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Determination of Risk Factors on Newborn Hearing Loss

Yenidoğan İşitme Kayıplarında Risk Faktörlerinin Belirlenmesi

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ABSTRACT Objective: The aim of the study was to determine the number of patients who did not pass the A-ABR test while being screened at the hearing screening center of our hospital and applied to the reference center, the degree of hearing loss, the effect of risk factors on hearing loss, and the age of their devices. **Material and Methods:** The study included 5,552 infants screened at the hearing screening center. The results of the diagnostic tests performed at the screening and reference center were compiled retrospectively with risk factors. **Results:** While 5,368 (96.7%) of the infants did not present with any risk factors, 184 (3.3%) presented with one or more; 267 (4.8%) of the infants who did not pass the A-ABR test in the screening center applied to the reference center, while 254 of the infants who applied to the reference center passed the tests, a total of 13 (0.23%) were diagnosed with sensorineural hearing loss (SNHL) (1 unilateral, 12 bilateral). There were no risk factors found in five of the infants diagnosed with SNHL, while eight had one or more risk factor. The rate of hearing loss was found to be statistically significant in infants exhibiting risk factors. **Conclusion:** The recommendations regarding the hearing screening tests of newborns include completion in the first month of life, diagnosis in the first three months, and receiving a hearing aid in six months and beginning rehabilitation. The hearing loss rate is known to be high in infants exhibiting risk factors. Thus, the early diagnosis and treatment of infants with hearing loss contribute to their speech language, social-emotional development, and academic success.

Keywords: Newborn; hearing screening; auditory brainstem responses; risk factors; hearing loss

ÖZET Amaç: Çalışmanın amacı, hastanemiz işitme tarama merkezinde A-ABR ile taranan ve kalan bebeklerden referans merkezine başvuranların sayısını, işitme kayıplarının derecesi, risk faktörlerinin işitme kaybına etkisi ve cihazlanma yaşlarının tespit edilmesidir. **Gereç ve Yöntemler:** Çalışmaya işitme tarama merkezinde taranan 5.552 bebek dâhil edildi. Tarama ve referans merkezinde yapılan tanısal testlerin sonuçları, risk faktörleriyle beraber retrospektif olarak derlendi. **Bulgular:** Bebeklerin 5.368 (%96,7)'inde herhangi bir risk faktörü bulunmazken; 184 (%3,3)'ünde bir veya birden çok risk faktörü mevcuttu. Tarama merkezinde, A-ABR testini geçemeyen bebeklerden 267 (%4,8)'si referans merkezine başvurdu. Referans merkezine başvuran bebeklerin 254'ü testleri geçerken; 1 bebeğe tek taraflı, 12 bebeğe çift taraflı olmak üzere toplam 13 (%0,23) bebeğe sensörinöral işitme kaybı (SNİK) tanısı konuldu. SNİK tanısı alan bebeklerin 5'inde herhangi bir risk faktörü bulunmazken, 8'inde bir veya birden çok risk faktörü mevcuttu. Risk faktörü bulunan bebeklerde işitme kaybı görülme oranı istatistiksel olarak anlamlı bulundu. **Sonuç:** Yenidoğanların işitme tarama testlerinin yaşamın ilk ayında tamamlanması, ilk 3 ay içinde tanılanması ve 6 ay içinde de cihazlandırılıp rehabilitasyonlarına başlanması önerilmektedir. Risk faktörü bulunan bebeklerde işitme kaybı oranının yüksek olduğu bilinmektedir. İşitme kaybı bulunan bebeklere erken tanı konması ve tedavilerine erken başlanması, bebeklerin konuşma-dil, sosyal, duygusal gelişimlerine ve akademik başarılarına katkı sağlamaktadır.

Anahtar Kelimeler: Yenidoğan; işitme tarama; işitsel beyin sapı yanıtları; risk faktörleri; işitme kaybı

Hearing loss is the most common congenital pathology in newborns, with a rate of one to three out of 1000.[1] It has been reported that this rate increases to 4 to 5% in infants exhibiting risk factors. When the diagnosis of postpartum hearing loss is not detected in a timely manner, language, speech, intelligence, and social and emotional development are affected. Because of this, it is recommended

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that all newborn infants receive a hearing screening within one month of life; if there is hearing loss, diagnosis should be made within the first three months of life, and the training program should begin with a device within six months at the latest.[2] If hearing screening is not performed in newborns, moderate to severe hearing losses may not be detected before an average of 24 months, and mild hearing losses may not be detected before school age.[3] The language and perception skills, environmental compatibility, peer communication, and academic success of the children diagnosed with hearing loss at early ages were found to be within normal limits.[4]

Today, transient evoked otoacoustic emissions (TEOAE) and/or auditory brainstem response (ABR) are widely used in newborn hearing screenings. Otoacoustic emission (OAE) is based on the principle of recording a stimulus given to the outer hair cells in the cochlea through the outer ear canal and reflects the condition of the cochlea independent of the central nervous system.[5] OAE screening is simple, fast, and easy; however, it is a disadvantage that there is serumen in the outer ear canal, fluid in the middle ear, and no response in hearing loss less than 35dB.[6]

Auditory brainstem response is the electrical response given to a stimulus by the auditory nerve and brainstem hearing pathways from electrodes placed on the scalp.[7] Automatic ABR (A-ABR) is accepted as the gold standard in newborn hearing screenings. Family history with hearing loss, intrauterine infections, syndromes or craniofacial abnormalities, intensive care unit admission, ototoxic drugs, hyperbilirubinemia or phototherapy treatments are risk factors for newborn hearing loss. In children presenting with risk factors for neonatal hearing loss, A-ABR is recommended to be performed first.[8,9] Infants who fail screening tests are subjected to advanced diagnostic tests, with hearing loss diagnosed and treatment programs begun accordingly. In our study, the aim was to determine the number of infants screened with A-ABR in the hearing screening center of our hospital as well as the number of applicants referred to the reference center, the degree of hearing loss, the effect of risk factors on hearing loss, and the age upon device administration.

MATERIAL AND METHODS

The study began with the approval of University of Health Sciences Turkey-Samsun Training and Research Hospital Non-interventional Clinical Researches Ethics Committee (Date: 01.29.2020/number 2020/4/15). Five thousand five hundred and fifty-two newborns born between January 1, 2019 and December 31, 2019 at University of Health Sciences Turkey-Samsun Training and Research Hospital, Obstetrics and Gynecology Clinic and underwent a screening test with A-ABR were included in the study. Two hundred and seventy-six of the infants who were referred after achieving fail results applied to the reference center. The results of the diagnostic tests performed at the screening and reference center were compiled retrospectively with risk factors.

To ensure the reliability of the results, the ABR test was performed while each baby was asleep or under the bed, in a clean, tummy, flatbed, quiet, calm bed, or on the lap of his parent. All infants included in the study were interviewed with their families, and an information form on risk factors was filled out. As hearing risk factors, neonatal intensive care history, respiratory failure, use of ototoxic drugs, bacterial meningitis history, extracorporeal membrane oxygenation (ECMO) application, microtia or ear tract atresia, hyperbilirubinemia, phototherapy, hearing loss in the family, craniofacial anomalies, and syndromic diseases were investigated. Hearing screening (hearing screening center) and diagnosis (reference center) protocol was applied.

HEARING SCREENING CENTER

The hearing screening test was performed with GN Otometrics MADSEN Accuscreen Pro and Maico MB 11 scan Automatic ABR (A-ABR) device in the room suitable for all newborn infants, including holidays, in the Hearing Screening Center in the Obstetrics and Gynecology Clinic. A-ABR measurements were made using the device's A-ABR by giving a 35 dB SPL stimulus, testing the stimulus spectrum between 0.5 kHz and 4 kHz, based on the ear canal for filtering and other effects, between 2 kHz and 4 kHz.

The first screening tests were conducted with the infants before they were discharged: within the first

72 hours after birth. Bilateral 'PASS' results were deemed as having normal hearing. Infants who had unilateral or bilateral 'FAIL' results were given appointments seven to 15 days after the test for repetition. If the second screening test resulted in another unilateral or bilateral 'FAIL', an appointment was scheduled in the following 15-30 days (no more than 30 days) for test repetition once again. The infants with unilateral or bilateral 'FAIL' results from this third screening were sent to our reference center to be evaluated via diagnostic audiological tests. Besides, even if babies who have risk factors such as family history with hearing loss, ototoxic drug usage of the mother during pregnancy, viral infection history, craniofacial abnormalities and syndromes, hyperbilirubinemia, phototherapy treatment, intensive care unit admission and receiving mechanical ventilation, pass any stage of the hearing screening, they were referred to the reference centres for 6 months, 1 year and 3 years control.

REFERENCE CENTER

After the third screening, infants with unilateral or bilateral 'FAIL' results were evaluated in our reference center. In the reference center, the infants were first tested with A-ABR. Those tested as a result of unilateral or bilateral 'FAIL' results from previous tests were referred for an otorhinolaryngology examination to evaluate a possible external ear canal or middle ear problem. Clinical ABR testing (Interacoustics Eclipse EP15; Denmark) was performed after treatment in infants with debris in the outer ear canal or fluid in the middle ear. Immitansmetric measurements, clinical OAE (Otometrics MADSEN Capella), and behavioral observation audiometry testing (Interacustic AC-40) were applied to infants with hearing loss after clinical ABR measurement.

Upon pediatric audiological evaluation, after applying all tests in accordance with the principle of cross control, hearing loss and degree were determined, and diagnoses were made. Families of babies with bilateral or unilateral hearing loss, diagnosed as a mild, moderate, severe or profound hearing loss with regarding American Speech and Hearing Association (ASHA) criteria were informed sufficiently. Necessary information was provided to the families of infants who were diagnosed with bilateral or unilateral moderate, moderately severe, severe, or profound sensory-neural hearing loss (SNHL). Regular audiological follow-up was planned for infants with unilateral SNHL. Infants with bilateral SNHL were included in the training programs by device. Device-applied infants were called for regular check-ups at the first, third, and six months, during which it was assessed whether they benefited from the hearing aids applied in their controls. The families of those who did not benefit or who under-benefitted from the hearing aid were informed about and recommended for the cochlear implant.

STATISTICAL ANALYSIS

The data obtained from the study were analyzed using the SPSS (Version 22 for Windows, SPSS Inc, Chicago, IL, USA) package program. Data were expressed in numbers and percentages (%). A Chi-square (χ^2) test was used for statistical comparisons, and statistical significance was accepted as $p < 0.05$.

RESULTS

Of the 5,552 infants included in the study, 2,711 (48.8%) were female and 2,841 (51.2%) were male. In the hearing screening center, 4,335 (78.1%) of the 5,552 infants who were screened with A-ABR within the first 72 hours of life passed the test, while 1217 (21.9%) failed the test. For the second time, 575 (52.8%) infants passed the A-ABR, which was applied to 1089 infants who came in 7-15 days, while 514 (47.2%) infants failed. The remaining infants were called in for a third screening within 15-30 days, and 101 (35.3%) of the 286 infants passed the test, while 185 (64.7%) failed the test. At this point, it was found that some families did not follow the recommendations and did not bring their infants in for testing. Of the 267 (4.8%) infants remaining from the screenings in the hearing screening center applied to the reference center, 254 passed the test, while 13 infants failed. As a result of the screening, 13 of the 5,552 infants (0.23%) were diagnosed with sensorineural hearing loss (Table 1).

Five thousand three hundred and sixty-eight (96.7%) of the 5,552 infants whose hearing screenings are completed had no risk factors, while 184

TABLE 1: Hearing screening results.

Hearing screening center	Number of newborns	Pass (%)	Fail (%)	Absentee
1. A-ABR	5,552	4,335 (78.1%)	1,217 (21.9%)	-
2. A-ABR	1,089	575 (52.8%)	514 (47.2%)	128 (10.5%)
3. A-ABR	286	101 (35.3%)	185 (64.7%)	228 (44.3%)
Reference center (A-ABR and diagnostic odiometric tests)	267	254 (95.1%)	13 (4.9%)	89 (48.1%)
Total	5,552	5,265 (94.8%)	13 (0.2%)	445 (8%)

A-ABR: Automatic auditory brainstem response.

TABLE 2: Risk factors and hearing loss relationship.

	SNHL-none	SNHL-present	Total	χ^2 value
	n (%)*	n (%)*	n (%)*	p
Risk factors-none	5,363 (99.9%)	5 (0.1%)	5,368 (100.0%)	
Risk factors-present	176 (95.7%)	8 (4.3%)	184 (100.0%)	120.2 < 0.0001
Total	5,539 (99.8%)	13 (0.2%)	5,552 (100.0%)	

*Row percentages.
SNHL: Sensory-neural hearing loss.

(3.3%) infants had one or more risk factors. Meanwhile, five (0.09%) infants without risk factors were found to have SNHL, while eight with risk factors (4.3%) were found to have SNHL. The hearing loss rate of the infants without risk factors was not statistically significant, while the hearing loss rate of the infants with risk factors was statistically significant ($p < 0.0001$) (Table 2).

There were no risk factors in 83 (31%) of the 267 infants who received fail test results at the hearing screening center of our hospital and were subsequently referred to the reference center, while 184 (69%) had one or more risk factors. The risk factors included intensive care history in 149 (81%) infants, hyperbilirubinemia in 78 (42.3%), phototherapy in 67 (36.4%), ototoxic drug usage in 54 (29.3%), family history of hearing loss in 30 (16.3%), craniofacial anomaly in 12 (6.5%), and syndromic disease in two (1.08%) cases, respectively. SNHL was detected in five infants with intensive care hospitalization (one of whom had a history of hyperbilirubinemia and phototherapy), and three with hearing loss in the family. Reasons for admission of the intensive care unit of babies with hearing loss were hyperbilirubinemia in 2 babies, respiratory distress in 2 babies and low-birth-weight (this baby had a history of CMV infection). SNHL was detected in 3 babies who had a family history of hearing loss.

As a result of the advanced audiological evaluations of the infants at the reference center, 13 were diagnosed with SNHL. Additionally, five (38.4%) of these infants did not present any risk factors, while eight (61.5%) had one or more risk factors. Unilateral hearing loss was present in one (0.018%) of the infants with hearing loss, while the other 12 infants (0.21%) had bilateral hearing loss. These infants were diagnosed with hearing loss within an average of 5.6 months (4-12 months) and began using hearing aids in an average of 6.3 months (6-13 months) from birth (Table 3).

DISCUSSION

Hearing loss, ranking fourth in disabilities worldwide, is the most common sensory disorder. The importance of early diagnosis, hearing aid use, and rehabilitation is accepted in order to reduce the negative effects of hearing loss at every stage of life. The incidence of hearing loss in newborns ranges between 0.1 and 0.3% worldwide.[1]

Çelik et al.[10] found the rate of hearing loss to be 0.27% in their study, in which they examined the screening tests of 142,128 infants . In our study covering 5,552 patients, we found the rate of hearing loss to be 0.23%. Cox et al.[11] found the rate of bilateral hearing loss to be within the range of 0.13-0.60% and the rate of unilateral hearing loss to be within the

TABLE 3: Detailed results of the infants diagnosed with hearing loss.

Subjects n=13	Risk factor	Risk factors	Hearing loss level	Diagnose age (mnt)	Hearing aid age (mnt)
1		-	Bilateral mild SNHL	4	Follow up
2		-	Left ear mild SNHL Right ear normal	5	Follow up
3	None (n=5)	-	Bilateral profound SNHL	5	6
4		-	Bilateral profound SNHL	6	7
5		-	Bilateral profound SNHL	10	11
6		Family history	Bilateral profound SNHL	4	5
7		Family history	Bilateral moderate-severe SNHL	5	6
8		Family history	Bilateral profund SNHL	6	6
9		ICU, hyperbilirubinemia, phototherapy	Bilateral moderate-severe SNH	6	7
10	Present (n=8)	ICU, hyperbilirubinemia, phototherapy	Bilateral profound SNHL	4	6
11		ICU, ototoxic drug usage, CMV infection history, low-birth-weight	Bilateral profound SNHL	12	13
12		ICU, ototoxic drug usage, CMV infection history, low-birth-weight	Bilateral profound SNHL	10	12
13		ICU, hyperbillirubinemia, phototherapy	Bilateral moderate SNHL	10	10

range of 0.17-0.38%. Övet et al. detected bilateral hearing loss in 17 of 18 newborn infants, one of which had unilateral hearing loss detected to be severe SNHL.[12] In our study, one (0.018%) of 13 infants with SNHL had unilateral hearing loss, and 12 (0.21%) had bilateral hearing loss.

Although neonatal hearing screening protocols differ, their results are similar. Today, OAE and ABR tests are used singularly or in combination in hearing screening.[13] The ABR test is an electrophysiological test that evaluates the auditory nerve and hearing pathways in the brain stem. The ABR test is recommended to be performed after the 35th week of life in premature infants due to the central nervous system and the development process of the auditory pathways.[14] The American Academy of Pediatrics recommends a maximum of 5% referral in hearing screenings.[6] In our study, we found the rate of infants being transferred from the screening center to the reference center to be 4.8%.

There are many risk factors that can cause hearing loss in newborns. The most frequent risk factors we identified in our study are as follows; intensive care hospitalization, hyperbilirubinemia, phototherapy, ototoxic drug use, and family history of hearing loss. If hyperbilirubinemia is not treated at the right time, it can lead to inner hairy cells, axons of spiral ganglion's neurons and/or hearing pathway of brain-stem.[15] Late-onset and progressive hearing loss are detected in babies who are admitted to the intensive care unit because of respiratory problems, due to alkalosis, hyperventilation and medications.[16] Ototoxic drugs such as aminoglycosides and loop diuretics which are used in babies who are treated in intensive care units increase the damage of cochlea which started previously.[17]

Hızlı et al. reported the results of hearing screening with the A-ABR and detected the highest risk factor as intensive care hospitalization in infants with hearing loss.[18] Even if infants with intensive care hospitalization history undergo screening, behavioral audiometry is recommended when they reach the age of one in terms of late-onset and progressive hearing loss.[19] In our study, intensive care hospitalization was the most common risk factor for hearing loss. Driscoll et al. found hearing loss in 1.43% of children with a family history of hearing loss.[20] In our study,

we detected hearing loss in three (10%) out of 30 children with hearing loss in the family. While the rate of hearing loss in healthy newborns is between 0.1-0.2%, this rate has been reported to increase to 4-5% in infants presenting with risk factors.[6] In our study, the rate of hearing loss was found to be 0.09% in infants without risk factors, while the rate of hearing loss in infants with risk factors was 4.3% ($p<0.001$).

When newborn hearing screening is not performed, the diagnosis of hearing loss takes 30 to 36 months. The early diagnosis of hearing loss in newborns facilitates the early acquisition of language, social and cognitive skills, and, consequently, normal development in terms of future academic success.[21] The American Academy of Pediatrics recommends completing hearing screening for all newborn infants within the first month of life, diagnosing those with hearing loss within three months and introducing them into training programs within six.[6] Yılmazer et al.[22] reported the age of diagnosis of 53 infants as 6.1 months and the age upon hearing aid receival as 9.5 months in their studies. In our study, it was observed that the infants referred to the reference center were diagnosed between four and 12 months (average 5.6 months) and had hearing aids administered between six and 13 months (mean 6.3 months) and included in the education programs.

CONCLUSION

It is recommended that hearing screening tests of newborns should be completed within the first month, diagnoses should be made within the first three months, and hearing aids should be administered and rehabilitation started within the first six months of life. A-ABR is a screening test which works in a short time when applied to a sleepy or calm baby. In the current study, the hearing loss ratio was found 23.2 times more in babies with risk factors comparing babies without risk factors. The most common risk factors were a family history of hearing loss and intensive care unit admission. However, for babies in the intensive care unit, as they have various risk factors and the effect of medications and interventions during hospitalization can make the reason of hearing loss more complicated.The early diagnosis and treatment of infants with hearing loss contributes to their speech-language, social and emotional development, and academic success.

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Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Dursun Mehmet Mehel, Ömer Küçüköner, Kağan Demir;* ***Design:*** *Dursun Mehmet Mehel, Doğukan Özdemir, Mehmet Çelebi;* ***Control/Supervision:*** *Mehmet Çelebi, Abdulkadir Özgür;* ***Data Collection and/or Processing:*** *Dursun Mehmet Mehel, Ömer Küçüköner, Doğukan Özdemir, Kağan Demir;* ***Analysis and/or Interpretation:*** *Dursun Mehmet Mehel, Doğukan Özdemir, Şule Özdemir, Abdulkadir Özgür;* ***Literature Review:*** *Dursun Mehmet Mehel, Samet Aydemir;* ***Writing the Article:*** *Dursun Mehmet Mehel, Ömer Küçüköner, Samet Aydemir;* ***Critical Review:*** *Mehmet Çelebi, Şule Özdemir, Abdulkadir Özgür;* ***Materials:*** *Dursun Mehmet Mehel, Ömer Küçüköner, Kağan Demir, Abdulkadir Özgür.*

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