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Newborn Hearing Screening Outcomes and Management in Our Hospital: A Cross-Sectional Study

Hastanemizde Yenidoğan İşitme Tarama Sonuçları ve Yönetimi: Kesitsel Bir Araştırma

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This study was presented as an oral presentation at 4. Otology and Audiology Congress, May 20-21, 2023, Online.

ABSTRACT Objective: It is aimed to present our newborn hearing screening algorithm and results in our region. **Material and Methods:** Hearing test results of infants who were screened and followed up at the University Hospital Newborn Hearing Screening and Reference Center between January 2021 and January 2023 were obtained by retrospective file review. The available data were analyzed and follow-up and treatment results were presented. **Results:** Automatic Auditory Brainstem Response test was performed in 4,061 babies born in our university hospital. Among the screened babies, 152 (3.7%) babies were referred to our reference center because they were unilateral or bilateral. Among these 152 (3.7%) babies, the number of babies with hearing loss confirmed by the Auditory Brainstem Response test result was 17 (0.41%). Examination of screening data for the 19 infants referred from different centers revealed hearing loss in 17 of them. Of a total of 34 infants with hearing loss, 10 were unilateral and 24 were bilateral. Of the 10 infants with unilateral hearing loss, 6 were sensorineural and 4 were conductive hearing loss and all of these infants were followed up. Of the 24 babies with bilateral hearing loss, 15 were fitted with hearing aids following confirmation of hearing loss, and 9 were followed up. **Conclusion:** This study is the first newborn hearing screening in our region and presents the rates of hearing loss in our region.

Keywords: Newborn hearing screening; automatic auditory brainstem response; hearing loss

ÖZET Amaç: Bölgemizdeki yenidoğan işitme tarama algoritmamız ve sonuçlarımızın sunulması amaçlanmaktadır. **Gereç ve Yöntemler:** Üniversite hastanesi yenidoğan işitme tarama ve referans merkezinde Ocak 2021-Ocak 2023 tarihleri arasında tarama ve takipleri yapılan bebeklerin, işitme testi sonuçları retrospektif dosya taraması ile elde edildi. Mevcut veriler incelenerek takip ve tedavi sonuçları sunulmuştur. **Bulgular:** Üniversite hastanemizde doğan 4.061 bebeğe, Tarama İşitsel Beyinsapı Cevabı testi yapıldı. Tarama yapılan bebeklerden 152 (%3,7) bebek tek veya çift taraflı kalarak referans merkezimize yönlendirildi. Bu 152 (%3,7) bebekten, İşitsel Beyinsapı Cevapları test sonucuna göre doğrulanmış işitme kayıplı bebek sayısı 17 (%0,41) idi. Ayrıca taramada sorun tespit edilerek farklı merkezlerden kliniğimize sevk edilen 19 bebeğin tarama verileri incelendiğinde, 17'sinde işitme kaybı tespit edildi. İşitme kaybı tespit edilen toplam 34 bebeğin, 10'u unilateral, 24'ü bilateraldi. Unilateral işitme kaybı olan 10 bebeğin 6'sı sensörinöral, 4'ü iletim tipi işitme kaybıydı ve bu bebeklerin hepsi takibe alındı. İşitme kaybı olan 24 bebeğin, 15'i sensörinöral işitme kaybının doğrulanmasını takiben işitme cihazı ile cihazlandırıldı, 9'u iletim tipi işitme kaybından dolayı takibe alındı. **Sonuç:** Bu çalışma, bölgemizde yapılan işitme tarama sonuçlarının değerlendirildiği ilk yenidoğan işitme taraması olup, bölgemizde işitme kaybı oranlarını sunmaktadır.

Anahtar Kelimeler: Yenidoğan işitme taraması; tarama işitsel beyinsapı cevabı; işitme kaybı

Senses play a crucial role in individuals' understanding of their surroundings, contributing significantly to their social, cognitive, and emotional development. Any issues in the auditory sense can disrupt the integrity of the perception process, leading to adverse effects on social, cognitive, and emotional aspects of life.[1,2]

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Hearing loss is the most common congenital disorder after visual impairment. When we look at the data on the number of hearing impaired in our country; 7.97% of the disabled people registered and alive in the National Disability Data System created by the Ministry of Family and Social Services are hearing impaired.[3]

Children with untreated hearing loss struggle to catch up with their hearing peers in communication, reading, cognitive, and socio-emotional development. These delays can result in lower educational attainment and vocational employment issues later in life. The goal is to minimize the negative impacts of hearing loss, thereby maximizing the language abilities and academic development of children with hearing impairment early use of hearing aids.[4,5]

The American Academy of Pediatrics recommended in 1994 that all newborns should undergo hearing screening within 30 days of birth, with detection of hearing loss within 3 months and hearing aid application within 6 months if necessary.[2-6]

Objective testing methods in infancy make it possible to detect hearing loss early. Two methods are accepted for newborn hearing screening. Initially, Automatic Otoacoustic Emission was widely used for newborn hearing screening. However, its disadvantage was the potential for inaccurate results in cases of blocked transmission and the risk of missing infants with Auditory Neuropathy Spectrum Disorder. Nowadays, the Automatic Auditory Brainstem Response (A-ABR) test, providing objective, non-invasive, and repeatable physiological measurements, is preferred in newborn hearing screenings.[7]

In our country, newborn hearing screening was first started in 1994 at Marmara University Hospital where the audiology department was located. In 2000, a protocol established between Hacettepe University and various hospitals laid the foundations for newborn hearing screening in all maternity and state hospitals in Türkiye. Since 2004, newborn hearing screening studies have been initiated nationwide.[5]

Within the scope of the national screening program implemented in some regions of our country, the prevalence of hearing loss was reported to be 0.27% in a large-scale study conducted in Ankara between 2005 and 2011, 0.1% and 3.4% in a national screening program in which healthy and high-risk newborns were screened at the Training and Research Hospital in Istanbul, and 0.54% in the Van Region.[8-10]

As there may be regional differences across the country, it is also important to analyze the data. Based on this, we aimed to share our follow-up and treatment results of infants screened at the Newborn Hearing Screening and Reference Center of the University Hospital.

MATERIAL AND METHODS

This cross-sectional study included infants born between January 2021 and January 2023 who underwent newborn hearing screening at the University Hospital Newborn Hearing Screening and Reference Center. Data were obtained by retrospective file analysis. This study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants (parents). Tokat Gaziosmanpaşa University Ethical approval was obtained from the Faculty of Medicine Clinical Research Ethics Committee (date: October 12, 2023; no: 23-KAEK-244). Data of 4,061 infants born at University Hospital, with initial screenings conducted in our clinic, and 19 infants referred to our clinic from other centers were evaluated.

Newborn hearing screenings were performed by audiologists and audiometrists working in the Ear, Nose, and Throat-Audiology Department of our hospital. In our study, the A-ABR test was conducted as the screening test for all newborns while the baby was calm and/or asleep. The A-ABR measurements yielded results of “pass” or “refer” automatically for both ears on the A-ABR device, with “pass” being the passing criterion.

The screening was conducted in three stages using the A-ABR device (MB 11 BERAphone®, MAICO Diagnostic GmbH, Berlin, Germany). In the first stage, the initial test was conducted within the first 72 hours (before the infant was discharged from the hospital). Both ears of the infants were tested, and those passing the bilateral A-ABR were considered to have passed the screening. Infants with one or both

ears remaining were scheduled for a follow-up test 1-2 weeks later. In the second stage, a retest was performed for infants with one or both ears remaining. Those passing the test bilaterally were considered to have passed the screening. Infants receiving an automatic "refer" response for one or both ears were scheduled for a follow-up within the first 30 days after birth. In the third stage, infants with one or both ears remaining were referred to our reference center for further evaluation (Figure 1).

The A-ABR test was also applied to newborns with risk factors. Infants with two consecutive "refer" responses on the A-ABR were referred to our reference center. Infants who initially passed but had risk factors were called for follow-up tests at 6 months to detect any potential late-onset hearing loss (Figure 2). Families of all screened infants were informed, warned about progressive hearing losses, and advised to consult our clinic if there were delays in their infant's language development.

Screening results were provided in writing to the families and the screening findings of the infants were recorded in the Ministry of Health Hearing Screening System.

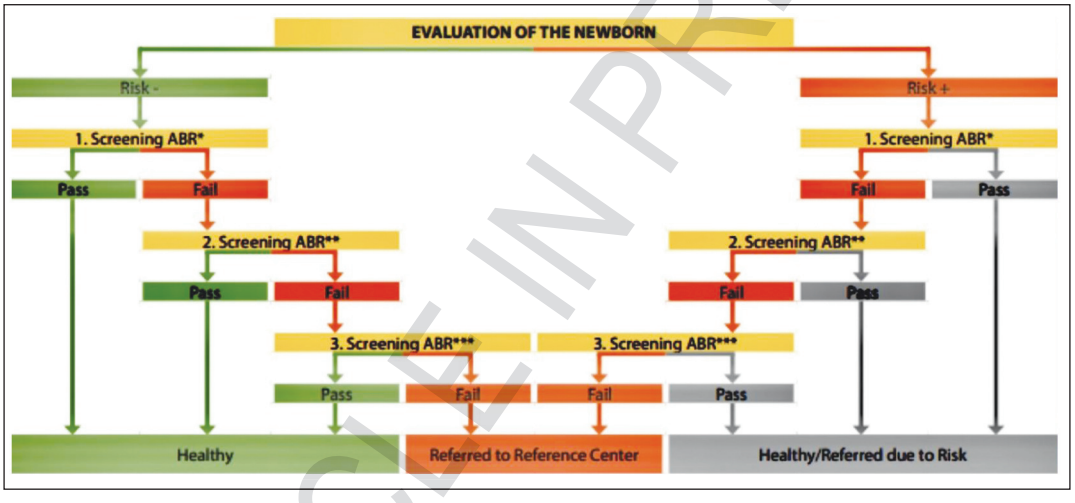

FIGURE 1: Screening ABR protocol flowchart.
ABR: Auditory Brainstem Response.
*https://hsgm.saglik.gov.tr/depo/birimler/cocuk-ergen-sagligi-db/Programlar/Guncel_Test_Protokolu_.pdf

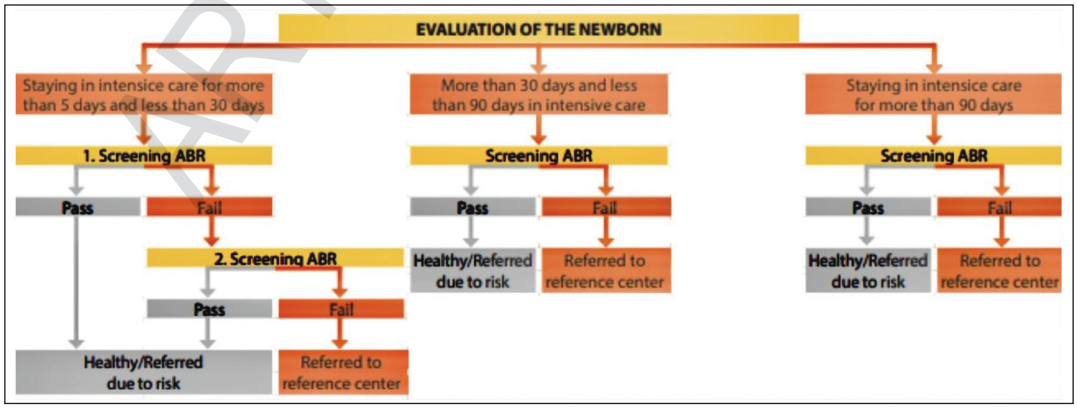

FIGURE 2: Flowchart of screening ABR protocol for infants in intensive care for more than 5 days.
ABR: Auditory Brainstem Response.
*https://hsgm.saglik.gov.tr/depo/birimler/cocuk-ergen-sagligi-db/Programlar/Guncel_Test_Protokolu_.pdf

All infants referred to the reference center underwent acoustic immitansmetry (1,000 Hz tympanometry) after otoscopic examination. In cases indicating middle ear problems acoustic immitansmetry, referrals were made to the Ear, Nose, and Throat outpatient clinic for treatment. After completing treatments, impedance audiometry was repeated. Infants with normal middle ear findings in impedance audiometry were subjected to ABR testing at our University Hospital Newborn Hearing Reference Center while the infant was spontaneously asleep or sedated (chloral hydrate). ABRs were recorded with disposable electrodes. Electrode placement was made as vertex (positive), ipsilateral and contralateral earlobe (negative) and forehead (ground). Care was taken to ensure that the electrode impedances were below 3 Kohms and the difference between the two electrodes did not exceed 0.5 Kohms. A 30-3,000 Hz band pass filter was used. Stimuli were used at a stimulus frequency of 21.1/sec. The recording window was organized to record the waves in the first 15 msec. Each recorded wave was repeated a second time. For infants with confirmed hearing loss, behavioral audiometry was performed to determine hearing thresholds. Infants with confirmed hearing loss were informed about hearing aids and rehabilitation and placed under follow-up.

RESULTS

Out of the 4,251 babies born at our university hospital, 4,061 completed their follow-ups at our clinic, while 180 had their hearing screenings done at an external facility or chose not to participate in the follow-up system; these patients were excluded from the analysis. Among the 4061 newborns evaluated, 3,280 (80.7%) passed the initial test, 780 (19.2%) were retested, and 632 (15.6%) received a "pass" response on the second test. 148 (3.6%) of the infants failed both screening tests. Together with those referred without testing, 152 (3.7%) of the infants were recommended for assessment at the reference center.

Among the infants referred to our reference center, 2 (0.05%) did not present to our center. ABR testing was conducted for infants referred to our reference center from the 4,061 infants included in the study, and hearing loss was confirmed in 0.41% of the infants. Of these infants, 13 were male and 4 were female.

Hearing loss was detected in 13 (0.32%) of the infants bilaterally and in 4 (0.09%) unilaterally. Among the infants with unilateral hearing loss, 2 had mild, 1 had moderate, and 1 had profound hearing loss. Among the 13 infants with bilateral hearing loss, 10 ears had mild, 9 had moderate, 1 had moderately severe, and 6 had profound hearing loss (Figure 3).

Sensorineural hearing loss was observed in 13 (0.32%) of the infants, and conductive hearing loss was found in 4 (0.09%). Among the sensorineural hearing loss cases, 2 (0.05%) were unilateral and 11 (0.27%) were bilateral. Among these infants, 10 received hearing aids, 1 received a cochlear implant, and 2 were placed under follow-up. Among the conductive hearing loss cases, 2 (0.05%) were unilateral, and 2 (0.05%) were bilateral. All four infants with conductive hearing loss were placed followed up (Figure 4).

Looking at the risk factors of infants referred to our reference center with confirmed hearing loss, 15 out of 17 infants (0.36%) had risk factors, while 2 (0.05%) did not. Infants with risk factors were observed to have multiple risk factors in some cases. The risk factor history of infants included 10 with intensive care, 2 with maternal diseases, 5 with a family history of hearing loss, 1 with ear tag, 6 with ototoxic drug use, 1 with cerebral complications, 3 with cleft palate and lip, 1 with hyperbilirubinemia requiring blood exchange and 1 with a history of mechanical ventilation treatment for 5 days or more.

Analyzing the screening data of the 19 infants referred to us from other centers, hearing loss was confirmed in 17 of them. Eleven of the babies with hearing loss were bilateral and six were unilateral.

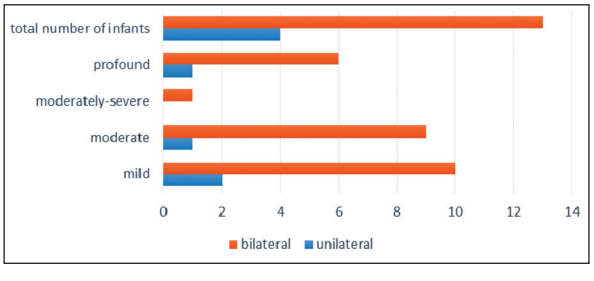

FIGURE 3: Distribution of unilateral and bilateral hearing loss according to degree.

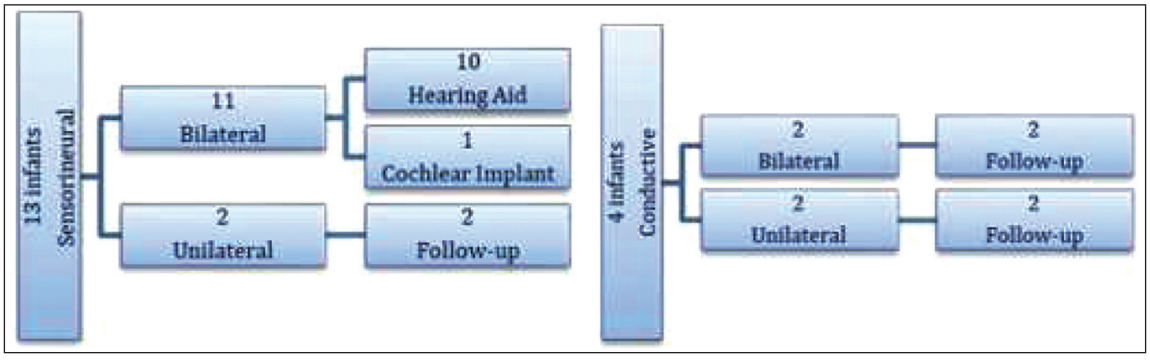

FIGURE 4: Type of hearing loss, direction of hearing loss and treatment applied.

Among the infants with bilateral hearing loss, 4 were fitted with hearing aids after confirmation of sensorineural hearing loss and 7 were followed up for conductive hearing loss. Among infants with unilateral hearing loss, 2 infants with conductive and 4 infants with sensorineural hearing loss were followed up.

DISCUSSION

In European countries, routine newborn hearing screenings within the framework of national health policies have been conducted since 1998. In Türkiye, these screenings began in 2000 at Ankara Etlik Zubeyde Hanım Women's Health Training and Research Hospital.[11] Initially, newborn hearing screenings were limited to newborns with risk factors, but later extended to all newborns.[12]

The frequency of congenital hearing loss in healthy newborns is approximately 0.1-0.6%, varying by country.[9,10] In neonatal intensive care units, the incidence of congenital hearing loss ranges from 2% to 4%.[9] Studies indicate a high rate, up to 10%, of sensorineural hearing loss in at-risk infants, with the cochlea being affected in most risk factors.[13]

About 50% of congenital hearing losses are genetic, with approximately 77% showing autosomal recessive inheritance. In Türkiye, 94% of genetic hearing losses exhibit autosomal recessive inheritance, a result of consanguineous marriages.[14] The high prevalence of autosomal recessive inheritance underscores the importance of consanguinity in the causes of hearing loss.[13] Examining the reasons for hearing loss in newborns in our country reveals that a family history of hearing loss and consanguineous marriage are the primary factors. Even in regions like Marmara and the Aegean, where consanguinity rates reach 17-20%, these rates are significantly higher than in the US and North European countries, where they range from 1-2%.[7] Bilateral hearing loss is more common than unilateral, and if unilateral hearing loss goes unnoticed in screening, it becomes more challenging for families to detect.[15] Following newborn hearing screenings, the incidence of congenital bilateral hearing loss ranges from 0.13-0.60%, and unilateral hearing loss ranges from 0.17-0.38%.[16]

In a successful newborn hearing screening program, it is essential to screen at least 95% of infants, have a false positive rate of less than 3%, a referral rate of less than 4%, a zero false negative rate, and conduct the screening before the newborn is discharged from the hospital.[12]

Reviewing the literature, the rate of infants failing the initial newborn hearing screening test is reported to be between 5-20%. The test results can be influenced not only by hearing loss but also by debris in the external ear canal, vernix caseosa, and amniotic fluid.[9,17]

In infants screened with A-ABR, we found a retention rate of 19.3% in the first test and 3.6% in the second test. Looking at other studies in a study by Kılıçaslan et al. involving 52,338 newborns, they reported a retention rate of 3.6% in the first test and 0.5% in the second and third tests, noting that the first test's retention rate was lower than in other studies (Figure 5).[10,12,18-23] Overall, studies suggest a range of

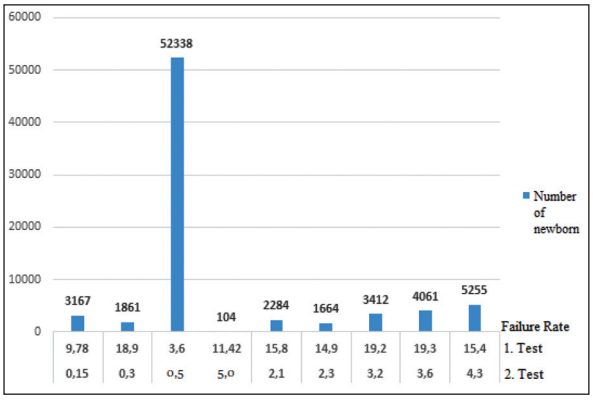

FIGURE 5: Percentages of failing screening tests in some studies.
Studies (years) from left to right; Aricigil et al. (2011-12), Özkurt and Özdoğan (2010-11), Kilicaslan et al. (2012-15), Rechia et al. (2012-13) (intensive care), (Karaca et al. (2009-12), Susaman et al. (2014-15), Oguzhan et al. (2012-13), In our study (2021-22), Demir and Sizer (2020).

2-7% for infants failing the newborn hearing screening test.[7] While our results align with the literature, the slightly higher rate of infants failing the initial test in our study is believed to be due to infants being hungry, restless, or not yet cleaned, impacting their ability to undergo the tests.

In our study, we determined a referral rate to the reference center of 3.7%. Analyzing the screening data of the 19 infants referred to us from other centers, hearing loss was confirmed in 17 of them. We think that this high rate of hearing loss is due to multiple risk factors in referred newborns. Comparing this with other studies Aliosmanoğlu et al. identified a high referral rate of 16.2% in a maternity hospital in Diyarbakır, explaining the elevated rate due to the lack of an Ear, Nose, and Throat specialist consultation within the hospital.[25] Our study's referral rate aligns similarly with these findings (Table 1).[9,10,12,15,23-25]

In the international literature, rates of congenital hearing loss screened through newborn screening programs vary between 0.13-0.60%, with regional differences observed. Studies such as Genç et al. at Hacettepe University reported 0.20% in 5,485 newborns, Ulusoy et al. found 0.19% (sensorineural), Kucur et al. found 0.15% (sensorineural) in a women's hospital screening 11,053 newborns, and in a study including infants in the intensive care unit in the Van region with high consanguinity rates, a rate of 0.52% was reported.[17,24,26,10] In Izmir, 711 newborns were screened, resulting in 0.42% (0.14% Newborn+0.28% Neonatal Intensive Care).[27] In 2013, with approximately 1.3 million live births in Türkiye, an average of 0.2% congenital hearing loss was reported.[28] Other national studies reported rates of 0.18% and 0.28%.[11] Rechia et al. found a 0.71% rate in newborns in intensive care due to risk factors.[23] Türkmen et al. reported a 0.12% rate of severe sensorineural hearing loss in infants born in their hospitals and a 2.1% rate in referred infants. This high rate was attributed to their hospital being a tertiary referral center, with approximately 70% of incoming infants having high-risk factors.[13] In a one-year screening program by Güvey et al. in Sakarya province, the lowest hearing loss rate of 0.07% was observed in all private and state hospitals.[29] Our study found a hearing loss rate of 0.41% in infants born in our hospital from 2021 to 2023, consistent with the literature, as we evaluated all infant data without making a distinction between newborns and those in neonatal intensive care.

TABLE 1: Referral rates in some regions in our country.

Regions	Years	Number	Referral rate
İstanbul	2009-11	5,985 newborn	0.1% (healthy) 3.4% (high risk)
Van	2012-15	52,338 newborn	0.54%
Mardin	2020	5,255 newborn	4.31%
Turkish National Newborn Hearing Screening Program	2004-8	764,352 newborn	0.17%
Western Türkiye (Çorlu and neighboring provinces)	2009-12	11,575 newborn	5.12%
Diyarbakır	2010-11	2,363 newborn	16.2%
In our study	2021-22	4,061 newborn	3.7%

TABLE 2: Bilateral and unilateral percentages of hearing loss diagnosed in some studies conducted in our country.

Studies	Number	Bilateral	Unilateral
Demir and Sizer[12]	5,255 newborn	0.17%	0.07%
Bolat et al.[15]	337,690 newborn	0.12%	0.09%
Yılmazer et al.[9]	5,116 newborn (healthy+high risk)	0.23%	0.02%
Başar et al.[11]	638 newborn (healthy)	1%	0.2%
	236 newborn (intensive care)	2%	0.2%
In our study	4,061 newborn	0.32%	0.09%

When examining rates of bilateral and unilateral hearing loss in studies Başar et al. found higher rates in their study with 1% bilateral and 0.2% unilateral hearing loss in 638 newborns from the Neonatal Unit, and 2% bilateral and 0.2% unilateral in 236 newborns from the Neonatal Intensive Care Unit (Table 2).[9,11-12,15,17] They attributed the higher rate to the distribution of multiple risk factors in hearing-impaired infants in their study.[11] According to the World Health Organization's 2009 report on hearing loss, rates in Brazil and Sweden were 0.1% bilateral, China had 0.5% unilateral and 0.1-0.3% bilateral, Germany reported 0.07% unilateral and 0.16% bilateral, Serbia had 0.03% unilateral and 0.01% bilateral, and the United States mentioned 0.045% unilateral and 0.105% bilateral in Colorado, while in Washington, it was 0.183% bilateral.[10] Our results, with 0.32% bilateral and 0.09% unilateral hearing loss in newborns, align with findings in other studies in the literature.

In our study, among the 17 newborns with confirmed hearing loss, 15 (0.36%) had risk factors, while 2 (0.05%) had no identified risk factors. A-ABR tests were conducted on 156 patients who remained Hızlı and Sivrikaya otoacoustic emissions test, and 66 of them failed the test. Previous research has identified low birth weight, preterm birth, and receiving postnatal intensive care as high-risk factors for newborn hearing loss.[30] In Kamran's study, among 13 newborns with confirmed hearing loss, 11 had risk factors, and the rate of a family history of hearing loss in newborns was found to be 5%.[7] Türkmen and colleagues found that approximately 70% of newborns referred to their hospital had risk factors, and these newborns had a high rate of hearing loss (2.1%).[13] Ulusoy and colleagues identified a family history of hearing loss in 10 out of 22 newborns with sensorineural hearing loss.[24] Increased awareness among healthcare professionals regarding careful questioning of patients about these risk factors and their inclusion in long-term follow-up programs is crucial. This is a vital step to ensure early diagnosis and effective treatment.

In a study conducted in our country regarding the time of diagnosis and intervention for infants, the average age for diagnosed infants was 7.4 months, while for infants fitted with hearing devices, it was 9.6 months.[13] These results indicate that hearing-impaired infants in our country still receive diagnoses and rehabilitation later than the recommended time by the American Academy of Pediatrics. Factors such as low awareness among families and healthcare providers, low socioeconomic status of families, and limited diagnostic and intervention services can contribute to delays in diagnosis and hearing aid fitting.[9]

In our study, we presented the results of newborn hearing screening between 2021 and 2023. Limitations of the study include the exclusion of a broader time frame due to archival gaps in previous years, as well as the lack of presentation of data on the age of diagnosis and device fitting due to insufficient archiving.

Since the opening of University Hospital Newborn Hearing Screening and Reference Center, it has served as a top center with a well-equipped team that consistently maintains monitoring and archiving for referred infants from surrounding provinces, as well as infants from its own center.

CONCLUSION

In individuals with hearing loss, newborn hearing screening is crucial for them to demonstrate performance in developmental areas similar to their peers

and benefit from the critical period important for maturation. Early diagnosis of untreated moderate hearing loss and recommendation of hearing aids will enhance the academic success of individuals. Early access to technologies such as cochlear implants for children with severe and profound hearing loss yields positive results in terms of language and speech. Newborn hearing screenings also allow for the early diagnosis of inner ear anomalies that may hinder a child's benefit from hearing aids, enabling timely interventions.[31,32]

Our screening results are presented to clearly determine whether the goals supported by the American Academy of Pediatrics have been achieved in our region. This study is the first newborn hearing screening study evaluating hearing screening results in …….. province in the Black Sea Region. Although our referral rates to the reference center are high, the rate of hearing loss is similar to other centers and provides important information about our region.

This study could make significant contributions to the literature and help assess the effectiveness of efforts to improve early diagnosis and access to treatment for children with hearing loss.

MAIN POINTS

This study is the first newborn hearing screening study evaluating the results of hearing screenings conducted in our region.

Ensuring no untreated hearing loss in children, integrating hearing-impaired individuals into society, promoting their productivity, and reducing the overall costs of hearing loss for both individuals and society are achievable through newborn hearing screening.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

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: *Meriç Yıldız;* ***Design:*** *Meriç Yıldız;* ***Control/Supervision:*** *Elif Kaya Çelik;* ***Data Collection and/or Processing:*** *Meriç Yıldız;* ***Analysis and/or Interpretation:*** *Meriç Yıldız;* ***Literature Review:*** *Meriç Yıldız;* ***Writing the Article:*** *Meriç Yıldız, Elif Kaya Çelik;* ***Critical Review:*** *Elif Kaya Çelik;* ***References and Fundings:*** *Elif Kaya Çelik;* ***Materials:*** *Meriç Yıldız.*

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