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Research Article

A study of brainstem auditory evoked responses in normal human subjects and normal variations as a function of stimulus and subject characteristics

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ABSTRACT

Background: Brainstem auditory evoked responses (BAERs) are electrophysiological investigations have widespread clinical utility in neurology, audiology, neonatology and anesthesiology. BAER responses exhibit a normal variability due to various non-pathologic factors and age is one of the variables suggested to have considerable influence on normal BAE responses. Aging changes in the auditory system may significantly influence the interpretation of the auditory brainstem responses in comparison with younger adults. The present study was undertaken to study the different parameters of brainstem evoked responses in normal subjects and their variations with changing stimulus and subject characteristics among average Indian people.

Methods: The test was conducted on 50 neuro-audiologically normal subjects (age-group of 5-60 years) selected from the OPD of ENT Department. Various audio-vestibular tests they were subjected to brainstem evoked response audiometry and responses were studied regarding various parameters of ABR details. An attempt was made to find out a normal range, normative values of various parameters and their variations with respect of their stimulus intensity and subject characteristics.

Results: In the present study it was observed that absolute latencies of all waves decreased with increasing stimulus intensity. The mean absolute latency values of all waves were prolonged in male than those of female subjects. The mean inter-peak latency values of I-III, III-V and I-V were also prolonged in male. Effects of change in stimulus rate on absolute latencies of all waves were observed. There were increases in absolute latencies of all waves with increasing stimulus rate.

Conclusions: Increased stimulus intensity caused decrease in latency values of all values. Wave V showed lesser degree of variation than the other components. Increase in stimulus rate caused increase in latency of all waves. Wave V showed lesser degree of variation than the other components. BERA can be performed with a wide range of stimulus variations. But what was clear in conclusion was that 60dB SL was the suitable intensity level. Also a wide variety of stimulus rate can be used in combination with either of the stimulus polarity. So any combination of stimulus intensity, rate and polarity may be used for clinical application of BERA. But essence is that there should be a prior adjustment of parameter norms according to subject and stimulus characteristics.

Keywords: Brainstem auditory evoked responses, Brainstem evoked response audiometry, Absolute latency, Inter-peak latency, Inter-aural latency

INTRODUCTION

Within the wider field of electrical response audiometry, Brainstem evoked response audiometry is found particularly useful. The interest and soundness of auditory brainstem responses as unique stem is its simplicity and brief procedure. Responses are not altered by subjective changes due to the use of sedatives, independent of the fact that the subject is awake of asleep. In view of the spectacular success of brainstem auditory responses in diagnosing the site of lesion (such as in cases with acoustic neuroma) and type of hearing loss some authors started debating that at that point it was necessary to decide whether the conventional test battery with behavioral methods be abandoned in favour of auditory brainstem responses.

Auditory brainstem evoked response is a type of electro-diagnostic test for determination of hearing status. It is also known as brainstem auditory evoked potentials (BAEPs). BAEPs represent the electrical activities generated in the auditory pathways between cochlea and the brainstem in response to the auditory stimuli. Activation of the eighth nerve, cochlear nucleus, tracts and nuclei of the lateral lemniscus and inferior colliculus result in the generation of BAEP waveform.[1]

BAEP recorded from a normal human subject consists of a series of waves with different latencies and amplitudes appearing within 10 ms of the stimulus onset. It also has the unique ability to diagnose the type and site of lesion in the auditory pathway as well as in diagnosis of some central neurological disorders like multiple sclerosis, brainstem lesions, intra-operative monitoring and in monitoring traumatic brain injury patients. BAER or BAEP responses exhibit a normal variability due to various non-pathologic factors including stimulus variable like stimulus intensity, stimulus rate, stimulus mode and phase, recoding parameters like electrodes and filter settings.[2] Age is known to have considerable influence on BAEP responses and one of the important factors in the clinical interpretation of the test as progression in age has been found to affect BAEP absolute latencies and interpeak latencies**.**[2-6]

The present study was undertaken to study the different parameters of brainstem evoked responses in normal subjects and their variations with changing stimulus and subject characteristics among average Indian people. Thus to help early detection of hearing disorders and to compare and correlate it with other time-tested methods.

METHODS

The present study was carried at the Department of ENT in association with the Neurology Department of a tertiary care teaching institute, Kolkata. Institutional Ethics Committee was taken before enrolling study subjects. A total 50 neuro-audiologically normal subjects were selected from the OPD of ENT Department. Informed consent was taken from each participant. Subjects were from both sexes and their age ranging from 5 years to 60 years. After history taking, clinical examinations, routine investigations and various audio-vestibular tests they were subjected to brainstem evoked response audiometry and responses were studied regarding various parameters of ABR details. An attempt was made to find out a normal range, normative values of various parameters and their variations with respect of their stimulus intensity and subject characteristics. Routine questions were asked to exclude the presence of any associated audiological symptoms like vertigo, tinnitus, and heaviness in the ears or pain in the ears. Past history of any otological diseases was sought and excluded from the study. ENT and head and neck examinations were done and recorded.

Rinne test, Weber test and absolute bone conduction (ABC) test were done using tuning fork of 512 Hz frequency. While testing the unilateral hearing the non-test ear was masked by Barany's noise box. Routine hematological and serological tests were done. X-ray of paranasal sinuses and internal auditory meatus, Town's view was done where it was indicated. Caloric test was carried out in all subjects as routine investigation for assessment of vestibular function. Otoscopic and microscopic examination of the ears and tympanic membrane was undertaken routinely. Pure tone audiometry was considered as a routine investigation. Threshold frequencies (250 Hz to 4000 Hz) in bone and air conduction were recorded. The average air conduction threshold of hearing in speech frequencies were determined and recorded. Subjects for the present study were selected only from those who were within the normal range of hearing i.e. upto 15 dB losses in air conduction and that upto 10dB for bone conduction.

The subjects who fulfilled the let-down criteria for selection were selected and submitted for Brainstem Evoked Response Audiometry. It was carried out with Neuromatic 2000c machine in a sound treated room. The instrument was with soft waro-controlled operation which was self-explanatory to the investigator. At one particular intensity of stimulation four readings were taken and when at least two of these readings overlap each other, were considered for calculation. More readings were taken where two readings did not overlap. Same procedure was repeated for another sound intensity and also after changing the rate of stimulus and after changing the phase of the sound stimulus. Using M1 short form of the average signal it was magnified upto 25 times. The save/show function was used for shaving the averaged signals. Latencies of individual waves were measured seeing time markers in msec. Inter-peak latencies (IPL) of I-III, III-IV, and I-V were also measured. Same procedure was carried out for the opposite ear. Inter-aural latency difference of wave V (ILD-V) and inter-aural inter-peak latency difference of I-V (IPLD, I-V) were also calculated in msec.

Sound pressure level was increased by 9 dB and same procedure and recordings were done for 2 such increments. Rate of click stimulus was increased to 30 and 50 clicks per second and latencies of waves I to V recorded. Polarity of stimulus was changed to condensation and again the latencies were noted. All these observations were studied regarding age, sex, presence of associated diseases, personal habit, occupation and residence to detect any cause-effect association. In a few cases the latency-intensity function of wave V was also studied for determination of threshold of hearing and its difference with the conventional behavioral threshold of hearing.

RESULTS

Fifty subjects were selected from the patients attending the ENT OPD of Medical College and Hospital, Kolkata. None of the subjects had any otological and neurological complain. There were no significant difference in their clinical presentation, nature of ailment as observed with respect to residence, economic status and occupation of subjects under study. Associated problems were noted as vertigo in 3 (6%), occasional tinnitus 2 (4%), hypertension 4 (8%) and diabetes in 2 subjects (4%). All of them were considered to be healthy from oto-neurological point of view after performing extensive investigative procedures as mentioned.

Out of 50 subjects 4 subjects had suspicion regarding their normal appearance of tympanic membrane for mild retraction. Those subjects underwent impedance audiometric test apart from the routine procedures like otoscopic and microscopic evaluation.

Rinne test was found to be positive in all the cases. Weber test was central in all subjects. Clinical vestibular function, Romberg's sign and test for all other cranial nerves were found to be normal in all the subjects. Hematological and serological tests results were non-significant. X-ray of chest (PA view) and paranasal sinuses was normal in all cases. Otoscopic and microscopic examination was done with ZEISS operating microscope and was non-significant in all the cases. Caloric test using Hallpike & Fitzgerald method was within normal limits in all cases i.e. the duration of nystagmus was between 75 to 150 seconds without any directional preponderance. Only 2 subjects (4%, n=50) had borderline results, those were submitted for electronystagmography.

All the subjects showed normal response to both hot and cold caloric stimulation in both the ears. Results thus obtained were plotted in the butterfly chart as suggested by Claussen and Kirtane.[7,8] All the observation were found to be within normal limits.

Pure tone audiometry was done in all the subjects as a routine investigation. The air and bone conduction threshold for each subject were determined and recorded at 250, 500, 1000, 2000 and 4000 Hz intensity. All the subjects had air conduction threshold at or below 15 dB and bone conduction threshold at or below 10 dB in both the ears. The inter-aural threshold differences were at or below 10 dB. The average threshold for air conduction (pure tone threshold) at speech frequencies was thus determined for comparison with BERA (for click intensity) threshold.

Brainstem evoked response audiometry (BERA)

One hundred ears of 50 subjects, selected for this study, were tested with rarefaction click stimulus at the rate of 10 clicks per sec. The sound pressure level was 60 dB above the subjective hearing threshold (SL) (Table 1). Only ipsilateral stimulation was tested with white noise masking (40 dB) of the non-tested ear. The mean absolute latencies of all waves and their standard deviation were calculated and analyzed.

Table 1: Latencies at 60 dB subjective hearing threshold (SL) (m. sec.).

Characteristics	I	II	III	IV	V
Male	1.659	2.615	3.789	4.721	5.675
Female	1.506	2.566	3.537	4.470	5.487
Mean	1.585	2.642	3.668	4.598	5.585
S.D.	0.135	0.170	0.120	0.074	0.094

Table 2: Age group specific latency values (m. sec.).

Age (yrs)	I			II			III		
	M (Male)	F (Female)	Mean	M	F	Mean	M	F	Mean
5-10	1.651	1.519	1.627	3.90	3.69	3.862	5.706	5.505	5.644
11-15	1.582	1.475	1.525	3.782	3.472	3.627	5.682	5.437	5.560
16-20	1.67	1.469	1.569	3.803	3.610	3.706	5.63	5.612	5.621
21-30	1.626	1.586	1.607	3.422	3.784	3.585	5.616	5.39	5.503
31-40	1.665	1.580	1.623	3.72	3.69	3.705	5.58	5.52	5.64
41-50	1.66	1.617	1.623	3.772	3.478	3.625	5.676	5.50	5.588
51-60	1.635	1.475	1.555	3.625	3.593	3.607	5.61	5.44	5.525

The latency of wave I was ranged from 1.26 to 1.72 m. sec and mean value was 1.585 (Table 1). The mean absolute latencies of wave I to V were 1.659, 2.615, 3.789, 4.721 and 5.675 m. sec respectively in cases of male subjects. Those in cases of females were 1.506, 2.566, 3.537, 4.470 and 5.487 m. sec respectively.

The inter-aural latency difference of wave V in the present study was ranged from 0.00 to 0.20 m. sec (Table 3).

The IPLD values of I-III, III-V and I-V were ranged from 1.64 to 2.42 m. sec, 1.60 to 2.40 m. sec and 3.70 to 4.38 m. sec respectively (Table 4). The IPLD I-V was further studied in details and the observations were:

i) The ILD of I-V was ranged from 0.00 to 0.20 m. sec in the study.

ii) The mean ILD I-V was 0.07 m. sec. The same values for male and female subjects were 0.059 and 0.081 respectively.

iii) The mean IPLD I-V was 4.0216 and 3.889 m. sec in male and female subjects respectively.

Table 3: The inter-aural latency difference (ILD) V values (m. sec.).

	Male	Female	Overall
Mean	0.0623	0.097	0.0792
S.D.	0.0426	0.0435	0.09

Table 4: The inter-peak latency differences (IPLD) values (m. sec.).

	I-III	III-V	I-V
Range	1.64 – 2.42	1.60 – 2.40	3.70 – 4.38
Mean	1.981	1.887	3.959

Table 5: Absolute latencies with changing stimulus intensity (m. sec.) (R= Right, L= Left).

Sl. No. of the subject	Ear	60 dB SL			69 dB SL			78 dB SL		
		I	III	V	I	III	V	I	III	V
11	R	1.54	3.42	5.38	1.30	3.20	5.14	1.10	3.02	5.02
	L	1.48	3.36	5.42	1.26	3.14	5.20	1.04	2.96	5.06
18	R	1.72	3.86	5.80	1.46	3.56	5.48	1.26	3.30	5.12
	L	1.68	3.90	5.82	1.46	3.58	5.54	1.22	3.30	5.12
21	R	1.38	3.64	5.46	1.18	3.40	5.26	1.04	3.14	5.10
	L	1.36	3.58	5.48	1.14	3.32	5.26	1.02	3.12	5.12
27	R	1.72	3.82	5.68	1.44	3.58	5.40	1.18	3.28	5.26
	L	1.62	3.70	5.68	1.32	3.58	5.40	1.14	3.30	5.22
35	R	1.72	3.60	5.60	1.22	3.40	5.42	1.04	3.12	5.20
	L	1.72	3.68	5.68	1.36	3.40	5.46	1.12	3.14	5.20
Mean		1.578	3.656	5.600	1.314	3.416	5.356	1.116	3.168	5.142
S.D.		0.136	0.125	0.155	0.135	0.161	0.136	0.11	0.118	0.138

Five subjects (serial nos. 11, 18, 21, 27 and 35) were studied regarding their BAER with changing stimulus intensity. The study was done at the same sitting and followed identical procedure except the stimulus intensity which at first was 60 dB SL and increased by 9 dB steps to 69 dB and 78 dB (Table 5). The mean absolute latency (and SD) of wave I was 1.578 (0.136), 1.314 (0.135) and 1.116 (0.11) at 60, 69 and 78 dB SL respectively (Table 5). The same values for wave III was 3.656 (0.125), 3.416 (0.161) and 3.168 (0.118) at 60, 69 and 78 dB SL respectively. It was observed that there was decrease in latency value of all waves with increasing stimulus intensity. Wave I was seen to be most sensitive than the earlier components. The mean decrease in wave V latency value was 25.5 m. sec per dB.

The amplitude of all waves was also seen to increase with increasing stimulus intensity. Wave V again appeared as the least sensitive component. Effects of changing stimulus rate on BAER were studied. Only stimulus rate was changed from 10 to 30 and 50 click per sec. Stimulus intensity was at 60 dB SL and polarity was rarefaction. It was observed that there were increases in latency values of all waves with stimulus rate. Those changes in wave I, III, and V were studied in detail. The mean (SD) latency of wave I was 1.485 (0.135), 1.666 (0.101), and 1.790 (0.132) m. sec at 10, 30 and 50 clicks per sound respectively. The mean (SD) latency of wave III was 3.452 (0.125), 3.612 (0.20), and 3.736 (0.191) at 10, 30 and 50 clicks per sec respectively. Those values for wave V was 5.426 (0.155), 5.566 (0.143) and 5.656 (0.125) at 10, 30 and 50 clicks per sound respectively. The amplitude of all waves shortened with increasing stimulus rate. Wave V was found to be least affected by change of stimulus rate.

Three subjects were studied with changing stimulus polarity of the click stimulus with stimulus intensity at 60 dB SL and rate was at 10 clicks per second. It was observed that there was a difference in latency values by a fraction of millisecond. It was also observed that there was no definite pattern in change of absolute latencies of various waves then they were compared. The change of absolute latency in change in polarity was inconsistent. However, in majority of the cases the C-latency showed higher value than that of R-latency.

All waves appeared with more distinct and clear cut forms when condensation clicks were used. The appearances of all five waves with sharp peaks were also observed. In the overall study wave III and V were the most constant waves and were present in all recordings. Wave V was the most prominent wave. Wave I was absent in 4% of the subjects. Wave II was absent in 14% of recordings and in 38% of recordings were IV was either absent or was in conjugation with wave V as IV-V complex.

Stimulus intensity level at 60 dB SL showed maximum identifiable waves. Reductions in number of waves at intensities below or above it were also observed. Total number of clicks used did not show any relation to absolute latencies or inter-wave latencies. In the present study, it was evident that around at 2000 clicks all well-formed waves were appeared and consistent.

DISCUSSION

Auditory evoked responses or potentials (AEPs) are very small electrical voltage potentials which originate from the brain and are recorded from the scalp in response to an auditory stimulus.[9, 10] So, Auditory evoked potentials or responses span activity from the full length of the auditory pathway, from cochlear hair cells to cerebral cortex. AEP can be classified according to latency (i.e time interval between presentation of sound stimulus and wave peak).[11-13] BAERs are the electrical activities resulting from the activation of the eighth nerve, cochlear nucleus, tracts and nuclei of the lateral lemniscus and inferior colliculus. BAERs or BAEPs are far field reflections of the electrical activity which occurs in the auditory nerve and brainstem in response to an acoustic stimulus and which can be extracted from the electroencephalograph by filtering and averaging.[10,12,14]

The evoked potentials or responses reflect the successive electrical events of the brainstem auditory pathways and are also named "far-field" potentials because they are recorded on the scalp, far from the origin. They occur within 10millisecond (msec) after each stimulus, they are called "Short-latency response."[10,15] These potential are called brainstem auditory evoked potential or response because they are generated by the activation of the brainstem pathways. The BAEP or BAERs consists of a series of five positive waves occurring within 10 msec following stimulus onset. They are labelled with Roman numerals: wave I to V. These waves represent the neuroelectrical activity which is generated by the neural generators in the auditory pathway between cochlea and the brainstem.[10,12,16]

Subjects from urban areas showed a little higher mean absolute latency values of all waves, than those from rural areas. This might be due to more exposure to noise in urban population. Weston and Rosen et al in their survey of incidence of hearing loss in age related urban and rural population, presumably due to higher overall noise exposure.[17,18]

The mean absolute latency values of all waves were prolonged in male than those of female subjects. The mean inter-peak latency values of I-III, III-V and I-V were also prolonged in male. The age specific groups also showed that latency values of all waves were delayed in male than those of female subjects. Manjuran and Arora observed that the males had delayed latency value for each wave than the corresponding values in females. Sharma et al also observed that females had shorter latency values for each waves than those of males.[19,20] Similar observations were also reported from Kjar.[21] They observed that the females had shorter latency values than those of males. Stokard et al also observed that IPLs of men were longer than those of females.[22]

Subjects of the present study were grouped into seven age groups. Each of the age groups again sub-grouped according to their sex. Age group specific distribution revealed that the absolute latency of waves I, II, III and V did not show any significant variations. The IPLs of I-III, III-V and I-V of specifically classified age groups also did not show any attributable difference. Hecox et al observed that the wave V latency shortened during infancy to attain its adult value between the ages of 12 to 18 months.[23] Deka and Kacker observed that the adult value was reached by the age of 2 years as the myelination of VIII[th] cranial nerve completes by this age.[24]

Ten subjects (all male) were chronic smoker with a history of smoking more than 10 cigarettes a day for over a period of more than 10 years. The mean latency value of wave V in smokers were little higher than those of non-smokers. Zelman observed that the percentage of hearing loss was greater for smokers in all frequencies.[25] A primary suspected mechanism of hearing impairment associated with smoking is vascular insufficiency of the cochlear end organ. But Drettnor et al could not find any significant difference in hearing loss between smokers and non-smokers.[26]

Virtaniemi J et al observed that latencies of auditory brainstem responses were significantly altered in diabetic subjects in comparison to those of normal.[27] Goldsher et al observed bilateral symmetrical prolongation of all peak latencies and prolongation of III-I, V-I and V-III inter-peak latency differences in diabetics and more so in those with peripheral neuropathy.[28] Sharma et al observed prolongation of wave III, IV and V latencies and also I-III and I-V inter-peak latencies in diabetics.[20]

The mean value of inter-aural latency difference of wave V (ILDV) was 0.0792 m. sec (0.09). The inter-aural latency difference of wave V was not more than 0.20 m sec in any of the fifty subjects studied. Female subjects showed a little higher value of ILD V (0.097±0.435) than those of males (0.0623±0.0426). ILD V was considered as a more reliable parameter than absolute latencies. However, it was applicable only in cases where at least one of the two ears was normal. Chiappa et al observed that the mean inter-aural difference of wave V latency was 0.11± 0.08 m sec.[29] The inter-peak latency differences of I-III, III-V and I-V and inter-aural inter-peak latency difference of I-V as observed in the present study were comparable to those observed by Chiappa et al.[29] Stokard et al concluded that IPLD was the standard parameter because it was relatively close among different laboratory observations.[30] On analysing the technical and population variables they also observed that the range and limits were important in diagnostic application of the test rather than the mean. They recorded a laboratory variation of upper range of IPLD I-V by more than 0.6 m sec though the difference in the mean was 0.2 m sec. The range of IPLDs I-III, III-V, and I-V in the present study was 1.64 to 2.42 m. sec; 1.60 to 2.40 m. sec and 3.70 to 4.38 m. sec respectively. The mean latency values of wave's I-V are comparable to those observed by Chiappa et al.[29]

In the present study it was observed that absolute latencies of all waves decreased with increasing stimulus intensity. Only those of wave I, III and V were evaluated in the present study. The mean increases in absolute latency values were found to be statistically significant. Further it was observed that wave V showed least sensitivity to change of stimulus intensity, whereas wave I was the most sensitive component in this regard. The decrease in wave V latency value was 21.4 m. sec and 14.4 m sec when stimulus intensity was changed from 60 to 69 dB SL and 69 to 78 dB SL respectively. The latency-intensity function of wave V was studied. It showed the tangential value of 17.85 micro sec per dB. Coats et al observed a systemic increase in latency of wave V with decreasing stimulus intensity.[31] They observed that it decreased from about 8.5 m. sec at 10 dB SL to 6.0 m. sec at 60 dB SL respectively. Stokard et al observed that the peak latencies increased with decreasing stimulus intensity.[30] They also observed that the magnitude of shift was greater for wave I than for the later components.

Vishwakarma et al observed that the mean value for latencies of all waves increased with decreasing stimulus intensity.[32] The mean decrease in wave V latency value was 20 micro sec/dB when stimulus intensity was increased from 60 to 70 dB SL. The same value was 11 micro sec/dB when the stimulus intensity was changed from 70 to 80 dB SL. The mean increase was 15.5 micro sec/dB. The amplitude of all waves increased with stimulus intensity. Wave V amplitude was found to be relatively stable than the other components.

Hecox et al observed that the amplitude and latencies of all waves varied with stimulus intensity.[33] They also observed that the wave V was least sensitive to stimulus intensity change. Hecox et al reported that amplitude all waves increased with decreasing stimulus intensity.[23] Wave I was observed to be bifid at high intensities. There were also increases in muscle artefacts with increasing stimulus intensity. Stokard et al observed that wave I separated into a bifid wave making identification of amplitude and latency of wave I difficult at high frequencies.[30] Montandon et al reported that stimulus at high intensities caused disturbance to the subjects relaxed posture and made the nearby muscles contract.[34] These additive activity caused increase in muscles artefacts and disruption of wave I morphology.

Vishwakarma et al observed that BERA had a bias to the basal turn of cochlea.[32] Action potential generating at that region in response to high intensity sound were included in BERA recordings and probably caused bifurcation of wave I.

Effects of change in stimulus rate on absolute latencies of all waves were observed. There were increases in absolute latencies of all waves with increasing stimulus rate. The change in latency values of wave I, III, and V were studied. Of these three waves studied were wave V was found to be most stable with regards to its response to changing stimulus rate. The mean increase in wave V latency value was 0.14 m sec when the stimulus rate was changed from 10 to 30 clicks per sec. The same value was 0.09 m sec when stimulus rate was changed from 30 to 50 clicks per sec. A decrease in amplitude of all waves was observed with increasing stimulus repetition rate. The change was least for wave V. Hecox et al observed a decrease in wave amplitude for all waves but to a lesser degree for wave V.[35] They also reported that at stimulus rates upto wave V maintained approximately 85% of its original amplitude. Chiappa et al reported the changes in absolute latency values with changing stimulus rate.[28] They particularly studied that effect on wave V latency. They observed that the latency of wave V was increased when the stimulus rate was changed from 10 to 80 clicks per sec. Stokard et al observed that when stimulus rate was increased from 10 to 80 clicks per sec there was increase in absolute latency values of all waves with increased IPLs values.[30] Wilder et al observed the similar type of findings.[36]

Stokard et al reported that there were some difference in latencies with inversion of stimulus polarity.[30] Emersion et al observed wave I to appear earlier in rarefaction.[37] In their study wave III and V also appeared to be insensitive to inversion of polarity. In the present study wave I was absent in 4% of cases. In about 38% of cases wave IV was absent. Wave V came out as the most stable wave. It was seen that wave V was least affected by change of stimulus character like stimulus intensity, rate and polarity. Coats et el, Stokard et al, Chiappa et al, Emersion et al, Vishwakarma et al, Patel KC et al and Gupta S et al reported the similar observations for wave V.[27,28.30-32,37]

The mean air conduction threshold in pure-tone audiometry was 8.475 dB. The mean BERA (click stimulus) threshold was 38.6 dB. None of the subjects of the present study had its behavioral threshold more than the BERA threshold. The mean difference between pure-tone and BERA threshold was 24.1 dB. Vishwakarma et al also observed that none of the subjects of their study had pure-tone threshold more than the BERA threshold.[32]

CONCLUSION

Auditory Brainstem Response pattern was studied in 50 normal subjects. Statistical evaluation of the recordings of the study put forwarded the following conclusions:

- Absolute latencies of all five waves, IPLs, and ILDs were seen to be prolonged in males than the corresponding values in females.
- Hypertensive and diabetic subjects showed little prolongation of latency values. The prolongations were not significant to account any cause-effect association.
- Increased stimulus intensity caused decrease in latency values of all values. Wave V showed lesser degree of variation than the other components.
- Increase in stimulus rate caused increase in latency of all waves. Wave V showed lesser degree of variation than the other components.
- Inversion of stimulus polarity did produce some difference in latency values. But the variations could not be simplified as above. Wave V here also was the most stable form.
- Increase in both stimulus polarities did produce some difference in latency values. But the variations could not be simplified as above. Wave V here also was the most stable form.
- Increase in both stimulus rate and intensity caused prolongation of latency values of all waves.
- Inter-aural latency difference of latency of wave V was not more than 200 micro secs in any of the subjects.
- Inter-aural latency differences of IPLs I-V were within normal range (0.02 m sec).
- One or more than one waves were seen to be absent in some normal individuals. This point made it clear that BERA always must be correlated with other behavioral test to arrive at a diagnosis.
- Wave V was the most constant wave with all subjects and stimulus character variations. It was also observed that it satisfied several important criterions for clinical use of its physiological responses.
- None of the subjects of the study had pure-tone threshold more than its BERA threshold. The mean difference was 24.1dB. The lowest stimulus intensity that can be produced by the instrument was also 24dB.
- BERA can be performed with a wide range of stimulus variations. But what was clear in conclusion was that 60dB SL was the suitable intensity level. Also a wide variety of stimulus rate can be used in combination with either of the stimulus polarity.

So any combination of stimulus intensity, rate and polarity may be used for clinical application of BERA. But essence is that there should be a prior adjustment of parameter norms according to subject and stimulus characteristics.

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