Research Article

The Correlation between Binaural Interaction Component of the Auditory Brainstem Response and Total Score of the Persian Version of the Spatial Hearing Questionnaire

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Highlights

- People with SNHL may have difficulty with binaural processing
- The ABR-binaural interaction component can represent binaural processing
- ILD and ITD must be used to distinguish the target sound from other sounds

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ABSTRACT

Background and Aim: People with spatial hearing impairment have difficulty perception of speech in the presence of noise, sound localization, and estimating the distance from the sound source. In this study, the comparison between amplitude and latency of the Binaural Interaction Component of the Auditory Brainstem Response (ABR-BIC) with the total score of the Persian version of the Spatial Hearing Questionnaire (SHQ) in adults with normal hearing and moderate sensorineural hearing loss (SNHL) was evaluated.

Methods: In this cross-sectional comparative study 55, 18–45-year-old individuals including 35 of normal hearing and 20 moderate SNHL participated. All participants underwent the assessments of medical history, otoscopy, conventional audiometry, tympanometry, SHQ questionnaire, and auditory brainstem response (ABR).

Results: There was no significant correlation between the amplitude and latency of the ABR-BIC and the Persian version of the SHQ in normal groups ($r=-0.085$, $r=0.116$) and in moderate SNHL groups ($r=0.030$, $r=0.119$). The mean value of ABR-BIC range of people with normal hearing and SNHL is statistically significant ($p=0.001$).

Conclusion: The results showed that the amplitude and latency of ABR-BIC were not correlated with the Persian version of the SHQ in people with normal hearing and with moderate SNHL but statistically significant between the mean amplitude and latency of ABR-BIC in people with normal hearing and people with hearing loss.

Keywords: Auditory brainstem response; spatial hearing questionnaire; binaural interaction component; spatial hearing; spatial hearing disorder

Introduction

The ability to hear is important to many species; in fact, auditory inputs are, in many everyday situations, the only source of information about events that occur at farther distances. Just as the identity of a sound source is important, so is its location in guiding living behavior. Peripheral receptors in the auditory system, unlike the visual and sensory systems, do not have a predetermined and absolute role. Instead, the receivers that transmit sound along the cochlea are based on frequency. Therefore, the brain must actively create a scene from the auditory space by converting and processing the audio inputs presented to each ear. In doing so, the brain takes advantage of the fact that certain aspects of acoustic input depend on the position of the sound source relative to the position of the listener. The brain must interpret and combine the information provided by these different spatial cues in order to create a coherent representation of the auditory space [1].

Spatial hearing ability can be defined as the ability to selectively pay attention to sounds coming from one direction, while sounds that come simultaneously from other directions are ignored. To do this, the Interaural Level Difference (ILD) and the Interaural Time Difference (ITD) must be interpreted to distinguish the target sound from other sounds [2]. Because both ILD and ITD require comparison of the inputs presented to the two ears, these cues are colloquially known as binaural spatial cues. In many cases, however, the usefulness of these binaural cues depends on the frequency. ILD is primarily used to locate high-frequency sounds and ITD is used to locate low-frequency sounds [1].

In addition to binaural cues, spatial information may be derived from the relative intensities of the various frequency components in one ear. This is because the head, neck, and ear filtering properties are used to shape the sound spectrum in a direction-dependent manner and are known as spectral cues. These spatial cues are more prominent at high frequencies and are thought to be important in distinguishing between locations with the same ILD and ITD values. In addition, spectral cues are very important in determining the pitch of a sound [1].

The auditory system eventually combines information provided by different spatial cues, but monaural and binaural cues are initially processed separately before merging at higher neural levels. In mammals, the acoustic inputs are converted by nerve cochlear cells into nerve signals and travel through the auditory nerve to the cochlear nuclei. In the Dorsal Cochlear Nucleus (DCN), single-spectral signals are processed. Branches originating from the Ventral part of the Cochlear Nucleus (VCN) go to the Superior Olivary Nucleus on both sides. This is the first intersection of the information from the two ears. The Lateral Superior Olivary nucleus (LSO) is mainly related to ILD processing and the medial superior olivary nucleus is related to ITD processing. Branches pass through the nuclei of the brainstem and ascend to the midbrain, leading to the Inferior Colliculus (IC). From IC, auditory signals travel through the medial geniculate body of the thalamus to the auditory cortex, which has been shown to play a key role in sound localization [1].

To perform spatial hearing, ILD and ITD must be carefully transmitted and interpreted at different points along the auditory pathway. Disturbances in the peripheral or central auditory system or even cognitive problems can lead to spatial hearing impairment [3-5]. Spatial hearing impairment is a decrease in a person's ability to selectively pay attention to sounds coming from one direction and ignore sounds that come simultaneously from other directions [3]. Various studies have shown that people with spatial hearing impairment have difficulty understanding speech in the presence of noise, sound localization, and estimating the distance from the sound source [1-3, 5-7]. People with sensorineural or transient hearing loss have spatial hearing impairment [8, 9]. Sensorineural hearing loss (SNHL) reduces the ability to perform frequency and temporal resolution faithfully. One of the important consequences of this type of resolution reduction is the reduction of the ability to process binaural signals [10]. In transient hearing loss, only a slight attenuation of the audio input to the affected ear occurs. Transient hearing loss delays the transmission of sound to the affected ear. Thus, even one ear deprivation has a profound effect on the processing of both ITD and ILD cues [8].

Assessing spatial hearing impairment, disability and severity is difficult due to the lack of adequate standard tests [11]. However, to evaluate spatial hearing ability via psychoacoustic (behavioral) tests such as Masking Level Difference (MLD), Dichotic Digit Test (DDT), Minimum Audible Angle (MAA), Listening in Spatialized Noise-Sentence (LiSN-S) test, and spatial word recognition score [2] and electroencephalography-based objective electrophysiology tests such as ABR, Frequency Following Response (FFR) [12], etc. are used. Self-assessment questionnaires have also been designed to assess spatial hearing impairment; including the Spatial Hearing Questionnaire (SHQ) and Speech, Spatial, and Qualities (SSQ) of hearing scale [13].

SHQ is a psychometric tool for assessing the effects of spatial hearing impairment on the patient's performance in daily life. This questionnaire was designed by Tyler et al. in the late 1990s and consists of 24 questions in 8 different situations that are important in binaural hearing. People give each question a score from 0 to 100, a zero indicates a very easy situation and a 100 indicates a very difficult situation. The overall SHQ score shows how the patient perceives their spatial hearing ability or disability [14]. The Persian version of this questionnaire was developed by Delphi et al. [15].

The brainstem auditory response is a powerful objective diagnostic measure that provides both valuable neurological and auditory information. Clinical applications of ABR include detecting neurological abnormalities in the eighth cranial nerve, auditory pathways of the brainstem, and estimating auditory sensitivity. ABRs are used for the electrophysiological study of the BIC. If we subtract the sum of the monaural right and left ear ABRs from the binaural ABR, BIC is obtained. BIC is emerged 4.5 to 7 milliseconds after the start of the click stimulus, which corresponds to peaks IV and V of the ABR [10]. BIC is generally assumed to be caused by the activity of binaural neurons in the pre-inferior colliculus auditory pathway, and the most likely structures that provide binaural contrast sites are two nuclei of the Superior Olivary Complex, the LSO, medial superior olivary nucleus, and their outputs [16].

The correlation between BIC amplitude and behavioral binaural hearing suggests that both are likely produced by the same neural complex, and thus dysfunctional spatial hearing may be reflected in BIC. Decreased or absent BIC in the presence of appropriate binaural stimuli may indicate a central auditory disorder of binaural function [17].

Since spatial hearing requires binaural auditory function and ABR-BIC is known as an objective measure of binaural auditory function, the SHQ questionnaire, which assesses the ability of people with spatial hearing to self-assess, and the fact that people with deafness is challenged to some extent by the possibility of receiving subtle spatial cues that play a vital role in the speech processing process. In this research, we investigated the correlation and comparison between the amplitude and latency of the binaural interaction component of the ABR with the overall score of the Persian version of the spatial hearing questionnaire in adults with normal hearing and moderate SNHL, so that in the event of a positive correlation, proposed this component as a biomarker of spatial hearing.

Methods

In this cross-sectional study,55, 18–45-year-old individuals in two groups including 35 normal hearing and 20 moderate SNHL participated.

The inclusion criteria for the normal hearing group were PTA≤25 dB in both ears and for the moderate hearing loss group PTA=41–55 dB [9] All cases had symmetric hearing levels (threshold difference between two ears <5 dB). Audiometry was conducted via the piano audiometer (Inventis company, Italy). All participants had normal middle ear function (tympanogram type A)[6].

To check the absence of central auditory processing disorder, the dichotic digit test was used, which should be within the normal range (a score of less than 76.7% is considered abnormal).

Before the beginning of the tests, a guideline for explaining the study conditions and procedure were distributed among the participants. Written informed consent was obtained from the participants.

ABR test was recorded via the Neuro-Audio device (manufactured by Neurosoft, Russia). During performing the ABR test, necessary explanations were introduced on how to perform this test so that the participants did not have any anxiety while performing the test and had proper cooperation with the examiner. To do so, we asked the participants to lie on a recliner chair. Since two channels were used for recording ABR, the electrode arrangement consists of an inverting electrode on Fz (upper forehead), a ground electrode on Fpz (lower forehead), and two inverting electrodes on both sides of the mastoid are placed. It was necessary to prepare lowers skin impedance prior to electrode placement which significantly reduces artifacts in all electrode applications. The impedance of each electrode was kept less than 5 kz and the impedance between the electrodes was kept less than 2 kz. Click stimulus with 0.1 ms duration, rarefaction polarity, the intensity of 85 dB SPL, presentation rate of 7.1 s, and 3000 swipes in the time window of 12 ms and the ER 3A insert phone were used [2]. First, monaural left and right ears ABRs were recorded. Then, binaural ABR was recorded.

After recording the responses, to obtain the amplitude and latency of ABR-BIC, first, determine the amplitude and latency of the waves from the monaural ABRs (right and left ear) based on the time of their emergence, and then determine the amplitude and latency of the V wave. We summed the amplitude and latency of monaural ABRs together and then, to calculate the amplitude and latency of ABR-BIC, we subtracted them from the amplitude and latency values of the binaural ABR, respectively. Following performing the objective tests, participants were asked to complete the SHQ questionnaire while receiving comprehensive instructions about the questionnaire.

In order to compare the averages of the desired variables in the two groups of normal hearing and moderate SNHL, the normality of the data in each group was evaluated using the Shapiro-Wilk test. If the data had a normal distribution, the independent t-test was used, otherwise, the non-parametric Mann-Whitney test was used to compare the means in two groups. To perform the independent t-test, the assumption of homogeneity of variances was also evaluated based on Lune's test. In order to check the linear correlation between the variables, if the data had a normal distribution, Pearson's correlation coefficient was calculated and otherwise, Spearman's correlation coefficient was calculated. All analyzes were performed in SPSS software version 17 A significance level of 5% was considered for all statistical analyses.

Results

The present study was performed on 55 individuals referred to the audiology clinic of Imam Khomeini Hospital of Hamadan University of Medical Sciences. of them, 27 (49.1%) were women and 28 (50.9%) were men. The mean and standard deviation of the age of the participants was 33.87)1.8(years, with a minimum of 22 years and a maximum of 45 years. The participants divided into two groups, the normal hearing group 63.6% and the SNHL group were 36.4%.

There was a significant difference between the mean total SHQ score of people with normal hearing and people with moderate SNHL (p=0.001).

The mean amplitude of ABR-BIC in people with normal hearing and SNHL is statistically significant (p=0.001). The value of this component was 0.21 µV for the normal group, and 0.09 µV for the hearing impaired group. The difference between the mean amplitude of ABR-BIC in people with normal hearing and people with SNHL was approximately 0.12, i.e. the average amplitude of ABR-BIC in the group with normal hearing was higher than the group with SNHL. There was a significant difference between the latency of ABR-BIC of participants with normal hearing and those with moderate SNHL. The value of this component is 5.53 ms for the normal group, and 5.88 ms for the hearing-impaired group. The average latency of ABR-BIC was lower in the normal hearing group than in the SNHL group.

Furthermore, the mean latency of V-wave of binaural ABR in the normal hearing group and in the moderate SNHL group was statistically significant (p=0.001). The mean value of the V-wave latency of binaural ABR was lower in the normal hearing group than in the SNHL group.

To investigate the linear correlation between the two variables, the normality of the variables was first calculated using the Shapiro-Wilk test. If both variables had a normal distribution, the Pearson correlation coefficient was used to measure the existence of a linear correlation between the two variables, otherwise, Spearman correlation coefficient was used to measure the existence of a linear correlation between the two variables. According to the results, in both groups of participants, there was no linear correlation between the overall score of SHQ and the amplitude and latency of the ABR-BIC (0.05) (Table 1).

Discussion

The aim of this study was to investigate the correlation and comparison between amplitude and latency of the ABR-BIC with the total score of the Persian version of the Spatial Hearing Questionnaire (SHQ) in adults with normal hearing and moderate SNHL. The results demonstrate that there is a significant difference between the mean of wave V amplitude in the binaural ABR of the normal hearing group and the moderate SNHL group. The mean value of wave V amplitude in binaural ABR in the present study is higher in people with normal hearing than in people with SNHL. These results were consistent with the study by Adarsh et al. They found that the amplitude of wave V is higher in normal people than in hearing loss people. In the present study, due to the larger number of samples, this difference is more remarkable. Studies have also shown that electrophysiological records are often not well replicated. Because researchers believe that the measurement of amplitude is highly variable [11]. The mean latency of wave V in binaural ABR of people with normal hearing and people with moderate SNHL are the statistically significant differences.

In the present study, the mean amplitude of ABR-BIC was statistically different from that of individuals with normal hearing and those with moderate SNHL. The average amplitude of ABR-BIC is higher in the group with normal hearing than in the group with SNHL. The mean

Table 1. The results of the correlation between spatial hearing questioner total score and amplitude and latency of binaural interaction component of the auditory brainstem response by separating two groups

Component	Study group			
	Normal hearing		Hearing loss	
	Total P-SHQ score		Total P-SHQ score	
	The correlation coefficient	p	The correlation coefficient	p
Amplitude BIC	–0.085*	0.627	0.030**	0.898
Latency BIC	0.116*	0.506	0.119**	0.618

P-SHQ; Persian version of the spatial hearing questionnaire, BIC; binaural interaction component

* Spearman correlation coefficient, ** Pearson correlation coefficient

latency of ABR-BIC was significantly different between the two groups of people with normal hearing and people with moderate SNHL. The average latency of ABR-BIC is lower in people with normal hearing, in the present study.

Furthermore, in order to investigate the effect of hearing loss on the overall SHQ score, the obtained data were compared between people with and without hearing loss. Based on the findings, there was a significant difference between the mean total SHQ score of people with normal hearing and people with moderate SNHL. So the total score of SHQ in hearing-impaired people was less than the normal people.

Accordingly, spatial hearing ability is affected by hearing loss, reducing the ability to process binaural signals, including ITD and ILD, and the ability to locate sounds in the hearing loss person. The result is consistent with Zamiri et al. who demonstrated that the total score of the questionnaire SHQ in three groups (22 people in each group) of normal people, mild and moderate SNHL showed a significant difference between the scores of the three groups (these scores 92.50(4.34), 79.43(8.56), and 65.70(9.45), respectively) and the total score of normal hearing is higher than in people with SNHL [8].

Based on these findings, in both groups of people with normal hearing and people with moderate SNHL, there was no linear correlation between the total score of SHQ and the latency and amplitude of ABR-BIC. Correlation in the normal hearing group and mean SNHL were r=–0.055 and r=0.030, respectively. The reason for this correlation can be explained by the fact that the questionnaires are subjective tests and people answer questions based on their listening experiences and the answers to the questions are influenced by cognitive factors while objective tests are not affected by cognitive situations and can be used to predict people's performance in real situations.

It may also be possible to attribute the lack of correlation to the type of stimulus used. In this study, a click stimulus was used to record ABR. The results may be affected by changing the type of stimulus used, for example, the use of speech and verbal stimuli, which needs further investigation.

On the other hand, as mentioned before, the values of ABR amplitude are very different in different studies so, the amplitude is not a reliable factor in electrophysiological records.

In the present study, in order to investigate the correlation between ABR-BIC latency and SHQ score, the obtained data were compared between people with and without hearing loss. Based on these findings, in both groups of people, there was no mean neural linear correlation between the total SHQ score and the ABR-BIC latency. Correlation in normal hearing group and SNHL were r=0.116 and r=0.119, respectively. The reason for the uncorrelated two variables, in the current study, could be explained by the psychometric nature of questionnaires which people answer questions based on their listening experiences, and the answers to the questions are influenced by cognitive factors while objective tests are not affected by the cognitive mechanisms which are explained beforehand. In addition, the type of stimulus should not be ignored.

Conclusion

This study, for the first time, aimed to compare the amplitude and latency of the brainstem binaural interaction component in adults with normal hearing and moderate sensorineural hearing loss, and also to investigate the correlation of these electrophysiological indicators with the overall score. The Persian version of the spatial hearing questionnaire was performed on the mentioned people. The findings showed that the amplitude and latency of Binaural Interaction Component (BIC) differ between the two groups of normal people and those with moderate sensorineural hearing loss so the amplitude of BIC is higher in normal people than in hearing-impaired people, and the latency of BIC in normal people is less than in hearing-impaired people. Also, the findings showed that there is no significant correlation between the amplitude and latency of BIC and the total score of spatial hearing questionnaire in both groups of normal and moderate sensorineural hearing loss.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the ethics committee of the Tehran University of Medical Sciences by the registration number of IR.TUMS.FNM.REC.1400.124.

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Authors' contributions

SMH: Study design, acquisition of data, interpretation of the results, statistical analysis, and drafting the manuscript; NR: Study design, interpretation of the results, statistical analysis as the project supervisor; AH: Study design, interpretation of the results, statistical analysis; SJ: Statistical analysis.

Conflict of interest

There are no competing financial interests.

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