Original Article

Evaluation of the Relationship Between the Air–Bone Gap and Prolonged ABR Latencies in Mixed–Type Hearing Loss

Ömer Faruk Birkent, Turgut Karlıdağ, Figen Başar, Şinasi Yalçın, İrfan Kaygusuz, Erol Keleş, Abdulvahap Akyiğit

Department of Otorhinolaryngology, Fırat University School of Medicine, Elazığ, Turkey (ÖFB, TK, ŞY, İK, EK)
Department of Otorhinolaryngology, Ondokuz Mayıs University School of Medicine, Samsun, Turkey (FB)
Clinic of Ear Nose Throat, Elazığ Training and Research Hospital, Elazığ, Turkey (AA)

OBJECTIVE: The aim of this study was to determine the air–bone gaps in adults with mixed-type hearing loss using air-conduction auditory brainstem response (ABR) latencies.

MATERIALS and METHODS: Thirty adults with mixed-type hearing loss (study group) and 30 adults with normal hearing (control group) were included in this study. Before performing ABR measurements, ear, nose, and throat examinations, pure tone audiometry, speech audiometry, acoustic immittance audiometry, and transient evoked autoacoustic emission testing were performed for all participants. Absolute latencies of I, III, and V waves and interpeak latencies (IPL) at 90 decibel hearing level dB nHL were evaluated and compared with air–bone gap results.

RESULTS: ABR latencies using click and tone-burst stimulation were obtained and found to be longer in the mixed-type hearing loss group than in the normal hearing group (p<0.05). A moderate positive relationship was detected between the air–bone gap and wave III/V latencies at 0.5/1 kHz, I–V/I–III/III–V IPL at 1 kHz. Only one strong relationship was found between 1 kHz air–bone gap and I–V IPL.

CONCLUSION: In this study, the magnitude of the air–bone gap could not determined using prolonged ABR latencies. Delays in ABR latencies were observed, but prolonged ABR latencies was not helpful for calculating the air–bone gap on mixed-type hearing loss.

KEYWORDS: Auditory brainstem response, mixed-type hearing loss, air–bone gap

INTRODUCTION

Auditory brainstem response (ABR) is an objective measurement method used in predicting both the hearing level and the diagnosis of a number of neuro-otological diseases. Because the method is non-invasive and the patient's subjective participation is not required for results but patient relaxation and/or sleeping during test is important, ABR is one of the methods used for differential diagnosis.

Two basic stimulation modes (click and tone-burst) can be used for obtaining ABRs. ABR thresholds obtained by click stimulation are reported to mainly reflect high-frequency area activation but do not provide data specific to the frequency [1]. On the other hand, tone-burst stimulation is frequency specific and provides information on the hearing function at the frequency used. Tone-burst ABR is a technique that particularly used in infants and children to determine pure tone thresholds [2]. Many researchers have stated that the electrophysiological thresholds obtained from the ABRs with tone-burst stimulation at 0.5-4 kHz and pure tone audiometry thresholds are nearly the same and that use in clinical practice is certainly justified [3, 4]. In Munnerley et al. [5] study on tone-burst stimuli in cases with normal hearing, it was reported that electrophysiological thresholds were 10 dB HL higher than pure tone thresholds and that this difference was even greater at 0.5 kHz. Fria and Sabo [6] proposed that, according to the normal values of conduction-type hearing loss, a 0.3-ms delayed Vth wave latency in ABR is equivalent to approximately 10 dB HL in pure tone thresholds. No interwave latency difference was observed because the latency shift was equal for all waves. Bone-conduction click and tone-burst ABR tests also important for differentiating between conductive and sensorineural hearing loss. Studies have shown the diagnostic value of these tests in both children and adults [7-9].

In Turkey, ABR is mostly used to obtain objective hearing data for official reporting. Air-conduction tests are always preferred over bone-conduction tests in ABR measurements for clinical protocols. It is problematic to obtain subjective hearing data because of providing interests, particularly in adults, for official reporting. Discordancy in the air-bone gap may be encountered.

The air-bone gap can be detected on audiogram using the threshold shift property of ABR in discordant conductive and/or mixed-type hearing losses. In this study, we aimed to determine the air-bone gaps in patients with mixed-type hearing loss using ABR findings obtained with click and tone-burst stimuli.

MATERIALS and METHODS

Subjects

This study was conducted after obtaining approval from Fırat University Non-Invasive Studies Ethics Committee and individuals who would be included in to this study.

Thirty volunteers with normal hearing (control group; CG) and 30 volunteers with mixed-type hearing loss (study group; SG) who were aged between 19 and 55 years participated in this study. The mean age of CG (17 females, 13 males) was 39.13±11.66 years and that of SG (17 females and 13 males) was 39.53±12.19 years. CG and SG were formed by matching the age and gender to each of these individuals. Each participant was informed, and consent forms were obtained and signed. Gender differences were not taken into account for participant selection. Ear, nose, and throat examinations of all the participants were performed by an otolaryngologist, and detailed histories of the ears were recorded. Before ABR measurements, pure tone and speech audiometry and acoustic immitansmetry were performed in both groups, and the spontaneous otoacoustic emission (S-OAE) test was performed in CG only.

The control group individuals had normal ear examinations, normal hearing, normal speech discrimination score, and pass results bilaterally in the S-OAE test [10, 11]. Participants in CG with known chronic diseases (diabetes, chronic renal failure, and others), history of ear surgery, history of autotoxic medication use, and history of acoustic and/or physical trauma were excluded from the study.

Participants in SG had air-conduction audiometric thresholds higher than 30 dB HL, bone-conduction thresholds higher than 20 dB HL, air-bone gaps higher than 10 dB HL, frequencies between 0.5 and 4 kHz, and normal speech discrimination scores [11]. Participants in SG who had history of ear discharge in the last 3 months, history of ear surgery in the last 6 months, and a known chronic disease (diabetes, chronic renal failure, and others) were excluded from the study.

Audiological Evaluations

Subjective audiological evaluations were performed in appropriate soundproof rooms in a standard quiet cabin (Industrial Acoustic Company Inc.; New York, USA). An Interacoustics (AC40; Assens, Middelfart,

Denmark) clinic audiometer with TDH 39P (Telephonics earphones, Denmark) was used for air threshold and speech tests. Bone-conduction hearing thresholds were obtained using the Radioear B-71 bone vibrator. In both ears, air-conduction thresholds were found to be 0.25-8 kHz and bone-conduction thresholds were found to be 0.5-4 kHz using the standard ascending method. AccuScreen (Madsen, Taastrup, Denmark) screening otoacoustic emission and AZ26 (Interacoustics, Middelfart, Denmark) tympanometry were used for CG in this study.

ABR Audiometry

Auditory brainstem response tests were performed using the Synergy T (Medelec, USA) equipment with ER- 3A insert earphones. ABR results were ipsilaterally obtained using 100 μs alternate click and tone-burst stimuli and absolute/interpeak latencies (IPL) were evaluated in both groups. ABR waves tend to be prolonged because of the difference in difference in contralateral recordings.

Furthermore, I and III waves frequently remain undetected; therefore, contralateral recordings were not used in this study.

Gold plate disc electrodes were used during the recording; the reference electrode was placed at the ipsilateral mastoid, the active electrode was placed at the forehead, and the ground electrode was placed at the contralateral mastoid. Care was taken to ensure that the impedance difference between electrodes was below 4 kohm.

Click ABR was made using a 20/s repetition rate and 90 dB nHL stimulation level. Tone-burst ABR was made with a 30/s repetition rate and 90 dB nHL stimulation level at 0.5, 1, and 2 kHz. Because this device has 80 dB nHL maximum output power at 4 kHz, tone-burst stimulus recordings could not be analyzed. Two separate traces for each frequency were provided with 2,000 cycles at 15-ms recording intervals.

Statistical Analyses

Statistical analyses were performed using the SPSS v.12 for Windows (IBM SPSS Statistics, IBM Corporation; Chicago, IL, USA) package program. For statistical evaluation, the t test for independent samples was used to determine any existing differences in the latency values of ABR in CG and SG; $p<0.05$ was accepted as statistically significant. The relationship between prolonged latency duration and air-bone gap was found using Pearson correlation coefficient.

RESULTS

The air- and bone-conduction pure tone average scores of groups between 0.5-4 kHz frequencies are given in Table 1. The absolute

Table 1. Mean hearing thresholds of individuals in control and study groups

		Hearing Thresholds (dB nHL)				
		0.5 kHz	1 kHz	2 kHz	4 kHz	PTA
Control group (n=30)	AC = BC	10.66±5.04	08.50±3.74	06.83±2.45	09.50±4.61	8.96±3.12
	Gap	0.00	0.00	0.00	0.00	0.00
Study group (n=30)	AC	52.66±09.44	50.16±09.42	43.83±10.56	52.00±12.07	50.00±7.44
	BC	24.16±09.00	25.33±08.99	25.66±08.38	26.50±10.75	26.03±6.16
	Gap	28.83±11.42	25.33±08.29	18.00±09.79	26.33±11.88	23.63±7.85

AC: air-conduction threshold; BC: bone-conduction threshold; Gap: air–bone difference; dB nHL: decibel hearing level; PTA: pure tone average (mean of pure tone hearing thresholds at 0.5, 1, 2, and 4 kHz)

Table 2. Wave and interpeak latencies of control and study groups at 90 dB nHL

Mode	Waves		Control group Mean±SD	Study group Mean±SD	p p<0.05
Click	latency	I	1.92±0.24	2.12±0.39	0.025
		III	4.05±0.19	4.43±0.48	0.000
		V	5.88±0.23	6.48±0.47	0.001
	IPL	I–V	3.95±0.26	4.35±0.61	0.002
		I–III	2.12±0.19	2.31±0.51	0.070
		III–V	1.82±0.16	2.00±0.38	0.020
0.5 kHz tone burst	latency	I	2.52±0.37	2.82±0.54	0.022
		III	4.76±0.34	5.38±0.68	0.000
		V	6.85±0.43	8.01±1.02	0.000
	IPL	I–V	4.34±0.39	5.22±0.97	0.000
		I–III	2.19±0.27	2.55±0.52	0.004
		III–V	2.14±0.24	2.67±0.60	0.000
1 kHz tone burst	latency	I	2.33±0.34	2.57±0.45	0.050
		III	4.77±0.26	5.20±0.68	0.005
		V	6.89±0.49	7.85±0.93	0.000
	IPL	I–V	4.61±0.53	5.37±0.92	0.001
		I–III	2.42±0.33	2.64±0.63	0.139
		III–V	2.18±0.38	2.71±0.60	0.000
2 kHz tone burst	latency	I	2.13±0.38	2.52±0.38	0.000
		III	4.48±0.34	5.11±0.48	0.000
		V	6.56±0.29	7.48±0.71	0.000
	IPL	I–V	4.42±0.42	4.96±0.54	0.000
		I–III	2.35±0.35	2.59±0.29	0.006
		III–V	2.10±0.36	2.37±0.46	0.016

SD: standart deviation; IPL: Interpeak latencies

latencies and IPL of groups with tone-burst and click stimuli at 90 dB nHL are provided in Table 2. Wave latencies and IPL with the click stimulus were found to be significantly longer in SG than in CG (p<0.05). Only wave I latency at 0.5 kHz in SG was not different from that in CG. Similarly, all wave latencies and IPL at 0.5/1 and 2 kHz were found to be significantly longer in SG than in CG (p<0.05), except for I-III IPL at 1 kHz.

The relationship between the air-bone gap and ABR latencies of SG is shown in Table 3. The relationship between absolute latencies and IPL and the air-bone gap was found to be very weak and weak with click, 0.5, and 2 kHz stimuli. Moderate and strong positive correlations were observed at wave III, V latency, and I-III, III-V, and I-V IPL, obtained by the 1 kHz tone burst stimulus. The maximum correlation was found at I-V IPL at 1 kHz.

DISCUSSION

In mixed-type hearing loss, the evaluation of air- and bone-conduction hearing thresholds, particularly in cases with symmetrical hearing loss, can be a difficult process for clinicians. This difficulty be-comes more obvious with the factors that affect patient cooperation and attention. In addition, determining the masked bone-conduction threshold may be time consuming in patients with symmetrical bilateral mixed-type hearing loss. ABR responses can generally be used in differential diagnosis. Wave latencies and IPLs are the most common parameters to distinguish pathologies [3, 12]. Click and tone-burst are the two main stimuli used in brainstem responses. Previous studies have shown that the age, gender, intensity of stimulus, stimulus repetition ratio, body temperature, use of medication, and type, degree, and configuration of hearing loss can cause differences in ABR results [4, 11, 13]. In order to minimize the effects of age on ABR wave morphology, adults aged between 19 and 55 years with mixed-type hearing loss were included in this study. This study was conducted without gender distinction in healthy volunteers using a constant intensity and stimulus repeat rate.

Parallel to the progression of the disease (in chronic otitis and oteo-sclerosis), in mixed-type hearing losses, decreases in both air- and bone-conduction thresholds may be observed over time. The reasons for decreasing air-conduction thresholds are increased damage of the tympanic membrane, middle ear, and/or ossicles during the disease process; decreases in bone-conduction threshold are due to the passage of toxins and drugs into the inner ear by means of the round window [14, 15]. Active middle ear infection causes a further decrease in air conduction. In this study, patients with chronic otitis media who had no active infection and fixed air- and bone-conduction hearing thresholds were included.

There are many studies related to hearing thresholds successfully identified by using ABRs [3, 4, 16, 17]. Research conducted on infants and children with normal hearing and sensorineural hearing loss has shown a high correlation between pure tone hearing thresholds and tone-burst ABR results [15]. Another study on tone-burst stimuli in cases with normal hearing has reported that electrophysiological thresholds were 10 dB HL higher than pure tone thresholds and that this difference was even greater at 0.5 kHz [5]. In this study, pure tone thresholds and ABR thresholds were not compared because investigating the correlation between hearing thresholds and ABR thresholds was not the objective of the study.

Auditory brainstem response latencies are prolonged in conductive and mixed-type hearing losses because the sound intensity decreases during transmission to the inner ear due to middle ear problems.

Interpeak latencies is not prolonged because all waves are equally prolonged. In conductive-type hearing loss, latency-intensity curves are above and parallel to the curves obtained from individuals with normal hearing. McGee and Clemis [18] found a good correlation between real audiological thresholds and thresholds obtained from ABR in conductive-type hearing losses. Similarly, Fria and Sabo [6] proposed that according to the normal values of conduction-type hearing loss, a 0.3-ms delayed wave V latency in ABR is equivalent to approximately 10 dB HL in pure tone thresholds. In our study, the latency-intensity graphic was not presented because detecting ABR wave thresholds was not an objective. Our main purpose was gap appointmentwith latency prolongation. In this study, the stimulus intensity at 90 nHL was used to detect clear ABR wave forms and latencies, by taking into consideration the SG hearing thresholds. Wave

Table 3. The relationship between air–bone gap and click/tone-burst ABR wave latencies in study group

	Intensity (dB nHL)			n	0.5 kHz Gap	1 kHz Gap	2 kHz Gap	4 kHz Gap	Gap mean
					Air–bone gap pure sound hearing thresholds (Pearson correlation coefficient)				
click ABR	90	Latencies	I	30	0.32	0.00	0.10	0.02	0.24
			III	30	0.22	−0.04	0.01	0.31	0.26
			V	30	0.12	0.00	0.18	0.45	0.17
		IPL	I–V	30	−0.08	0.00	0.07	0.35	0.00
			I–III	30	−0.04	−0.04	−0.06	0.28	0.06
			III–V	30	−0.17	0.00	0.04	0.11	−0.21
	70	Latencies	I	30	0.38	0.24	0.22	0.17	0.36
			III	30	0.32	0.09	0.11	0.32	0.33
			V	30	0.22	0.18	0.14	0.28	0.23
		IPL	I–V	30	−0.07	0.00	0.03	0.15	−0.04
			I–III	30	0.00	−0.12	−0.09	0.21	0.04
			III–V	30	−0.15	0.12	0.04	−0.06	0.16
0.5 kHz tone-burst ABR	90	Latencies	I	28	0.34				0.27
			III	28	0.52				0.53
			V	30	0.50				0.47
		IPL	I–V	28	0.33				0.35
			I–III	28	0.33				0.41
			III–V	28	0.25				0.20
	70	Latencies	I	24	0.37				0.05
			III	26	0.40				0.31
			V	30	0.42				0.39
		IPL	I–V	25	0.16				0.23
			I–III	24	0.18				0.22
			III–V	27	0.17				0.28
1 kHz tone-burst ABR	90	Latencies	I	22		0.08			0.00
			III	23		0.41			0.54
			V	30		0.44			0.68
		IPL	I–V	22		0.51			0.73
			I–III	21		0.46			0.53
			III–V	23		0.29			0.58
	70	Latencies	I	23		0.04			0.20
			III	23		0.05			0.42
			V	30		0.38			0.59
		IPL	I–V	22		0.49			0.56
			I–III	19		0.15			0.23
			III–V	22		0.50			0.59
2 kHz tone-burst ABR	90	Latencies	I	30			0.17		0.07
			III	30			−0.10		0.00
			V	30			−0.03		−0.03
		IPL	I–V	30			−0.18		−0.09
			I–III	30			−0.24		−0.10
			III–V	30			−0.03		−0.03
	70	Latencies	I	30			0.15		0.10
			III	30			0.03		−0.12
			V	30			0.02		−0.03
		IPL	I–V	30			−0.07		−0.09
			I–III	30			−0.08		−0.25
			III–V	30			−0.01		0.12
4 kHz tone-burst ABR	70	Latencies	I	30				0.30	0.32
			III	30				0.32	0.24
			V	30				0.43	0.47
		IPL	I–V	30				0.46	0.48
			I–III	30				0.11	0.04
			III–V	30				0.46	0.54

Gap mean: mean air–bone gap (mean of pure tone air–bone gap at 0.5, 1, 2, and 4 kHz)
Pearson correlation coefficient: 0–0.25→Very weak, 0.26–0.49→Weak, 0.50–0.69→Moderate, 0.70–0.89→Strong, 0.90–1.00→Very Strong

latency prolongation correlated with that reported in the literature [3, 12, 13]. The wave V and I-V IPL were found to be significantly longer in mixed-type hearing loss in SG than in that in CG with click and 0.5, 1, and 2 kHz tone-burst stimulation at 90 dB nHL.

The relation between latency prolongation and air-bone gap was separately evaluated. The relation between absolute latencies and IPL and air-bone gap was found to be very weak and weak with click, 0.5 and 2 kHz stimuli. The reason for weak relations with click and 2 kHz stimuli may be a narrower air-bone gap in 2 kHz than in frequencies.

Moderate and strong positive correlations were observed at wave III, V latency, and I-III, III-V, and I-V interpeak latency was obtained by 1 kHz tone burst stimulus. The maximum correlation was found in I-V IPL at 1 kHz. When this study was planned, it was thought that the air-bone gap could be estimated using click or tone-burst stimulus in mixed-type hearing losses. Because of its properties, the weak correlation value obtained by the click stimulus was an unexpected status because the click stimulus has the best relationship with hearing thresholds. On the other hand, a relationship could not be obtained with either click or 2 kHz stimulus as the air-bone gap was lower in these frequencies than in other frequencies. Nevertheless, this study has also revealed a positive relationship between the air-bone gap and the prolongation of wave V at 1 kHz. We believe that this positive relation is related to obvious bone-conduction thresholds at 1 kHz. The importance of using this particular frequency was presented as being the relationship between the air-bone gap and wave latency prolongation.

Ethics Committee Approval: Ethics committee approval was received for this study from Fırat University Non-Invasive Studies Ethics Committee.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - Ö.F.B., T.K., F.B.; Design - Ö.F.B., T.K., A.A.; Supervision - F.B., S.Y.; Resources - Ö.F.B., T.K.; Materials - Ö.F.B., T.K., F.B.; Data Collection and/or Processing - Ö.F.B., T.K., F.B., A.A.; Analysis and/or Interpretation - S.Y., I.K., E.K.; Literature Search - Ö.F.B., I.K., E.K.; Writing Manuscript -Ö.F.B., T.K., F.B., A.A.; Critical Review - T.K., F.B., S.Y.

Conflict of Interest: No conflict of interest was declared by the authors.

REFERENCES

1. Sininger YS, Abdala C. Hearing threshold as measured by auditory brain stem response in human neonates. Ear Hear 1996; 17: 395-401. **[CrossRef]**
2. Gorga MP, Johnson TA, Kaminski JR, Beauchaine KL, Garner CA, Neely ST. Using a combination of click- and tone burst-evoked auditory brain stem response measurements to estimate pure-tone thresholds. Ear Hear 2006; 27: 60-74. **[CrossRef]**
3. Pinto FR, Matas CG. A comparison between hearing and tone burst electrophysiological thresholds. Rev Bras Otorrinolaringol 2007; 73: 513-22. **[CrossRef]**
4. Stapells DR. Threshold estimation by the tone-evoked auditory brainstem response: a literature meta-analysis. J Speech Lang Pathol Audiol 2000; 24: 74-83.
5. Munnerley GM, Greville KA, Purdy SC, Keith WJ. Frequency specific auditory brainstem responses relationship to behavioural thresholds in cochlearimpaired adults. Audiology Online 1991; 30: 25-32. **[CrossRef]**
6. Fria TJ, Sabo DL. Auditory brainstem responses in children with otitis media with effusion. Ann Otol Rhinol Laryngol Suppl 1980; 89: 200-6. **[CrossRef]**
7. Hatton JL, Janssen RM, Stapells DR. Auditory Brainstem Responses to Bone-Conducted Brief Tones in Young Children with Conductive or Sensorineural Hearing Loss. Inter J Otolaryngol 2012; 2012: 284864 **[CrossRef]**
8. Campbell PE, Harris CM, Hendricks S, Sirimanna T. Bone conduction auditory brainstem responses in infants. J Laryngol Otol 2004; 118: 117-22. **[CrossRef]**
9. Cone-Wesson B. Bone conduction ABR tests. Amer J Audiology 1995; 4: 14-9. **[CrossRef]**
10. Northern JL, Downs MP. Hearing in Children. Philadelphia: Lippincott Williams & Wilkins, 2002.
11. Silman S, Silverman C. Auditory Diagnosis: Principles and Applications. Sandiago London: Singular Pub Group, 1997.
12. Casali RL, Santos MF. Auditory Brainstem Evoked Response: response patterns of full-term and premature infants. Braz J Otorhinolaryngol 2010; 76: 729-38.
13. Thornton AR. Stimulus, recording and subject factors influencing ABR diagnostic criteria. Br J Audiol 1987; 21: 183-9. **[CrossRef]**
14. Paparella MM, Goycoolea MV, Schachern PA, Sajjadi H. Current clinical and pathological features of round window diseases. Laryngoscope 1987; 97: 1151-60. **[CrossRef]**
15. Wilson D, Hodgson R, Talbot J. Endolymphatic sac obliteration for large vestibular 251 231 aqueduct syndrome. Am J Otol 1997; 18: 101-6.
16. Stapells DR, Gravel JS, Martin BA. Thresholds for auditory brain stem responses to tones in notched noise from infants and young children with normal hearing or sensorineural hearing loss. Ear Hear 1995; 16: 361-71. **[CrossRef]**
17. Laukli E, Fjermedal J, Mail IWS. Low-frequency auditory brainstem response threshold. Scandinavian Audiol 1988; 17: 171-88. **[CrossRef]**
18. McGee TJ, Clemis JD. Effects of conductive hearing loss on auditory brainstem response. Ann Otol Rhinol Laryngol 1982; 91: 304-9. **[CrossRef]**