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Research Article

Screening for Abnormal Hearing in Newborns and Assessment of High-Risk Group

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Abstract

Objective: This study analyzed the risk factors for abnormal hearing in newborns in rural areas of Istanbul. In order to determine the risk factors, the medical records of newborns with abnormal hearing were compared to newborns with normal hearing.

Methods: Bilateral Otoacoustic Emissions (OAE) was performed on the third day of life, and each ear was tested at least twice in all newborns. If OAEs were obtained, the newborn was considered to have a normal hearing level. If no signal was obtained from the cochlea or the newborn had at least one or more risk factors, an Auditory Brainstem Response (AABR) analysis was performed. The high risk factors were assessed according to the 2007 Joint Committee on Infant Hearing's definition.

Results: A total of 20,500 newborns screened for abnormal hearing were analyzed retrospectively between 2007 and 2009. Auditory brainstem response was performed in 1,300 newborns who failed the OAE test and/or had risk factors. Of these, 1,068 newborns with complete data were analyzed. Thirty babies with confirmed abnormal hearing and 1,038 babies with normal AABR test results were compared in terms of descriptive characteristics and risk factors. While the rate of preterm birth was significantly lower in the newborns with abnormal hearing, the rates of consanguineous marriage, family history for abnormal hearing, exchange transfusion, hydrocephalus, and hydrocephalus with shunt, convulsion, cytomegalovirus infection, meningitis, and hearing loss-related syndromes were significantly higher in the newborns with abnormal hearing.

Conclusions: Screening newborns for abnormal hearing should definitely be performed to prevent potential future problems. Newborns without risk factors should also be included in screening procedures.

Keywords: Newborn; Abnormal hearing; Auditory brainstem response; Otoacoustic emission

Introduction

Congenital or early childhood onset of deafness or severe-to-profound hearing impairment, as reported by the World Health Organization (WHO), is encountered in approximately 0.5–5 per 1,000 neonates and infants [1]. Early diagnosis of abnormal hearing may prevent severe educational, linguistic, and psychosocial repercussions [2]. Therefore, screening for early detection of congenital abnormal hearing is absolutely recommended not only in the high-risk group but in all newborns [3,4]. Most countries have national screening programs within this context or are preparing for extensive implementation by means of studies being carried out in pilot regions [1-4]. Although the etiology of congenital or early-onset abnormal hearing varies among countries, genetic mutations are the most commonly accepted reason. In addition to hereditary abnormal hearing, a number of intrauterine and neonatal conditions, including infections, birth asphyxia, low birth weight, hyperbiliribunemia, and trauma, are other predisposing factors [1]. A clinical diagnosis of hearing is not possible in early years of life, so Otoacoustic Emission (OAE) and Auditory Brainstem Response (AABR) are the most effective and most performed methods for abnormal hearing screening in newborns [3,4].

This study to analyze all of the risk factors for abnormal hearing and to evaluate the incidence of abnormal hearing in high-risk newborns in rural areas of Istanbul. Further motivation for this study was elaborating on how the rate of hearing loss or risk factors may differ in the rural areas around Istanbul from other countries. For this purpose, a two-stage screening procedure was applied to all newborns: first OAE was applied to all subjects, and AABR was applied to those who were unable to pass OAE and/or had risk factors.

Materials and Methods

A total of 20,500 newborns were evaluated and screened for hearing function in the Pediatric Department of Istanbul, Bakirkoy Maternity and Children's Hospital between 2007 and 2009.

The ethics committee of our hospital gave its approval, and all of the patients' parents gave their written informed consent. Hearing tests were performed in the hospital in an independent and silent room by two audiometric technicians. Bilateral Transient-

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Table 1: Characteristics of the newborns with and without hearing loss.

Undergoing ABR (Preterm and Term) (N:1068)				
Hearing loss				
Total		No (N=1038)	yes (N=30)	p
Preterm (<37 weeks)	717	708 (%68.2)	9 (%30.0)	0.001
Ototoxic drug use***	611	596 (%57.4)	15 (%50.0)	0.418
Phototherapy-requiring hyperbilirubinemia	484	475 (%45.8)	9 (%30.0)	0.126
Sepsis	283	275 (%26.5)	8 (%26.7)	0.983
Very low birth weight (<1500g)	251	246 (%23.6)	5 (%16.7)	0.370
Mechanical ventilation	216	208 (%20.0)	8 (%26.7)	0.247
History of multiple pregnancy	174	170 (%16.4)	4 (%13.3)	0.656
Respiratory distress syndrome	151	149 (%14.4)	2 (%6.7)	0.233
Meningitis	76	71 (%6.8)	5 (%16.7)	0.039
Intraventricular hemorrhage	67	64 (%6.2)	3 (%10.0)	0.393
Consanguineous marriage	50	46 (%4.4)	4 (%13.3)	0.023
Bronchopulmonary dysplasia	45	44 (%4.2)	1 (%3.3)	0.808
Convulsion	20	17 (%1.6)	3 (%10.0)	0.001
Meconium aspiration syndrome	20	20 (%1.9)	0 (%0.0)	0.443
Syndromes**	20	18 (%1.7)	2 (%6.7)	0.049
Periventricular leukomalacia	16	16 (%1.5)	0 (%0.0)	0.493
Perinatal asphyxia	12	12 (%1.2)	0 (%0.0)	0.554
Craniofacial anomalies	11	10 (%1.0)	1 (%3.3)	0.205
Family history of hearing loss	10	4 (%0.4)	6 (%20.0)	0.001
Hydrocephalus	9	7 (%0.7)	2 (%6.7)	0.001
Exchange transfusion	8	6 (%0.6)	2 (%6.7)	0.001
Hydrocephalus with shunt	3	2 (%0.2)	1 (%3.3)	0.001
TORCH*	3	0 (%0)	3 (%10)	0.001
Pulmonary hypertension	2	2 (%0.2)	0 (%0.0)	0.810

One patient has one or more risk factors. TORCH: Toxoplasmosis, rubella, cytomegalovirus, herpes simplex.*Cytomegalovirus infection in three infants, **Down syndrome in 18 and Pierre Robin syndrome in 2 infants, ***Use of Amikacin in 607 and gentamycin in 4 infants.

Evoked Otoacoustic Emissions (TEOAEs) were recorded on the third day of life, and each ear was tested at least twice in all healthy newborns regardless of risk factors. Depending on the general status of the infants, those that spent time in the intensive care unit were screened within several weeks. Every newborn was tested at 2 and 4 kHz frequencies at a Sound Pressure Level (SPL) of 85 dB using OAE through the technical specifications of devices. If signals were obtained, the infant was considered to have a normal hearing level. Due to limited facilities, AABR analysis was only performed on infants who did not pass the TEOAE analysis or in newborns with risk factors. All AABR measurements were performed with an AABR device (Madsen Accuscreen Pro; Madsen-GN Otometrics, Taastrup, Denmark) using a 35 dB click stimulus. No medication was used for sedation before the test. Screening for abnormal hearing was performed during the newborns' natural sleep. AABR analysis was performed at least three times if there was no signal. Newborns who failed the AABR test were referred to a tertiary hospital for further investigation.

Newborns who had at least one risk factor were included in our study. The risk factors were assessed according to the Joint Committee on Infant Hearing's definition (JIHC) definition: ototoxic drug use, phototherapy-requiring hyperbilirubinemia, sepsis, mechanical ventilation, history of multiple pregnancy, meningitis, bronchopulmonary dysplasia, convulsion, syndromes, periventricular leukomalacia, craniofacial anomalies, family history of hearing loss, hydrocephalus, exchange transfusion, hydrocephalus with shunt, and pulmonary hypertension [5]. Other risk factors for abnormal hearing that were not listed by the JCIH were also evaluated, including consanguineous marriage, meconium aspiration syndrome, preterm birth (< 37 weeks), very low birth weight (< 1500g), perinatal asphyxia, respiratory distress syndrome, and intraventricular hemorrhage.

Statistical Analysis

Data were analyzed using the Number Cruncher Statistical System 2007 (NCSS, Kaysville, UT, USA) and the Power Analysis and Sample Size 2008 (PASS, Kaysville, UT, USA). In addition to descriptive statistical methods (mean, standard deviation, frequency, and ratio), the chi-square test and Fisher's exact chi-square test were used to compare the qualitative data. The significance level was set at $p < 0.05$. The same newborn was not included more than one time in the statistical analysis for detecting the p-value.

Results

A total of 20,500 newborns between 2007 and 2009 were included in our study. AABR was performed in 1,068 newborns with complete data; this was included in the analysis. Of these newborns, 50.8% (n = 548) were boys, and 33.7% (n = 364) were born vaginally. Distribution of the risk factors in the infants undergoing AABR is presented in (Table 1). Of the 1,068 newborns who underwent AABR, 2.2% (n = 24) had unilateral abnormal hearing, while 2.6% (n = 28) had bilateral abnormal hearing. These 52 newborns with abnormal hearing were referred to a tertiary hospital to establish a definite diagnosis. Of the 52 cases evaluated in a tertiary hospital, 22 had normal hearing and 30 had abnormal hearing. The rate of exact abnormal hearing was 2.9% in the 1,068 newborns who underwent AABR.

Thirty babies with confirmed abnormal hearing and 1,038 babies with normal AABR test results were compared in terms of descriptive characteristics and risk factors (Table 1). The rate of preterm birth was significantly lower in the newborns with abnormal hearing. However, meningitis, rates of consanguineous marriage, convulsion, hearing loss-related syndromes, family history of abnormal hearing, hydrocephalus, exchange transfusion, hydrocephalus with shunt, and TORCH (toxoplasmosis, rubella, cytomegalovirus, herpes simplex, human immunodeficiency virus) were significantly higher in the newborns with abnormal hearing ($p < 0.05$). There were no significant differences between the groups in terms of other risk factors.

The majority (70%) of the newborns with abnormal hearing were term newborns. In order to assess the risk factors for abnormal hearing in term newborns, the term newborns with abnormal hearing (n = 21) were compared to the term newborns with normal hearing (n = 330) (Table 2). The rates of consanguineous marriage, convulsion, exchange transfusion, family history of abnormal hearing, and TORCH (CMV infection) were significantly higher in the term newborns with abnormal hearing. In the newborns with abnormal hearing, the rate of phototherapy-requiring hyperbilirubinemia was lower. Because the number of preterm infants with abnormal hearing was quite low, comparisons between the term newborns with abnormal hearing and those without could not be performed.

There were no significant differences between the newborns with and without abnormal hearing in terms of the number of risk factors ($p > 0.05$) (Table 3).

Table 2: Characteristics of term newborns with and without hearing loss.

Undergoing ABR (term)			
Hearing loss			
	No (n=330)	Yes (n=21)	P
Phototherapy-requiring hyperbilirubinemia	176 (%53.7)	4 (%20.0)	0.003
Ototoxic drug use	65 (%19.7)	8 (%38.1)	0.054
Sepsis	54 (%16.4)	4 (%19.0)	0.748
Meningitis	44 (%13.3)	3 (%14.3)	0.901
Meconium aspiration syndrome	19 (%5.8)	0 (%0.0)	0.729
Mechanical ventilation	16 (%4.9)	1 (%4.8)	0.438
Consanguineous marriage	14 (%4.2)	4 (%19.0)	0.003
Syndromes	9 (%2.7)	1 (%4.8)	0.587
Convulsion	7 (%2.1)	3 (%14.3)	0.001
History of multiple pregnancy	7 (%2.1)	0 (%0.0)	0.500
Craniofacial anomalies	6 (%1.8)	1 (%4.8)	0.349
Exchange transfusion	5 (%1.5)	2 (%9.5)	0.011
Family history of hearing loss	3 (%0.9)	4 (%19.0)	0.001
Respiratory distress syndrome	4 (%1.2)	0 (%0.0)	1.000
Pulmonary hypertension	2 (%0.6)	0 (%0.0)	1.000
Perinatal asphyxia	1 (%0.3)	0 (%0.0)	1.000
Bronchopulmonary dysplasia	1 (%0.3)	0 (%0.0)	1.000
Intraventricular hemorrhage	0 (%0.0)	1 (%4.8)	0.060
Hydrocephalus	0 (%0.0)	1 (%4.8)	0.060
TORCH	0 (%0.0)	3 (%14.3)	0.001

Data are presented as number (%).
TORCH: Toxoplasmosis, rubella, cytomegalovirus, herpes simplex.

Discussion

The JCIH published the risk factors for abnormal hearing in 2007 [5]. Some studies have suggested that criteria other than those defined by the JCIH are also risk factors for abnormal hearing and that risk-based screening may miss the diagnosis of some cases [6-9]. In our study, in addition to the JCIH's criteria, other risk factors such as very low birth weight, respiratory distress syndrome, pulmonary hypertension, bronchopulmonary dysplasia, meconium aspiration syndrome, periventricular leukomalacia, intraventricular hemorrhage, hydrocephalus, and convulsion were also evaluated.

The prevalence of abnormal hearing in newborns has been reported as 1–3/1,000 [10,11]; it has been reported as 20–40/1,000 in infants with a history of intensive care treatments [11]. Similarly, 30 out of 20,500 newborns who were screened for abnormal hearing (1.5/1,000) and 27 out of 1,270 newborns who have risk factors (21/1,000) had abnormal hearing in our study.

Bielecki et al. [12] reported that the syndromes associated with abnormal hearing and mechanical ventilation exceeding five days were significant risk factors for abnormal hearing in newborns. They also reported that the most common risk factors were ototoxic drug use, premature birth (< 34 weeks), low birth weight (< 1500g), and an intensive care stay of more than seven days. Ohl et al. performed hearing screening procedures on newborns with risk factors (n = 1,461). The related risk factors for sensorineural abnormal hearing were reported as severe birth asphyxia, neurological disorder, syndromes known to be associated with abnormal hearing, TORCH infections, and family history of deafness [13]. However, they reported that low birth weight (< 1500g) and premature birth (< 34 weeks) were not associated with abnormal hearing [13]. In Turkish literature, the related risk factors for sensorineural abnormal hearing were ototoxic drug use, premature birth, low birth weight and intensive care stay [14,15]. Similar to these studies, in our study, the most common risk factors were preterm birth (67%), ototoxic drug use (56.6%), hyperbilirubinemia (45.1%), sepsis (26.5%), and low birth weight (23.7%). Risk factors significantly associated with abnormal hearing were consanguineous marriage, family history of abnormal hearing, exchange transfusion-requiring hyperbilirubinemia, hydrocephalus, convulsion, CMV infection, meningitis, and hearing loss-related syndromes. Consanguineous marriage, family history of abnormal

Table 3: Comparison of the newborns with and without hearing loss in terms of number of risk factors.

Number of risk factors	Hearing loss		P
	No (n=1038)	Yes (n=30)	
≥2	773 (%74.5)	21 (%70.0)	0.580
≥3	559 (%53.9)	13 (%43.3)	0.255
≥4	353 (%34.0)	9 (%30.0)	0.648
≥5	180 (%17.3)	5 (%16.7)	0.923
≥6	70 (%6.7)	3 (%10.0)	0.486

hearing, exchange transfusion-requiring hyperbilirubinemia, convulsion, and CMV infection were found to be significant risk factors in term newborns, who accounted for the majority of the newborns with abnormal hearing in our study.

Studies have reported that abnormal hearing is common in preterm infants [16,17]. However, some studies have found no significant difference between term and preterm groups [18,19]. Nevertheless, the rate of abnormal hearing was lower in preterm newborns undergoing AABR as compared to that in term newborns (1.3% *vs.* 6.0%, p = 0.001). This might be due to improved intensive care and perinatal care conditions. Additionally, the term newborns in our study had risk factors. Low birth weight is another important risk factor for abnormal hearing [20,21]. However, in certain studies, low birth weight has not been found to be a risk factor [7,19-21]. In our study, most of the newborns with abnormal hearing weighed more than 1500g. Nevertheless, no significant difference was found between the groups with and without abnormal hearing in terms of the rate of infants born weighing less than 1500g.

In our study, the rate of consanguineous marriage was significantly higher in the newborns with abnormal hearing compared to those without (13.3% *vs.* 4.4%, p = 0.023). Consanguineous marriage is quite common in Turkey [22]; thus, consanguineous marriage might be the main risk factor in the current study population. Since the rate of consanguineous marriage is very low in developed countries, this would probably not be determined as a risk factor for abnormal hearing. Another interesting result in the present study is that all of the cases with abnormal hearing due to consanguineous marriage or family history were bilateral.

Hyperbilirubinemia is known to be a risk factor for abnormal hearing [4]. It has been reported that severe hyperbilirubinemia primarily causes retrocochlear damage, and OAE testing alone is not adequate in these babies [23]. In the present study, the rate of phototherapy-requiring hyperbilirubinemia did not differ between the newborns with and without abnormal hearing. However, the rate of exchange transfusion due to hyperbilirubinemia was significantly higher in the infants with abnormal hearing (6.7% *vs.* 0.6%, p = 0.001). This result supports the results of previous studies that found that infants with exchange transfusion-requiring hyperbilirubinemia ran the risk of abnormal hearing [24].

The auditory nucleus, located in the brain stem, is very sensitive to hypoxia. Perinatal asphyxia is an important risk factor for abnormal hearing [25]. The present study found no difference between newborns with and without abnormal hearing in terms of the rate of perinatal asphyxia. In some studies, respiratory problems such as respiratory distress syndrome, bronchopulmonary dysplasia, and meconium aspiration syndrome have been suggested to be risk factors for abnormal hearing [7,8]. The present study found no significant difference between the newborns with and without abnormal hearing in terms of respiratory system parameters.

There are studies suggesting intraventricular hemorrhage as a risk factor [26], as well studies that argue the opposite [19]. In the present study, the rate of intraventricular hemorrhage did not differ between the newborns with and without abnormal hearing. Moreover, we found that infants with hydrocephalus ran the risk of abnormal hearing, which is similar to the study by Lieu et al. [8]. However, Kountakis et al. [7] reported that hydrocephalus was not a risk factor for abnormal hearing. Neonatal convulsions have been reported to be risk factors for abnormal hearing [27]. In the present study, the rate of convulsion was found to be significantly higher in the newborns with abnormal hearing compared to those without (10.0% *vs.* 1.6%, p = 0.001).

Bao and Wong [28] found the frequency of abnormal hearing in bacterial and aseptic meningitis to be 34.6% and 20.9%, respectively. In our study, the rate of meningitis was significantly higher in newborns with abnormal hearing as compared to that in those without abnormal hearing (16.7% *vs.* 6.8%, p = 0.039).

CMV infection has been reported as one of the most important risk factors for abnormal hearing in infants [27-29]. In our study, three of the infants with abnormal hearing had CMV infection. The rate of CMV infection was significantly higher in the newborns with abnormal hearing.

Ototoxic drug use is another well-known cause of abnormal hearing [26]. In our study, ototoxic drug use was present in 56.6% of the babies. However, the rate of ototoxic drug use did not differ between the newborns with and without abnormal hearing. This might be due to the use of amikasin, which is a less ototoxic drug, is used in short duration, and has increased intervals between doses according to weight. Syndromes and craniofacial anomalies are other important risk factors for abnormal hearing [7,26]. However, in our study, the rate of craniofacial anomaly did not differ between the newborns with and without abnormal hearing.

Overall, we did not find a significant difference between the newborns with and without abnormal hearing in terms of the number of risk factors.

In conclusion, the risk factors of consanguineous marriage, family history of abnormal hearing, exchange transfusion-requiring hyperbilirubinemia, hydrocephalus, convulsion, CMV infection, meningitis, and the presence of a syndrome were found to be significantly associated with abnormal hearing. Screening for abnormal hearing should be performed in all newborns to prevent potential future problems.

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