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Quantitative Study on the Effect of Gender and Age on Brainstem Auditory Evoked Responses

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Abstract*— Brainstem auditory evoked responses (BAERs) are the evoked potentials which are recorded in response to an auditory stimulus from electrodes placed on the scalp. They reflect neuronal activity in the auditory nerve pathway, cochlear nucleus, superior olivery complex and inferior colliculus of the brainstem, and are used in the diagnosis of neurological hearing loss. In the present work, BAERs are evaluated by testing the normal peak and interpeak latency (IPL) values in different age groups and gender. The BAERs peak latency and IPL values are measured and evaluated for the changes in 39 subjects, in the age groups of 1-20, 21-40 and 41-70 years, in men and women. The results shows that, in the different age groups the peak latency and IPL of BAERs recorded from right and left ears of the subjects significantly vary with the difference in age and gender. The result in this paper confirms that there is a significant difference ($p < 0.05$) in the latency and interpeak latency values in different age groups as well the response in female's shows shorter latency and IPL values compared with that of males.

***Index Terms*— Brainstem Auditory Evoked Response (BAER), Hearing Loss, Interpeak Latency (IPL), Peak Latency.**

I. INTRODUCTION

The BAER is a neurologic test of auditory brainstem function in response to auditory stimuli, which are first described by Jewett and Williston in 1970 [1]. These potentials are called brainstem auditory evoked potentials (BAEPs) or responses because they are generated by the activation of the brainstem pathways [2]. The BAER is one of the best recognised electrophysiological tools used by neurologist and audiologists. From the BAEPs a neurologist is able to determine the time it takes for an aural stimulus to travel from the point at the inner ear where the physical sound is translated into a bioelectrical impulse to the brainstem. From these readings the neurologist comes to know about the proper conduction of the auditory nerve. For example, an acoustic neuroma (a benign tumour in the ear canal) can stretch or compress the auditory nerve resulting in a long time for the processing of aural stimuli.

The primary clinical application of the BAER signals is the objective determination of hearing threshold in individuals who cannot participate in behavioral testing, such as infants and handicapped individuals. These are also used in monitoring traumatic brain injury patients, and intraoperative monitoring for skull base surgery [3]. In addition, the auditory brainstem response ability to test peripheral auditory function directly has made it a valuable tool in infant hearing screening. In monitoring applications, the latencies of the major waves are observed over time, and major changes outside of statistical fluctuations are interpreted for evaluation. Age and gender may have an effect on BAEP measurements [4]. The newborns tend to have longer latencies, which changes with the age. The influences of physiological and methodological factors on recordings of BAEPs are greater in children than in adults [5].

The BAER signals can be generated in the nerve pathway from brainstem to auditory cortex by a short click or tone transmitted from an acoustic transducer to ears through the headphones. The response in the waveforms form is recorded by surface electrodes placed at the vertex of the scalp and ear lobes. The amplitude of the signal (µv) is averaged and plotted against the time (ms). Amplitudes and latencies are the parameters used clinically to characterize the peaks [6].The typical BAEP signal peaks/waves labeled as I-VII is shown in Fig.1 [3].The generation and propagation of action potentials at various stages from auditory nerve to auditory cortex are represented by various peaks of BAEP. The peak I occurs at auditory nerve, peak II at cochlear nucleus, peak III at superior olivery complex, peak IV at lemniscuses tracts, peak V at upper part of pons and lower midbrain, peak VI at medial geniculate body, and peak VII occurs due to the generator activity of the auditory relations [4]. These peaks normally occur within a 10-11 ms time period after a click stimulus presented at intensities 70-90 dB of

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normal hearing level. In the present work only the peaks I-V are considered, as VI and VII are not routinely used for diagnosis of hearing loss [7].

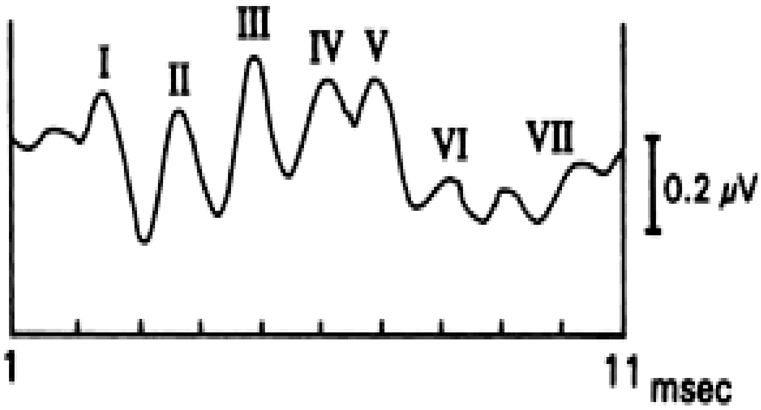

Fig.1 Typical BAER Signal [2]

Age-related hearing loss is an increasingly common form of sensory neural hearing loss and the auditory brainstem response is the common experimental and clinical tool in audiology and neurology. Some of the changes that occur in the aging auditory system may significantly influence the interpretation of the auditory response in comparison to the auditory responses of younger adults. Age related changes in the evoked potentials are not completely known but may are a result of several changes in the lateral wall of the cochlea, since the volumes of the cochlear nucleus in the older humans are reduced due to a loss of myelin surrounding axons [8]. There is also a general agreement on the fact that females have shorter absolute and interpeak latencies than males. This study focuses on the changes in the aging and different gender auditory system that may influence BAER interpretation.

II. METHODOLOGY

A. *BAERs Recording System*

The BAERs were recorded using a commercially available device (RMS EMG-EP MK-11 Version 1.1 from Recorders and Medicare Systems) in a sound proof chamber. The basic block diagram of the system is as shown in Fig.2. The BAEPs were recorded using small disk surface electrodes made up of Ag/AgCl. The measuring electrodes were placed on mastoid and over the left or right ear lobes; reference electrode was placed on the scalp at the vertex, and the ground electrode on the forehead. This configuration is known as "vertex-positive-up" and is usually employed in such practices [9]. The exact positions of electrodes were according to the 10-20 electrode system of EEG.

To record the data, standard click stimulation generated by a computerized system was given to the ear being tested through headphones. The average response for 10 ms from 1000 to 2000 clicks was displayed on the monitor. The sampling frequency of 10 kHz for duration of 1000 clicks of 0.5μV was set. The repeated click at a frequency of 10/sec were presented binaurally or monaurally at an intensity of 85-110 dB. The magnitudes of the BAER are very small, approximately 0.01 to 1 μv and are amplified by instrumentation amplifier set at a gain of 120 dB. The amplified signal was passed through a band-pass filter with lower and upper cut off frequencies of 100 *Hz* and 3000 *Hz* respectively. The output of band-pass filter which was in the order of a few hundred of μv was again amplified by a post amplifier (gain of 40 dB) to a few volts. The stimulus click frequency was restricted to 10 or 11 *Hz* as the auditory system showed adaptation beyond this frequency and hence the response would not be identical for every stimulus [9]. The recording unit included 14 bit Analog to digital converter of 250-8000Hz with 2- 4 Input Channels. The Stimulator was of Headphone type, Click stimuli were with Rarefaction, Condensation or Alternating types on selection. The duration of the recording for 2000 clicks stimuli at the rate of 11.1Hz was 2-3 minutes. The recorded Data was stored in Excel sheet or exported to MATLAB or sent to other systems through Email.

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B. *Data Collection*

The BAER data was collected from 39 normal subjects aged between 1 to 70 years. The normal values of BAERs in this study were considered taking the reference values quoted by Chaippa [12] and Misra and Kalita [14]. These 39 patients were divided into three groups according to the gender and age group as 1-20, 21-40 and 41-70. The mean age and standard deviation (SD) for different age groups are shown in the Table I and II.

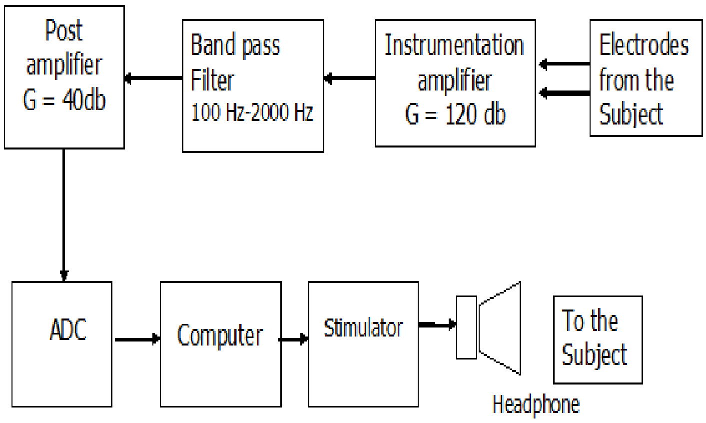

Fig. 2 Recording System of BAER [4]

For each subject the data was recorded for both ears and the whole procedure of recording completed in 10-15 minutes. The recorded BAERs are non-invasive measures of the auditory pathways functions produced in response to the auditory stimulation using surface electrodes. A large number of sweeps has to be averaged to obtain a meaningful signal at stimulation levels due to a poor signal to noise ratio [10]. The most common way to measure BAER is using ensemble averaging (EA) technique for determining stimulus related BAER components. EA technique is the mean of the summation of all responses to the repetitive auditory stimulations. The technique has been successfully used in many acquisition systems [11].

C. *Analysis of BAERs*

Neural elements within the auditory pathway are the cochlea, spiral ganglion, eighth nerve, cochlear nucleus, superior olivary complex, the inferior colliculus, and the medial geniculate body. The stimulated click sound will travel along these elements to reach the auditory cortex to perceive the sound input. The stimulation causes generation of action potentials at neural elements resulting in various peaks of BAER. The typical BAER signals recorded for male and female subjects are shown in Fig. 3 and Fig. 4. The response of the 60 year old male is shown in Fig. 3 and Fig. 4 shows the auditory response of a 42 year old female.

In the first 10ms after the auditory stimulus, a series of potentials corresponding to the sequential activation of the peripheral, pontomedullary, pontine and midbrain portion of auditory pathways are recorded. At the vertex and earlobe, these form vertex positive and vertex negative waves which are called BAERs. The initial five peaks are of clinical interest. Wave I is the initial up-going peak in the recording channel, appears 1.4ms after the stimulus. It has a wide distribution of positivity and negativity. Wave II appears as a small peak along the down-going slope of wave I or in the up-going slope of wave III. Wave III is usually a prominent peak and is followed by a prominent III trough, appears between peak I and V approximately at equidistance. Wave IV may normally be closer to peak III than to V. Wave V is the most prominent peak appearing 5.5ms after the stimulus. It starts above the baseline and its trough is maximal below the baseline. Absolute latency measurements are taken from the peak of the respective wave. The markings on the peaks are done by the clinician mentally or physically on the graph plot on the computer system. The assessments are made on the critical parameters such as the absolute peak latency values and the interpeak latencies. The commonest IPLs employed in the clinical practice are I-V, I-III and III-V. The latency difference between peak V and I is a measure of IPL I-V, peak III and I is IPL I-III and the latency difference of peak V and peak III is IPL III-V. The measurements of the above peaks I-V are plotted on the graph as a function of stimulus intensity with respect to the time.

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There is no clinically important effect of peripheral hearing disorders on central BAER interpeak latencies. Therefore if the peaks I, III and V are clearly visible in the auditory response then, the final part of the interpretation of abnormal interpeak latencies might read: (1) Abnormal I-III interpeak latency, suggests the presence of a conduction defect in the brainstem auditory system between the eighth nerve close to the cochlea and the lower pons. (2) Abnormal III-V interpeak latency, suggests the presence of a conduction defect in the brainstem auditory system between the lower pons and the midbrain. (3) When wave I is absent and III-V separation is normal, it is due to a peripheral hearing disorder. Here, the state of conduction in the segment of the brainstem auditory pathway between peripheral eighth nerve and lower pons would not be determined. Lower pons to midbrain conduction might be normal [12].

III. RESULTS

The mean and SD values of peak latency and IPLs recorded for 39 normal subjects are shown in Table I and Table II. The results contain the information about the variation in the peak latency and IPL values of the subjects in the different age groups and in different genders. All the data were found to be normal when compared with earlier standards [12], [14]. The statistical significance of the difference in the peak latency and IPL values between the male and female subjects was evaluated by statistical *t*-test. The data collected from both male and female showed that there is a significant variation in the peak latency and IPL values. From the tables we observed that there is a noticeable difference in the peak latencies in all the three age groups in the male and females. The IPL values in male and female also seemed to differ significantly in all the three age groups. It is observed that the latency peak values for females were slightly less than men. Females have a shorter latency and higher amplitude of BAERs, which attribute to higher core body temperature and shorter length of brainstem auditory pathway [13], [14]. However, little difference were observed in the first age groups latency and interpeak values as there appears to be no significant sex difference in prematures, newborns and young children [12].

IV. DISCUSSION

There are various clinical studies indicating that with increase in the age there is change in absolute peak latencies and interpeak latencies of the BAER components [4], but there is no quantitative study indicating the gender differences. The present study confirms that the latencies in females are shorter than men in the different age groups. The females have the shorter latencies due to higher internal body temperature and shorter length of brainstem auditory pathway [12], [13], [14].

The data in Table I shows that peak latency values differs in different age groups recorded from right and left ears of both genders. From Table II shows the interpeak values are comparatively larger in males and in older age groups in both the ears. A little extent of values falling away from the standard values was observed in the study. The interpeak latency values in male and female in the different age groups recorded from both ears, showed a slight different values away from the standard normal values. For example, the normal interpeak values for the IPL I-V is 4.28ms [15] whereas the corresponding mean values in the current study was 4.01 and 3.91 in right ear, 3.9 & 3.85 in left ear for male and females respectively.

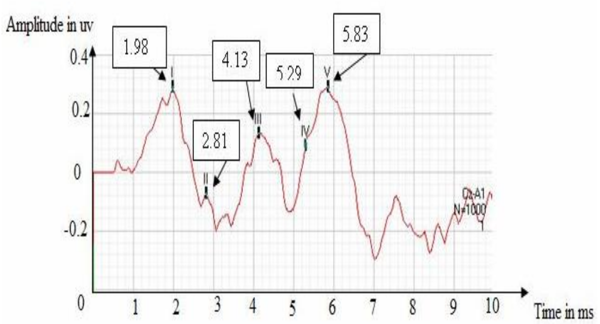

Fig. 3 BAER of male subject: age 60

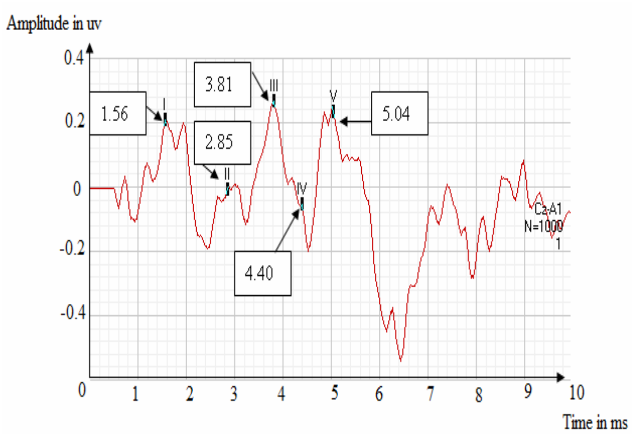

Fig. 4 BAER of female subject: age 42

Table I. Mean peak latency values (a) Right ear (b) Left year

(a) Right ear

Age Group	No of males(M), females(F), Age±SD	Mean peak latency (ms)				
		I	II	III	IV	V
1-20	M=7 4±4	1.55±0.11	2.45±0.14	3.79±0.24	4.84±0.16	5.63±0.34
	F=6 6±5	1.54±0.12	2.6±0.22	3.63±0.22	4.63±0.26	5.49±0.2
		p=0.00001	p=0.0006	p=0.007	p=0.008	p=0.0007
21-40	M=7 31±7	1.7±0.26	2.63±0.15	3.66±0.36	4.75±0.19	5.71±0.31
	F=7 32±7	1.6±0.16	2.52±0.26	3.52±0.29	4.57±0.28	5.44±0.15
		p=0.001	p=0.0005	p=0.007	p=0.007	p=0.0004
41-70	M=7 55±9	1.72±0.17	2.75±0.2	3.81±0.18	4.9±0.21	5.69±0.15
	F=5 55±11	1.68±0.28	2.69±0.11	3.76±0.31	4.8±0.35	5.59±0.25
		p=0.01	p=0.0002	p=0.006	p=0.0001	p=0.00008

(b) Left ear

Age Group	No of males(M), females(F), Age±SD	Mean peak latency (ms)				
		I	II	III	IV	V
1-20	M=7 4±4	1.62±0.18	2.64±0.18	3.74±0.33	4.79±0.35	5.63±0.37
	F=6 6±5	1.55±0.13	2.64±0.23	3.7±0.23	4.75±0.15	5.46±0.1
		p=0.0004	p=0.003	p=0.0001	p=0.007	p=0.0004
21-40	M=7 31±7	1.75±0.33	2.65±0.17	3.74±0.22	4.9±0.23	5.63±0.29
	F=7 32±7	1.61±0.15	2.61±0.13	3.6±0.19	4.68±0.22	5.45±0.18
		p=0.003	p=0.00006	p=0.006	p=0.007	p=0.0009
41-70	M=7 55±9	1.76±0.17	2.73±0.12	3.81±0.19	4.92±0.21	5.57±0.18
	F=5 55±11	1.63±0.07	2.71±0.2	3.86±0.11	4.69±0.32	5.49±0.29
		p=0.001	p=0.005	p=0.00008	p=0.008	p=0.00008

Table II .Mean interpeak latency (IPL) values (a) Right ear (b) Left year

(a) Right ear

Age Group	No of males(M), females(F), Age±SD	Mean interpeak latency (IPL) values (ms)		
		I-III	III-V	I-V

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1-20	M=7 4±4	2.24±0.15	1.84±0.24	4.08±0.26
	F=6 6±5	2.09±0.13	1.87±0.24	3.95±0.22
		p=0.01	p=0.002	p=0.005
21-40	M=7 31±7	1.96±0.29	2.04±0.39	4.01±0.27
	F=7 32±7	1.92±0.38	1.92±0.35	3.84±0.08
		p=0.009	p=0.01	p=0.0005
41-70	M=7 55±9	2.09±0.27	1.88±0.24	3.96±0.15
	F=5 55±11	2.08±0.5	1.86±0.46	3.94±0.21
		p=0.02	p=0.02	p=0.002

(b) Left ear

Age Group	No of males(M), females(F), Age±SD	Mean interpeak latency (IPL) values (ms)		
		I-III	III-V	I-V
1-20	M=7 4±4	2.12±0.27	1.89±0.15	4±0.32
	F=6 6±5	2.12±0.21	1.79±0.22	3.9±0.16
		p=0.005	p=0.0006	p=0.0003
21-40	M=7 31±7	2±0.33	1.89±0.27	3.89±0.37
	F=7 32±7	1.99±0.26	1.85±0.22	3.84±0.25
		p=0.006	p=0.0001	p=0.005
41-70	M=7 55±9	2.05±0.23	1.76±0.21	3.81±0.21
	F=5 55±11	2.26±0.15	1.64±0.24	3.86±0.25
		p=0.01	p=0.01	p=0.00003

V. CONCLUSION

It is observed that the peak latency and IPL values of the normal subjects showed significant difference ($p<0.05$) between the genders. It is also found that these BAER parameters in females are with shorter values compared to men. The study and the data suggests that the gender and hearing loss must be considered when evaluating the effects of advancing age on the latency values in BAERs. This study did not find a major difference in the interpeak latencies in the different genders, if this is a valid result and if there really is a difference amongst genders and ages there might be an interest for future studies to investigate this difference in the abnormal cases using brainstem response measurements.

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