 3.84 ms respectively. Mean values for left and right ear hearing threshold was 26.25 dBnHL.

**Conclusion:** ABR parameters show variation in values depending upon age, myelination process, maturation of auditory pathway, environmental factors, laboratory setup etc. Hence it is concluded that each laboratory should have its own normative data which can be used as a baseline data for screening of patients with hearing loss.

**Key Words:** Auditory Brainstem Response (ABR); Normative Data; Absolute Latency; Hearing Threshold

## INTRODUCTION

The primary application of Auditory brainstem response (ABR) is for screening and estimating the degree of hearing loss, the type of hearing loss and the configuration of the hearing loss, especially in difficult to test population like premature newborns, mentally retarded child, child with delayed milestones, attention deficits and other sensory impairment. Another use of ABR is in intraoperative monitoring of auditory system during neurosurgery.<sup>[1,2]</sup> ABR, when used and interpreted properly, provides a powerful tool for obtaining reliable estimates of auditory sensitivity in infants, young children and other individuals who cannot or will not provide reliable results on behavioral hearing tests.

To reduce the impact of hearing loss in children, early identification of hearing loss and thus appropriate diagnosis and early intervention is very important. It is now possible to record in humans the electrical activity generated along the auditory pathway in its course from the cochlea to the cortex using surface electrodes.<sup>[3]</sup>

The neural generators of ABR consists of five wave peaks labeled with roman numerals I to V that primarily represents electrical activity generated from cochlear nerve to inferior colliculus. The interpeak latency between these waves reflect neural conduction in the corresponding segment of auditory pathway.

There is a discrepancy in reporting ABR parameters like absolute latency, inter peak latency (IPL), threshold and wave amplitude.<sup>[4]</sup> Wave I (latency) which reflects the peripheral transmission mature faster as compared to subsequent waveforms, like wave III & V, that reflect the central transmission. Increase in ABR thresholds and wave I latency in infants is attributed to (i) immaturity of basal part basilar membrane due to low stiffness (ii) immaturity of the hair cell auditory synaptic function and (iii) mechanical attenuation of sound in middle ear. The wave I-V interpeak latency is prolonged in infants due to improper myelination of auditory pathway and improper efficacy of higher order

neurons.<sup>[2]</sup> ABR matures to adult pattern over a period from birth to age of 18 to 24 months. There is a decrease threshold by 5dB at the end of one year. Hence there are several differences in ABR recordings of infants, children and adult population although the generators of all waveforms are same.<sup>[5]</sup>

The effect of monaural versus binaural stimulation on the ABR has been studied by several researchers. Monaural stimulation means that one ear is stimulated at a time and responses are recorded from the same ear while binaural stimulation means that both the ears are stimulated and recording is done for both the ears simultaneously. The ABR response for binaural stimuli is more prominent than monaural stimuli with significantly larger amplitudes and lower (better) thresholds than monaural stimuli. The fact that the binaural response is not the same as the sum of monaural responses indicates that there are differences in the response of the auditory system to binaural versus monaural stimulation.<sup>[6]</sup> Binaural mode of stimulation is preferred for either neurological or hearing evaluation in the presence of bilateral disorders, and it will not reveal the presence of unilateral disorder. Hence the normative data for binaural mode of presentation needs to be separately established.

Some of the stimulus and recording characteristics of ABR, reported by previous researchers conclude that (i) the responses were independent of level of arousal or attention (ii) their latency varied systematically with signal intensity (iii) they are present at birth and their latency changes with maturation.<sup>[7]</sup>

In addition to these there are inter-laboratory differences and substantial inter subject variability for a given stimulus intensity, moreover the reported interpeak latencies at a given age also show wide scatter. The combination of these and other sources of error described above presents a formidable obstacle to the reliable assessment of central auditory transmission in patients.<sup>[4]</sup>

This article presents evidence bearing directly on clinically important details of recording and evaluating ABR details that we hope will eventually be helpful in standardization of our neurophysiology lab, in such a manner that ABR recordings on a routine basis will produce better and meaningful results for interpretation.

### Rationale of the Study

The fact that waveform latency, amplitudes, their ratios and the interpeak latency depend upon chronological age and the thresholds recorded are variable (higher) in infants than that in children above 2 years, creates a necessity for establishment of normative data in child population. This fact that ABR have variations in normal values of its parameters has been noted by earlier workers, including Picton et al.<sup>[8]</sup>

Hence, the subjects were selected for this study with the objective to obtain the normative data required for recording the ABR in children without hearing loss by using binaural mode of presentation.

## MATERIALS AND METHODS

**Study Settings:** This study was conducted in the laboratory of neurophysiology department of 850 bedded tertiary care hospital and teaching institute, Jawaharlal Nehru Medical College, DMIMS Deemed University (NAAC Accredited Grade A), Wardha.

**Study Duration:** December 2008 to December 2011

**Ethical Committee Clearance:** Approval and clearance was obtained from institutional ethical committee.

**Study Design:** Present study is a Cohort (a type of observational study).

**Research Plan:** Sampling included 40 apparently healthy individuals with normal hearing as assessed by audiological investigations. Mean age for subjects selected was  $7.62 \pm 2.39$  yrs and both

the sexes were involved with 75% males and 25% females. All the participants were selected from OPD of ENT and Paediatrics departments for ABR assessment. None had a history of neurological problems or hearing loss and all had the same Hearing threshold (within 10 dB).

**Evaluation:** The participants were evaluated according to predesigned protocol, after their due consent and data was collected using structured interview information related to presence of ear diseases and other otological disorders. The examination of each patient was carried out using an otoscope to verify the condition of external ear and exclude the cases with impacted wax for ABR assessment.

**Study Instrument:** ABR assessment was done using multichannel polyrite system. Silver chloride disc electrodes were used on standard scalp locations.<sup>[9]</sup>

**Recordings:** Evoked potentials were recorded after sedating the apprehensive patients with oral Triclofos syrup and testing them in quiet and relaxed test environment.<sup>[10]</sup> ABR recordings were obtained by monaural mode of presentation following the standard test protocol given by Hall.<sup>[11]</sup> A total of 2000 stimulations were averaged and all the parameters were compared at 70 dB stimulus intensity level. Masking with white noise was given in non-test ear for monaural recordings.<sup>[12]</sup> The low filter settings were adjusted at 100 to 250 Hz and high filter settings at 5000 Hz. Any electrical activity above 5000 and below 100 was filtered out. Intensity of click stimulus used was 60 dB suprathreshold and the click rate was 11.1 per second. ABR threshold was taken as the lowest level at which peak V was identified.

**Electrode Placement in Binaural Stimulation: (2 Channel Mode):** Cz (Vertex) – Reference or positive electrode was connected to second channel by jumper connector wire. FPz (Nasion) – Ground was connected to second channel by jumper connector wire. A1 – A2 (Mastoid) - Both Active or recording electrodes were connected at the same time to both the channels.

**Parameters Used for Establishment of Normative Data:**

The most prominent peaks i.e. waves I, III and V were considered for analysis. Except for determining thresholds, all the parameters were compared at 70 dB stimulus intensity level.<sup>[2]</sup>

- a. Absolute Latency of waves I, III and V in milliseconds (ms) of each ear separately.
- b. Amplitudes in microvolt ( $\mu$ V) of wave I, and V.
- c. Wave V/I amplitude ratio.
- d. Inter- peak latencies of wave I, III and V in ms.
- e. Hearing Thresholds in (dBnHL) of each ear separately.

Absolute latencies were measured from stimulus to the positive peak of each wave or between two waves. (Interpeak latency) Where waveform was not well defined, a midpoint of the waveform was estimated, this was also done when a bifid wave III was present. When waves IV and V were fused into a single complex, the latency was taken to the point of final inflection before the negative limb of wave V, and this was recorded as wave V latency only. Each ear was assessed differently using the sensitivity of 0.2  $\mu$ V/div. ABR parameters like Absolute latencies, amplitudes, amplitude ratios, Inter- peak latencies and thresholds were assessed for their normative values which are required to establish a baseline data.

**Statistical Analysis:** Descriptive analysis was done to find out mean, standard deviation and standard error of mean.

**RESULTS**

Out of 50 subjects who came, 40 were included in the study, 5 participants were excluded from the study on account of having asymmetrical hearing loss, otological disorders, impacted wax in external ear and aural discharge. Five subjects were excluded from the study due to excessive muscle artifacts during the test that could not be abolished by usual techniques. All the parameters pertaining to ABR recordings were evaluated and

compared for right and left ear separately.

In this study, we investigated the mean values of the Interaural difference of absolute latencies for wave I, III and V by using monaural mode of presentation as depicted in Table1. These were found to be within normal limit (<0.2 ms) which means that there was no gross asymmetry in absolute latencies of right and left ears in subjects. Different parameters used for establishment of normative data are presented in tables 2 to 6.

**Table-1: Interaural Latency Difference in the Subjects**

Mode of Presentation	Wave I (ms)	Wave III (ms)	Wave V (ms)
Binaural (n=40)	0.004 $\pm$ 0.23	0.03 $\pm$ 0.45	0.05 $\pm$ 0.77

**Table-2: Mean and SD for Absolute Latencies of Wave I, III, V (in ms) at 70 dBnHL in Subjects Using Binaural Mode of Presentation**

Ear	Wave	Mean $\pm$ SD	SEM
Left (n=40)	I	1.77 $\pm$ 0.21	0.03
	III	3.73 $\pm$ 0.20	0.03
	V	5.70 $\pm$ 0.36	0.05
Right (n=40)	I	1.77 $\pm$ 0.34	0.05
	III	3.76 $\pm$ 0.42	0.06
	V	5.56 $\pm$ 0.77	0.12

**Table-3: Mean and SD for Amplitudes ( $\mu$ V) of Wave I, and V at 70 dBnHL in Subjects Using Binaural Mode of Presentation**

Ear	Wave	Mean $\pm$ SD	SEM
Left (n=40)	I	0.36 $\pm$ 0.35	0.05
	V	0.56 $\pm$ 0.22	0.03
Right (n=40)	I	0.31 $\pm$ 0.29	0.04
	V	0.52 $\pm$ 0.43	0.08

**Table-4: Mean, SD & SEM for Amplitude Ratio (wave V/I) in Subjects Using Binaural Mode of Presentation**

EAR	Wave V/I (Mean $\pm$ SD)	SEM
Left (n = 40)	3.06 $\pm$ 3.41	0.53
Right (n=40)	1.80 $\pm$ 1.31	0.20

**Table-5: Mean and SD for Inter-Peak Latencies (in msec) of Wave I-III, III-V, I-V at 70 dBnHL in Subjects Using Binaural Mode of Presentation**

Ear	IPL (ms)	Mean $\pm$ SD	SEM
Left (n=40)	I-III	2.01 $\pm$ 0.27	0.04
	III-V	2.03 $\pm$ 0.51	0.08
	I-V	3.89 $\pm$ 0.72	0.11
Right (n=40)	I-III	1.98 $\pm$ 0.29	0.04
	III-V	2.02 $\pm$ 0.51	0.08
	I-V	3.84 $\pm$ 0.74	0.11

**Table-6: Mean Value for Right and Left Ear, SD and SEM for ABR Thresholds (in dBnHL) in Subjects Using Binaural Mode of Presentation**

Hearing Thresholds	Mean $\pm$ SD	SEM
N = 40	26.25 $\pm$ 4.90	0.77

## DISCUSSION

The clinical utility of absolute latency measurements and interpeak intervals is evident that these factors have been used by most authors investigating ABR in abnormal neurological conditions, hence we present normative values for these measurements obtained from a group of normal hearing subjects. These values now can be applied for interpretation of data in ABR of neurological disorders and hearing loss patients.

The normative data was established as reported in Tables 2,3,4,5 and 6 for various parameters of ABR like absolute latency, amplitude, amplitude ratio, interpeak latency and threshold respectively. Any prolongation of data above the normative values can be considered abnormal and can be used for screening the patients of hearing loss. Application of this normative data is hence started for interpretation and diagnostic purpose at our neurophysiology laboratory.

It has been well reported by the researchers that latency values for the later ABR waves III & V are very prolonged in normal hearing neonates when compared to higher age child population values. Authors explained this delay on the basis of incomplete nerve fiber myelination, reduced axon diameter, and immature synaptic functioning.<sup>[13]</sup> Binaurally obtained threshold was approximately 4 dB lower (better) than monaural threshold.<sup>[14]</sup>

The effect of low body temperature and environmental factors on ABR has been extensively investigated. Documentation of body temperature prior to recording ABR is required for valid interpretation of seriously ill patients only, and not for routine recordings. A correction factor of 0.2 ms for wave I-V interpeak latency should be considered for every degree fall in body temperature below normal (37° C) to account for hypothermia. But for hyperthermia there are no published guidelines for correction factor.<sup>[15]</sup>

Earlier studies also suggested that increasing the

stimulus rate to 30 or more clicks per second would help in disclosing neurological abnormalities which are difficult to detect by standard stimulation click rate.<sup>[16]</sup> Studies also reported that ABR recordings are not influenced by giving medication to patients like sedatives, relaxants, barbiturates or anesthesia.<sup>[17]</sup>

Brainstem auditory evoked responses have shown to be an important tool and a useful screening test that the clinical neurophysiologist can offer the neurologist, neurosurgeon or otologist so as to aid in the diagnosis and management of the disorders affecting the nervous system. It is therefore important to verify as completely as possible the range of normal values seen in the test as it is clinically performed both to aid in interpretation and to encourage standardization of the test and meaningful clinical interpretations.

### Implications of Study

The normative data thus obtained through this study will be used as a base line data for assessment of ABR recordings of our neurophysiology lab and it will be implemented for screening patients with hearing loss.

### Limitations and Future Research

Study comprised of child population only with mean age of  $7.62 \pm 2.39$ . Future research can be taken to obtain normative data for other age groups like for infants and old age group.

## CONCLUSION

Age, myelination process, maturation of auditory pathway, environmental factors, laboratory setup etc. are some of the factors responsible for showing variations in values of ABR parameters. Therefore each laboratory should have its own normative data for a specific age group which can be used as a baseline data for screening of patients with hearing loss.

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