Maturation of Auditory Brainstem Responses in Babies from Birth to 6 Months of Age

Doğumdan 6 Aylığa Kadar Olan Bebeklerde İşitsel Beyin Sapı Cevaplarının Matürasyonu

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ABSTRACT Objective: Newborn hearing screening plays an important role in making a diagnosis within the first six months of life in congenital hearing losses. In this age group, the infant's maturation is influential in the evaluation of the Auditory Brainstem Response (ABR) test, which is important in diagnosis. Because many ABR characteristics vary with age, age-related maturational values must be established for all populations to be evaluated. The purpose of the present study was to establish age-related maturational changes for infants aged 0-6 months. **Material and Methods:** ABR was measured in 180 subjects from 0 months to 6 months of age. Transient Evoked Otoacoustic Emission (TEOAE), Automated Auditory Brainstem Response (AABR) and diagnostic ABR tests were performed respectively for each subject. **Results:** In our study, maturational data of ABR absolute latencies and interpeak latencies obtained at different age groups and stimuli intensity level were presented. According to our study results, absolute latencies of waves I, III, V, and I-III, III-V, I-V interpeak latencies decreased as a function of advancing age. While absolute latencies of waves I, III, V showed a systematic increase, I-III, III-V, I-V interpeak latencies decreased as stimulus intensity decreased from 80 dB nHL to 20 dB nHL. To our results, there were no significant differences between gender and ears in terms of wave absolute latencies and interpeak latencies. **Conclusion:** Knowledge on the ABR characteristics within first six months of life will enable clinicians to discriminate normal situations from pathologic ones in diagnosing hearing loss for the infant population.

Key Words: Evoked potentials, auditory, brain stem; infant, newborn

ÖZET Amaç: Yenidoğan işitme taraması, doğumsal işitme kayıplarında yaşamın ilk altı ayında tanı koymada önemli rol oynar. Bu yaş grubunda tanıda önemli olan işitsel beyin sapı cevabı (İBC) testinin değerlendirilmesinde bebeğin matürasyonu etkilidir. Çünkü pek çok İBC özelliği yaşla değişir; yaşa uygun matürasyon değerleri, değerlendirilecek olan tüm populasyonlar için belirlenmelidir. Bu çalışmanın amacı, 0-6 aylık bebeklerde yaşla uyumlu matürasyonel değişikliklerin belirlenmesidir. **Gereç ve Yöntemler:** Çalışmada, 0-6 aylık 180 olguda İBC ölçüldü. Her olguya sırayla kısa süreli uyarılmış otoakustik emisyon (KUOE), otomatik işitsel beyin sapı cevabı (OİBC) ve tanısal İBC testleri yapıldı. **Bulgular:** Çalışmamızda, farklı yaş gruplarından elde edilen İBC oluşum sürelerinin maturasyonel verileri ve dalga tepeleri arası oluşum süreleri ve uyarı şiddet düzeyi sunuldu. Bizim çalışma sonuçlarımıza göre, ilerleyen yaşın bir işlevi olarak I, III, V. dalgaların oluşum süreleri ve I-III, III-V, I-V dalga tepeleri arası oluşum süreleri azaldı. I,III,V. dalgaların oluşum süreleri sistematik bir artış gösterirken, I-III, III-V, I-V dalga tepeleri arası oluşum süreleri uyarı yoğunluğu 80dB nHL den 20 dB nHL'ye düştükçe azaldı. Bizim sonuçlarımıza göre, dalga oluşum süreleri ve dalga tepeleri arası oluşum süreleri açısından cinsiyetler ve kulaklar arasında belirgin fark yoktur. **Sonuç:** Klinisyenlerin 0-6 aydaki İBC özelliklerini bilmeleri, bu populasyonda işitme kaybının tanısında normal durumları patolojik durumlardan ayırmayı kolaylaştıracaktır.

Anahtar Kelimeler: Uyarılmış potansiyeller, işitsel, beyin sapı; bebek, yenidoğan

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Newborn hearing test is very important in the sense that it provides for an early diagnosis in babies who suffer from congenital hearing loss and allows them to develop as closely as possible to their peers.[1,2] The aim of the newborn hearing test is to make a diagnosis when the infants are 3 months old.[3] In addition, diagnostic tests are as important as scan tests, because they allow recommendation to be made for hearing aids when the infants are 6 months old.[4,5] Auditory brain stem response (ABR) tests also have a significant role during the newborn period and in the evaluation of hearing. The automated auditory brainstem response (AABR) is widely used as a hearing screening test during the first few months of life in newborns.[1,2,6-8] While babies with possible hearing loss are determined during the hearing scan with this test, the diagnostic ABR has a critical role in the definitive diagnosis of babies with possible hearing loss.[9] Although diagnostic ABR is among objective testing methods, it also carries a subjective characteristic, due to its evaluation method and the role of the clinician in the evaluation of the results. In ABR interventions in infancy, in addition to the experience of the clinician, the maturation of the infant is effective on the results.[9]

Parallell to the increased number of newborn hearing screening, the number of ABR tests is also rising in the first six months of life. The maturation level of the infant should be considered in the interpretation of the ABR test results for true outcomes.[10,11] Overlooking the maturation level in the interpretation of results may cause a baby who has normal hearing to be diagnosed with hearing loss.[11] Thus, maturational values in this period are very important.[10,11]

Age, even marked in hours after birth, is a very pertinent variable affecting the ABR. The ABR changes with age, particularly during the first 12 to 18 months of life, as the central auditory system continues to mature.[12,13] The clinician must always rule out, or at least take into account, the possible influence of subject age in recording and analyzing an ABR, before the results of testing are interpreted.[14]

It is essential to have a clear definition of the normal response before abnormal responses can be detected in ABR testing of infants, because, maturation markedly alters response latency and influences waveform morphology. To make adjustments for these maturational effects each clinic conducting ABR testing routinely develops its own response latency norms for different conceptual ages.[15]

The purpose of this investigation was to quantify the characteristics of the ABR to click stimuli of various intensity levels during the first 6 months of age. The characteristics of the ABR investigated in this study were; 1) mean absolute latencies and standard deviations (SDs) of waves I, III, and V, and 2) mean interpeak latencies and SDs of wave I-III, III-V and I-V.

MATERIAL AND METHODS

Hacettepe University Faculty of Medicine Ethical Commission approved the study protocole. (LUT 07/35).

SUBJECTS

The study population comprised full-term children (gestational age ≥38 weeks) who underwent newborn hearing screening. The criteria for being assigned to any of the study groups were to have passed the Transient Evoked Autoacoustic Emission (TEOAE) and AABR tests. The participant babies were randomly selected from hearing screening archives and were assigned to 6 groups. The groups were formed based on age. The families of the babies were called and those who approved their baby to join the study were invited. The reported ABR data were obtained from 180 subjects (90 boys and 90 girls) aged between 2 and 180 days. Each group consisted of 30 babies.

Six groups were formed according to the chronologic age of the subjects, ranging from 1-30 days to 151-180 days (Table 1). All subjects who had risk factors for hearing loss published by the Joint Committee on Infant Hearing were excluded. All subjects who passed the TEOAE and AABR screening tests for both ears were included to take the diagnostic ABR test.

TABLE 1: Chronological and gestational ages of groups.

Groups	Chronological age (days)		Gestational age (weeks)	
	Min-Max	Mean	Min-Max	Mean
Group I (1-30 days)	2-29	15,2	38-40.1	38.8
Group II (31-60 days)	32-58	45	38-41	39.6
Group III (61-90 days)	61-89	77	38-40	38.6
Group IV (91-120 days)	92-120	107	38-40	39.2
Group V (121-150 days)	121-148	137	38-40.4	39.7
Group VI (151-180 days)	152-180	178	38.1-40	39.4

STIMULI

The acoustic stimulus in each case was an unfiltered click (0.1 ms duration) transduced with a clinical insert earphone and presented at alternating polarity. Click stimuli were presented monaurally to the right and left ears of each subject without the use of contralateral masking. Click repetition rates employed were 11.1 clicks/s. The absolute latencies of waves I, III and V of the ABR were recorded at stimulus levels of 80 dB nHL, 60 dB nHL, 40 dB nHL and 20 dB nHL, respectively.

RECORDING TECHNIQUE

Responses were recorded from scalp electrodes attached to the forehead at the hairline and the ipsilateral mastoid process. The contralateral mastoid process served as ground. Interelectrode impedances did not exceed 3000 ohms. The ongoing EEG was sampled throughout a 15-ms post-stimulus period, amplified by a factor of 10^5, filtered between 30 and 3000 Hz, and averaged over at least 1500 click presentations using an Intelligent Hearing System (IHS). For every condition, at least two replicating trials were run. The individual wave latencies obtained from replicating trials of each subject were averaged, yielding a single absolute latency for each identifiable wave at every condition. The original nomenclature of Jewett and Williston was used for identifying ABR waves I through V.

PROCEDURES

All testing was performed in a sound-isolated room while the infants were in natural sleep; no sedation was required for any subject. For each subject TEOAE, AABR and diagnostic ABR were performed, respectively. TEOAE and AABR were performed initially using MADSEN Accuscreen Pro handled GN Otometrics, Denmark combined screening Otoacustic Emission (OAE) and ABR system. Diagnostic ABR tests were performed in subjects who passed the TEOAE and AABR screening tests for both ears. In diagnostic ABR for each ear, the initial stimulus level typically was a click at 80 dB nHL, which always resulted in a clear response. Stimulus level was then decreased by 20-dB steps down to a level of 20 dB nHL. Mean absolute latencies and SDs for waves I through V were determined for both ears for each chronological age group and at every stimulus intensity level, except for 20 dB nHL. Because of low stimulus intensity level, it was not possible to identify waves I and III in a large proportion of subjects at 20 dB nHL. In addition, interpeak latencies were calculated for each subject and then were averaged across each age group. At 20 dB nHL, mean absolute latencies of wave V were calculated only and therefore, interpeak latencies could not be calculated. Based on the result of diagnostic ABR tests, data from both ears of each subject were used in developing our age-matched norms.

STATISTICAL ANALYSIS

The '*SPSS 11 for windows*' software package was used for statistical analyses. The descriptive statistics, independent samples t-test and paired samples t-test were used in the statistical analysis. A p value of <0.05 was considered significant.

RESULTS

Mean absolute latencies and SDs for waves I through V, at each stimulus intensity level and for each chronologic age group, was calculated from the individual subject data. In addition, interpeak latencies were calculated for each subject and then were averaged across each age group.

ABSOLUTE LATENCIES

Table 2 and Table 3 summarize mean absolute latencies and standard deviations of wave I, III, and V for right and left ear, respectively for each age group and stimulus intensity level. At 20 dB nHL, absolute latency of wave V only was averaged and reported here for both ears as explained before (Table 2, Table 3).

The absolute latencies of wave I through V decreased systematically with increasing stimulus level. The absolute latencies of wave I decreased with increasing chronological age up to the 61-90 days age category for both ears ($p<0.05$). Starting from this age category, wave I latency did not significantly change at any intensity level for both ears ($p>0.05$). If wave I latency is considered a measure of peripheral response maturity, then it appears that the peripheral response to click stimuli is mature early in life.

There was a very orderly progression in wave III and V latency as chronologic age increased. Wave III and V latencies were shorter for subjects 151-180 days of age compared to subjects in the 1-30 days age category. The largest changes occured in the earlier age groups, and the changes became progressively smaller in the subsequent age groups. Both waves III and V were characterized by decreases in absolute latency, while still not reaching adult values by 180 days of life. As the infants developed, wave III and V latencies decreased toward adult values.

The mean absolute latencies of wave I through V from Table 2 were plotted in Figures 1 to 3 as a function of level with age for the right ear.

The mean absolute latencies of wave I through V from Table 2 were plotted in Figures 4 to 6 as a function of level with age as the parameter for the left ear.

TABLE 2: Mean absolute latencies(M) and standard deviations(SD) of waves for right ear in each group.

		Group 1		Group 2		Group 3		Group 4		Group 5		Group 6	
Wave	Intensity level	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Wave I	80 dB nHL	1.97	0.25	1.85	0.20	1.77	0.25	1.80	0.27	1.77	0.17	1.76	0.27
	60 dB nHL	2.09	0.25	1.99	0.21	1.88	0.25	1.92	0.28	1.89	0.27	1.89	0.25
	40 dB nHL	2.23	0.24	2.12	0.21	2.03	0.24	2.05	0.25	2.03	0.26	2.03	0.17
Wave III	80 dB nHL	4.60	0.26	4.41	0.27	4.30	0.28	4.26	0.27	4.21	0.27	4.17	0.24
	60 dB nHL	4.64	0.20	4.48	0.28	4.37	0.29	4.33	0.27	4.29	0.24	4.25	0.28
	40 dB nHL	4.73	0.20	4.58	0.26	4.45	0.20	4.42	0.25	4.37	0.28	4.34	0.28
Wave V	80 dB nHL	6.95	0.27	6.77	0.27	6.55	0.20	6.46	0.27	6.40	0.26	6.35	0.26
	60 dB nHL	7.01	0.27	6.83	0.26	6.61	0.20	6.51	0.17	6.46	0.26	6.42	0.26
	40 dB nHL	7.07	0.27	6.89	0.26	6.67	0.20	6.58	0.29	6.53	0.28	6.50	0.26
	20 dB nHL	7.23	0.26	7.09	0.28	6.85	0.22	6.74	0.26	6.68	0.27	6.65	0.27

TABLE 3: Mean absolute latencies(M) and standard deviations(SD) of waves for left ear in each group.

		Group 1		Group 2		Group 3		Group 4		Group 5		Group 6	
Wave	Intensity level	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Wave I	80 dB nHL	1.98	0.24	1.84	0.20	1.78	0.25	1.80	0.26	1.78	0.26	1.77	0.25
	60 dB nHL	2.10	0.23	1.98	0.21	1.90	0.25	1.90	0.26	1.88	0.25	1.87	0.25
	40 dB nHL	2.23	0.23	2.11	0.20	2.03	0.27	2.03	0.28	2.00	0.26	2.00	0.28
Wave III	80 dB nHL	4.55	0.22	4.40	0.27	4.31	0.29	4.26	0.27	4.23	0.27	4.19	0.23
	60 dB nHL	4.62	0.22	4.48	0.28	4.39	0.29	4.34	0.28	4.31	0.28	4.26	0.24
	40 dB nHL	4.71	0.21	4.57	0.28	4.47	0.28	4.43	0.29	4.39	0.26	4.35	0.24
Wave V	80 dB nHL	6.94	0.25	6.77	0.26	6.58	0.20	6.46	0.07	6.42	0.27	6.38	0.26
	60 dB nHL	6.99	0.25	6.83	0.25	6.64	0.21	6.52	0.27	6.47	0.27	6.44	0.26
	40 dB nHL	7.06	0.27	6.90	0.26	6.71	0.21	6.59	0.25	6.54	0.28	6.50	0.28
	20 dB nHL	7.22	0.24	7.09	0.27	6.86	0.29	6.70	0.29	6.68	0.26	6.66	0.27

The difference between the right and the left ears for absolute latency values was not significant in any group (p>0.05).

INTERPEAK LATENCY

Table 4 and Table 5 summarize mean interpeak latencies and standard deviations of wave I-III, III-V, and I-V for the right and left ears, respectively for each age group and stimulus intensity level. At 20 dB nHL, interpeak latency could not be calculated and reported for both ears as explained before (Table 4, Table 5).

There was a systematic decrease in the I-III, III-V, and I-V interpeak latencies with increasing chronological age and with decreasing stimulus intensity level. As the intensity level decreased, the absolute latency of wave I increased more compared to the absolute latencies of wave III and V. Therefore, I-III and I-V interpeak latencies decreased as the intensity level decreased. Interpeak latencies for waves I-III, III-V, and I-V were characterized by decreases in latency, while still not reaching adult values by 180 days of life. As the infants developed, I-III, III-V, and I-V interpeak latencies decreased toward adult values.

The mean interpeak latencies from Table 4 were plotted in Figures 7 to 9 as a function of level with age as the parameter for the right ear.

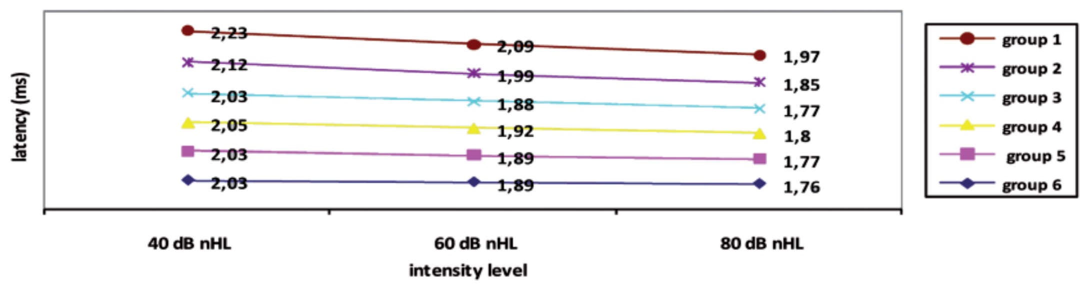

FIGURE 1: Absolute latency of wave I at click levels from 40 dB nHL to 80 dB nHL for the right ear in each group.
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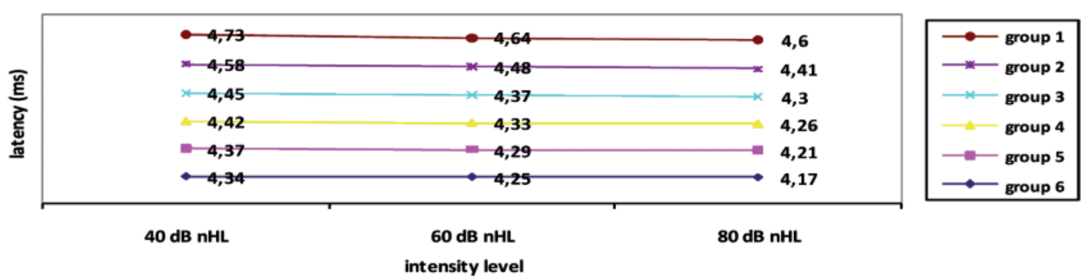

FIGURE 2: Absolute latency of wave III at click levels from 40 dB nHL to 80 dB nHL for the right ear in each group.
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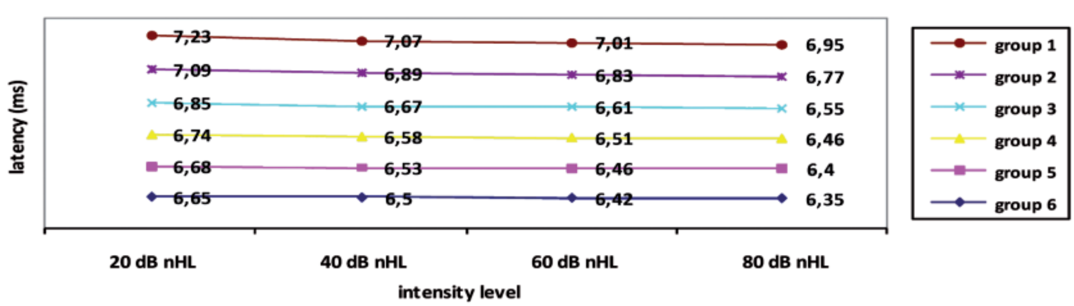

FIGURE 3: Absolute latency of wave V at click levels from 20 dB nHL to 80 dB nHL for the right ear in each group.
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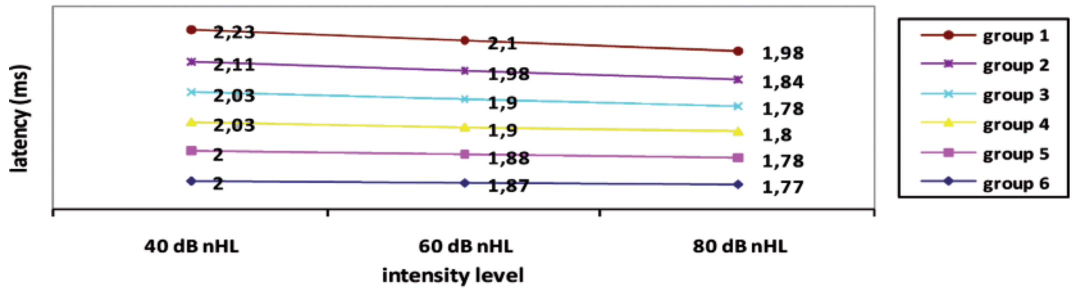

FIGURE 4: Absolute latency of wave I at click levels from 40 dB nHL to 80 dB nHL for the left ear in each group.
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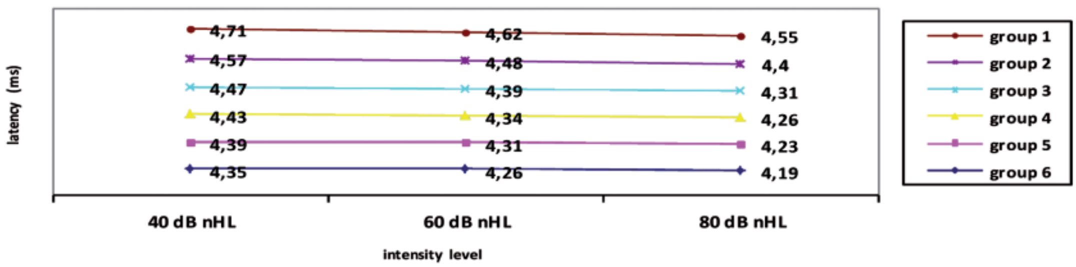

FIGURE 5: Absolute latency of wave III at click levels from 40 dB nHL to 80 dB nHL for the left ear in each group.
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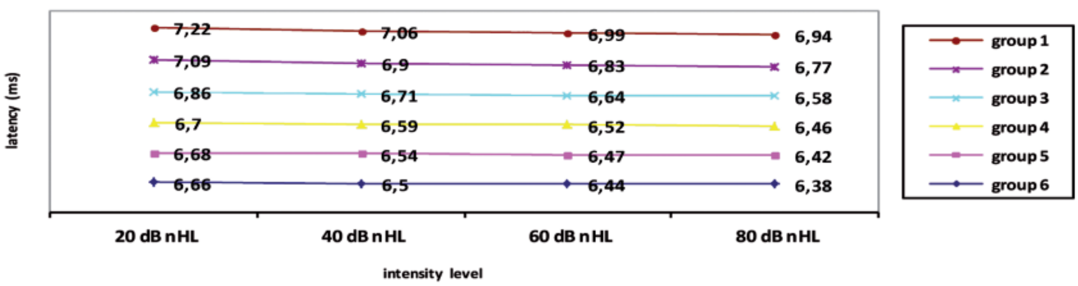

FIGURE 6: Absolute latency of wave V at click levels from 20 dB nHL to 80 dB nHL for the left ear in each group.
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)

TABLE 4: Means (M) and standard deviations (SD) of interwave latencies from 80 dB nHL to 40 dB nHL as a function of age for the right ear.

		Group 1		Group 2		Group 3		Group 4		Group 5		Group 6	
Wave	Intensity level	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
I-III interpeak latency	80 dB nHL	2.60	0.22	2.56	0.29	2.53	0.28	2.46	0.29	2.44	0.20	2.41	0.29
	60 dB nHL	2.55	0.24	2.49	0.29	2.48	0.28	2.41	0.29	2.39	0.20	2.35	0.29
	40 dB nHL	2.50	0.22	2.46	0.30	2.42	0.29	2.37	0.30	2.35	0.22	2.31	0.28
III-V interpeak latency	80 dB nHL	2.38	0.24	2.36	0.27	2.26	0.20	2.20	0.26	2.18	0.26	2.19	0.27
	60 dB nHL	2.36	0.24	2.34	0.27	2.23	0.28	2.18	0.25	2.17	0.26	2.17	0.27
	40 dB nHL	2.34	0.26	2.30	0.26	2.23	0.20	2.16	0.25	2.16	0.28	2.16	0.29
I-V interpeak latency	80 dB nHL	4.97	0.29	4.91	0.27	4.79	0.20	4.66	0.28	4.63	0.27	4.59	0.27
	60 dB nHL	4.91	0.29	4.84	0.28	4.72	0.29	4.59	0.29	4.56	0.27	4.52	0.26
	40 dB nHL	4.83	0.20	4.76	0.29	4.65	0.28	4.53	0.29	4.51	0.28	4.47	0.27

The mean interpeak latencies from Table 5 were plotted in Figures 10 to 12 as a function of level with age as the parameter for the left ear.

The difference in the interview latency values between the right and the left ears was not significant for any group (p>0.05).

TABLE 5: Means (M) and standard deviations (SD) of interwave latencies from 80 dB nHL to 40 dB nHL as a function of age for the left ear.

		Group 1		Group 2		Group 3		Group 4		Group 5		Group 6	
Wave	Intensity level	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
I-III interpeak latency	80 dB nHL	2.57	0.20	2.56	0.20	2.53	0.28	2.47	0.28	2.46	0.29	2.42	0.27
	60 dB nHL	2.53	0.21	2.50	0.21	2.49	0.28	2.44	0.28	2.44	0.29	2.39	0.27
	40 dB nHL	2.49	0.21	2.46	0.21	2.44	0.26	2.40	0.29	2.39	0.28	2.34	0.29
III-V interpeak latency	80 dB nHL	2.38	0.26	2.37	0.27	2.28	0.30	2.20	0.26	2.18	0.26	2.19	0.27
	60 dB nHL	2.37	0.26	2.35	0.27	2.25	0.31	2.18	0.26	2.16	0.28	2.17	0.27
	40 dB nHL	2.35	0.28	2.33	0.28	2.23	0.21	2.16	0.26	2.15	0.26	2.13	0.26
I-V interpeak latency	80 dB nHL	4.96	0.25	4.93	0.28	4.81	0.30	4.66	0.27	4.64	0.28	4.60	0.26
	60 dB nHL	4.89	0.25	4.86	0.28	4.74	0.30	4.61	0.27	4.60	0.27	4.56	0.25
	40 dB nHL	4.84	0.27	4.79	0.29	4.67	0.31	4.56	0.28	4.54	0.28	4.48	0.25

DISCUSSION

Auditory Brainstem Response is an important test procedure in terms of not only the assessment of hearing loss but also for determining neurologic maturation in infants.[11,16] Since differences in stimulus conditions and bandpass filter settings result in different ABR wave latency values,[17,18] the conclusions in this report are unique to the specific stimuli and electroencephalogram (EEG) recording parameters employed in this investigation.

Although ABR is an objective and reliable test, non-pathological factors in tested subjects may influence the outcome of the test. Non-pathological factors include age and gender, body temperature, state of arousal, attention, and the possible effects of drugs.[11,19,20]

Numerous reports confirmed the ABR as an indirect measure of the maturation of the auditory system in developing normal infants.[21-23] Unfortunately, it is difficult to compare results across stud-

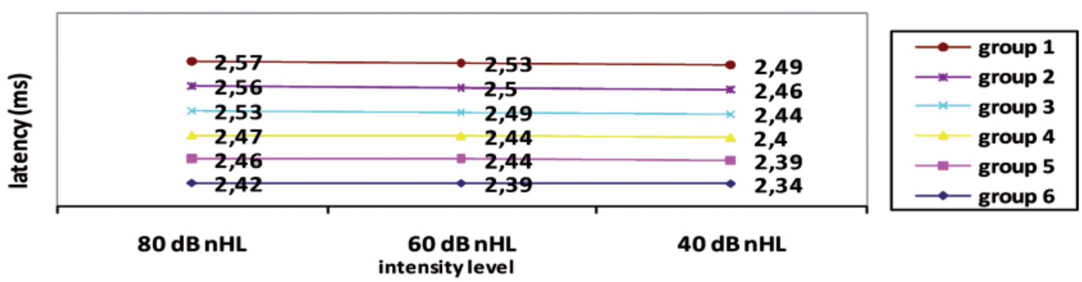

FIGURE 7: Interwave latency of wave I-III at click levels from 80 dB nHL to 40 dB nHL for the right ear in each group. (See for colored form http://tipbilimleri.turkiyeklinikleri.com/)

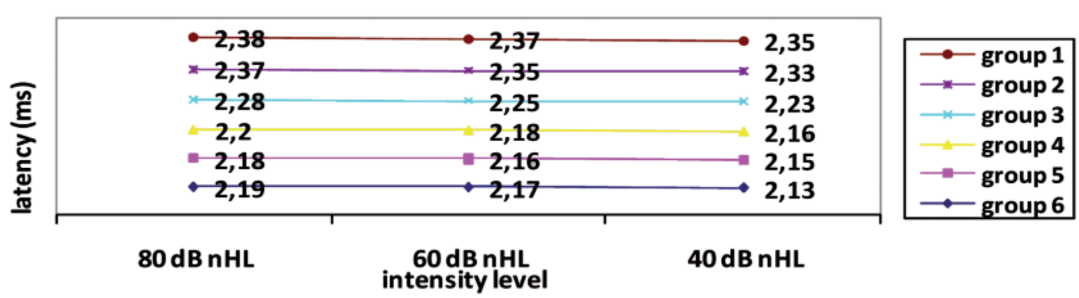

FIGURE 8: Interwave latency of wave III-V at click levels from 80 dB nHL to 40 dB nHL for the right ear in each group. (See for colored form http://tipbilimleri.turkiyeklinikleri.com/)

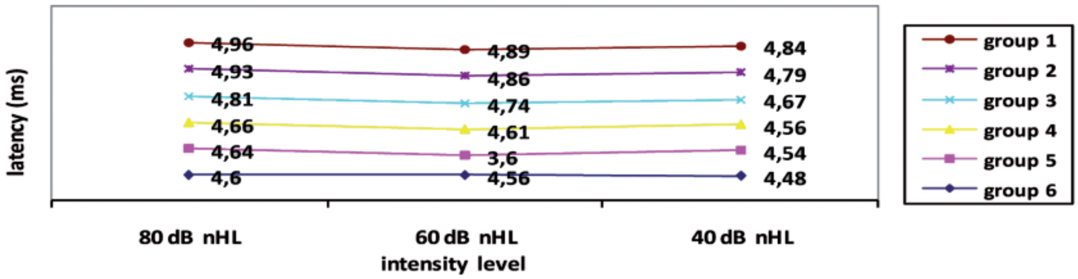

FIGURE 9: Interwave latency of wave I-V at click levels from 80 dB nHL to 40 dB nHL for the right ear in each group.
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)

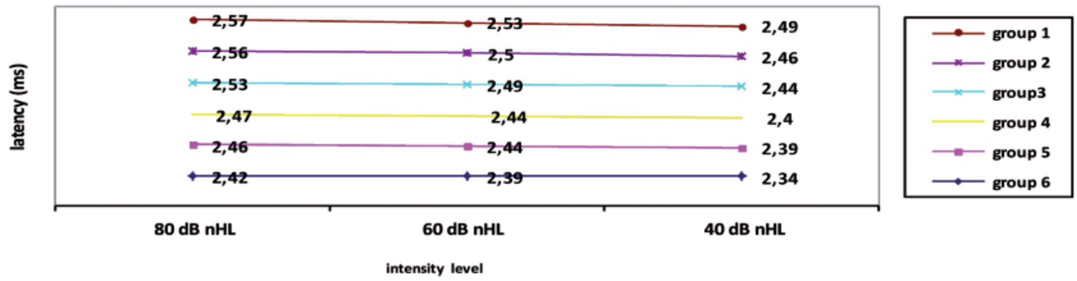

FIGURE 10: Interwave latency of wave I-III at click levels from 80 dB nHL to 40 dB nHL for the left ear in each group.
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)

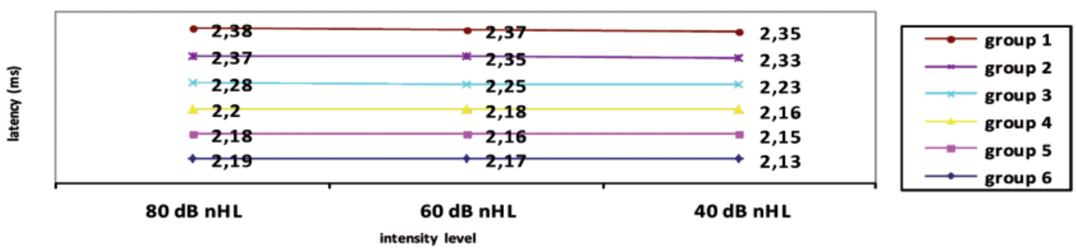

FIGURE 11: Interwave latency of wave III-V at click levels from 80 dB nHL to 40 dB nHL for the left ear in each group.
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)

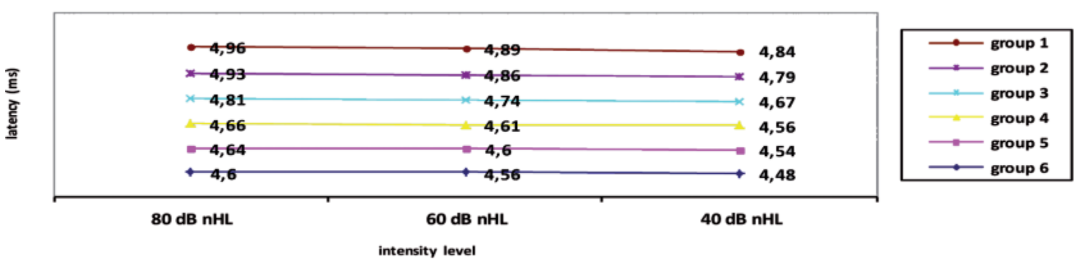

FIGURE 12: Interwave latency of wave I-V at click levels from 80 dB nHL to 40 dB nHL for the left ear in each group.
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)

ies because of a diversity of stimulus variables and subjects. In contrast to earlier studies, this study included a homogeneous group and investigated multiple stimulus intensity levels to develop an age-related maturational data.

The data obtained in this study were used to quantify ABR changes occurring within the first 6 months of life and to develop age-related norms. Subject selection criteria were stringently applied to assure a normal full term subject population. Multiple stimulus intensity levels were employed to provide maturational values in different age groups. In this study, changes in ABR latencies were studied for only the first six months of life.

Joint Committee on Infant Hearing suggested that the hearing of all infants should be screened using objective, physiological measures to identify those with congenital or neonatal onset hearing loss. Audiological evaluation and medical evaluations should be in progress before 3 months of age. Infants with confirmed hearing loss should receive intervention before 6 months of age from healthcare and education professionals with expertise in hearing loss and deafness in infants and young children.[3] It is clear that the first 6 months of life is crucial for diagnosing hearing loss and for receiving educational intervention. To diagnose hearing loss in this population, age-related maturational values are needed to interpret ABR results accurately.

There is considerable variability among investigations in their categorization of infant age. For example in a study published by Fria and Doyle,[22] the newborn group includes infants with conceptional ages (gestational age at birth in weeks plus number of week since birth) ranging from 32 to 44 weeks. Older infants were categorized by chronological age (weeks after birth) without consideration of the gestational age (GA) of the infants. Jacobson et al. grouped newborns by GA only, and included 25 subjects who had attained an implausible GA of more than 46 weeks.[24] The present study grouped subjects according to their chronological ages at which ABR testing was implemented and subjects whose gestational age was £38 weeks were excluded from the study.

Some studies reporting normative values were based on data from relatively small groups of subjects.[25] In some cases, the sample size was unspecified. However, a series of reports exist that describe developmental changes in ABR latencies through adulthood based on large sample sizes.[21] In the present study, a large sample size were used to develop maturational value norms and each group was equally distributed in terms of sample size.

In the present study, wave I latency did not change from 61-90 days to 151-180 days of life. This suggests that the functional maturity of the peripheral system is complete within the first 61-90 days following full-term birth. There exists, however, considerable variability among investigations of the developmental course of wave I in the infant. Some investigators have reported that wave I latency approximates adult values at full-term birth (40 weeks GA); others have suggested that the latency of wave I continues to decrease for 6 to 12 weeks following full-term birth; still others have observed changes in wave latency as late as the seventh month of life.[25-27]

Wave III and V latencies systematically decrease as chronological age increases. As the infant develops, wave III and wave V decrease toward adult values. In this study, wave III and V did not reach adult values up to 6 months of age, which was the upper age limit of our study and continued their maturation. However, the rate of maturation for waves III and V exhibits remartkable similarity. The age of maturation however, differs between the studies. Fria and Doyle calculated the maturation of wave III and wave V at 107 and 113 weeks of chronological age, respectively.[22]

According to our study results, absolute latencies of waves I, III, V and I-III, III-V, I-V interpeak latencies decreased with advancing age. While absolute latencies of waves I, III, V showed a systematic increase, I-III, III-V, I-V interpeak latencies decreased as stimulus intensity decreased from 80 dB nHL to 20 dB nHL. These results were identical to the results of previous reports.[28]

If a clinician who works in an Ear, Nose and Throat or pediatric clinic does not take into account the latency properties related to neurologic maturation, an infant who has normal hearing can be misdiagnosed with hearing loss. ABR test results must be crosschecked with maturational data to avoid false negative diagnosis. Maturational values determined in a clinic can be used by another clinic on condition that the same protocol is used.

The present investigation represents infant ABR characteristics using a careful design and protocol. In order to derive comprehensive information regarding ABR development, stimulus intensity levels were manipulated within different age groups. Thus, absolute latencies and interpeak latencies over a wide range of stimulus levels were reported for infants from birth to 6 months of age.

The data reveal that the ABR absolute and interpeak latencies of infants are significantly different from those of adults, but progressively approximate the adult function with increasing age.

CONCLUSION

Newborn hearing test is very important in the sense that it provides information for an early diagnosis in babies who suffer from congenital hearing loss and allows them to develop as closely as possible to their peers. As the newborn hearing screening becomes more widespread, the use of ABR will increase during the first six months of life. Outcomes of this study showed that functional maturity of the peripheral system was complete within the first 61-90 days following full-term birth. The absolute latencies of wave I through V decreased with increasing chronological age and stimulus levels while I-III, III-V, and I-V interpeak latencies decreased with increasing chronological age and decreasing stimulus levels. The level of maturation should be considered in the interpretation of the ABR test results for accurate outcomes. Overlooking the maturation level when interpreting test results, may cause a baby who has normal hearing to be diagnosed with hearing loss.

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REFERENCES

1. Stevens J, Parker G. Screening and surveillance. In: Newton VE, ed. Pediatric Audiological Medicine. 2nd ed. Chichester: West Sussex, Wiley-Blackwell; 2009. p.29-51.
2. Genç GA, Ertürk BB, Belgin E. [Newborn hearing screening: past to present]. Turkish Pediatric Journal 2005;48(2):109-18.
3. American Academy of Pediatrics, Joint Committee on Infant Hearing. Year 2007 position statement: Principles and guidelines for early hearing detection and intervention programs. Pediatrics 2007;120(4):898-921.
4. McGrath AP, Vohr B, O'Neil CA. Newborn hearing assessment in 2010. Med Health R I 2010;93(5):142-4.
5. White KR. Newborn hearing screening. In: Madell JR, Flexer C, eds. Pediatric Audiology. 1st ed. New York: Thieme; 2008. p.31-41.
6. Ahlfors CE, Amin SB, Parker AE. Unbound bilirubin predicts abnormal automated auditory brainstem response in a diverse newborn population. J Perinatol 2009;29(4):305-9.
7. Tuncer Ü, Demir H, Aydoğan BL, Yüce E, Narlı N. Unbound bilirubin predicts abnormal automated auditory brainstem response in a diverse newborn population. J Perinatol 2009; 29(4): 305-9.
8. White KR. Screening programs for hearing loss. In: Luxon L, Furman JM, Martini A, Stephens D, eds. Textbook of Audiological Medicine, Clinical Aspects of Hearing and Balance. 1st ed. London: Taylor&Francis Group; 2003. p.339-48.
9. Purdy SC, Kelly AS. Auditory evoked response testing in infants and children. In: Madell JR, Flexer C, eds. Pediatric Audiology. 1st ed. New York: Thieme; 2008. p.132-44.
10. Pratt H. Human auditory electrophysiology. In: Luxon L, Furman JM, Martini A, Stephens D, eds. Textbook of Audiological Medicine, Clinical Aspects of Hearing and Balance. 1st ed. London: Taylor&Francis Group; 2003. p.271-87.
11. Hall III JW. ABR Analysis and Interpretation. New Handbook of Auditory Evoked Responses. 1st ed. Boston: Allyn and Bacon; 2007. p. 212-57.
12. Hood LJ. The normal auditory brainstem response. Clinical Applications of ABR. 1st ed. San-Diego-London: Singular Publishing; 1998. p.60-1.
13. Don M, Kwong B. Auditory brainstem response: differential diagnosis. In: Katz J, ed. Handbook of Clinical Audiology. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2002. p.274-97.
14. Jiang ZD, Zheng MS, Sun DK, Liu XY. Brainstem auditory evoked responses from birth to adulthood: normative data of latency and interval. Hear Res 1991;54(1):67-74.
15. Gorga MP, Kaminski JR, Beauchaine KL, Jesteadt W, Neely ST. Auditory brainstem responses from children three months to three years of age: normal patterns of response. II. J Speech Hear Res 1989;32(2):281-8.
16. Issa A, Ross HF. An improved procedure for assessing ABR latency in young subjects based on a new normative data set. Int J Pediatr Otorhinolaryngol 1995;32(1):35-47.
17. Wilkinson AR, Jiang ZD. Brainstem auditory evoked response in neonatal neurology. Semin Fetal Neonatal Med 2006;11(6):444-51.
18. Stockard JE, Stockard JJ, Westmoreland BF, Corfits JL. Brainstem auditory-evoked responses. Normal variation as a function of stimulus and subject characteristics. Arch Neurol 1979; 36(13):823-31.
19. Hall III JW. Auditory evoked response measurements princi ples. Handbook of Auditory Evoked Responses. 1st ed. Boston: Allyn and Bacon; 1992. p.229-35.
20. Hall III JW, Swanepoel DW. Auditory brainstem response. Objective Assessment of Hearing. 1st ed. San Diego: Plural Publishing; 2010. p.67-105.
21. Gorga MP, Reiland JK, Beauchaine KA, Worthington DW, Jesteadt W. Auditory brainstem responses from graduates of an intensive care nursery: normal patterns of response. J Speech Hear Res 1987;30(3):311-8.
22. Fria TJ, Doyle WJ. Maturation of the auditory brain stem response (ABR): additional perspectives. Ear Hear 1984;5(6):361-5.
23. Starr A, Amlie RN, Martin WH, Sanders S. Development of auditory function in newborn infants revealed by auditory brainstem potentials. Pediatrics 1977;60(6):831-9.
24. Jacobson JT, Morehouse CR, Johnson MJ. Strategies for infant auditory brain stem response assessment. Ear Hear 1982;3(5):263-70.
25. Hecox K, Galambos R. Brain stem auditory evoked responses in human infants and adults. Arch Otolaryngol 1974;99(1):30-3.
26. Eldredge L, Salamy A. Functional auditory development in preterm and full term infants. Early Hum Dev 1996; 45(3): 215-28.
27. Zimmerman MC, Morgan DE, Dubno JR. Auditory brain stem evoked response characteristics in developing infants. Ann Otol Rhinol Laryngol 1987;96(3 Pt 1):291-9.
28. Musiek FE, Johnson GD, Gollegly KM, Josey AF, Glasscock ME 3rd. The auditory brain stem response interaural latency difference (ILD) in patients with brain stem lesions. Ear Hear 1989; 10(2):131-4.