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Early detection of hearing impairment in neonates with dual/multiple toxoplasma, rubella, cytomegalovirus infections: a cross-sectional study

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Abstract

Introduction: Hearing impairment is often associated with pregnancy infections such as Toxoplasma, Rubella, Cytomegalovirus (TORCH). **Objective:** To determine the prevalence of hearing impairment using Otoacoustic Emissions (OAE) and to analyze the associated risk factors in neonates with dual/multiple TORCH infections. **Methods:** This cross-sectional study was conducted from September to November 2019. Infants admitted to the intermediate room during the study period were included in the study and underwent OAE testing to evaluate for hearing impairment. Infants with OAE refer tested with TORC examination. Prevalence of hearing impairment with dual/multiple TORC infections was calculated, and the Odds Ratio for specific risk factors was measured using Fisher's exact test. **Results:** Over the period, 50 babies were screened. Forty-three babies (86%) presented with normal hearing on OAE testing. Seven babies (14%) responded to OAE referral. Out of 7 infants, one infant classified as OAE refer had early discharge, and the six of them underwent TORC examination. Of the 6 infants, 5 had dual or multiple TORCH infections. By univariate analysis, the highest risk factor for hearing impairment and dual/multiple TORC infection was the premature rupture of membranes, OR 41; 95% CI 3,65–46,03. Correlation between dual/multiple TORC infection and hearing impairment was statistically significant, p = 0.001, R = 0.826. **Conclusion:** The incidence of hearing impairment among neonates in our study is almost similar to that in the previous study. Eighty percent of them had dual/multiple TORC infections. The premature rupture of the membrane is the commonly associated risk factor in this study.

Keywords: Neonates. Hearing impairment. TORC. Risk factors.

Introduction

Hearing impairment in neonates is a common condition with serious effects on the development of speech, language, cognitive, and social skills. The Indonesian Health Surveys (1993-1996) in 8 provinces reported a prevalence of 0.4% for deafness and 16.8% for hearing loss [1]. An easy, fast examination method is needed to recognize the disorder earlier. Hearing impairment is often associated with infections during pregnancy, including toxoplasmosis, rubella, and cytomegalovirus (CMV) (TORC) [2].

Hearing screening is practically important because 50% of newborns with risk factors can develop hearing loss from birth. Based on these considerations, efforts to detect hearing loss in infants early are carried out through the Newborn Hearing Screening (NHS) program. OAE and Automated Auditory Brainstem Response (AABR) tests are the gold standards for early detection of hearing loss in infants [2].

There is no clear data about the relationship between toxoplasmosis and the incidence of hearing loss. In rubella infection can cause hearing loss with the degeneration process of the organ Corti, the process of adhesion between the Corti and Reissner membranes, causing partial or complete strophy

atrophy and a degeneration process of the nerve elements, whereas CMV infection in pregnant women has a 40% chance of transmitting to the fetus which can cause congenital abnormalities in the fetus including congenital deafness **[3]**. Therefore, this study was conducted to determine the importance of early detection of congenital deafness in neonates with dual/multiple TORC infection in Dr. Soetomo Hospital Surabaya.

Materials and Methods

This research used a cross-sectional study from September to November 2019, all neonates in the intermediate room of Dr. Soetomo Hospital were included in the study. Neonates with external and middle ear abnormalities were excluded because OAE testing could not be performed due to non-technical factors and the patient's unstable condition.

The following data were collected for each subject: sex, prematurity, family history for hearing impairment, consanguinity between parents, maternal infections, use of supplementation oxygen, maternal diseases during pregnancy, maternal use of medicines during pregnancy, Apgar score, hyperbilirubinemia, low birth weight, septicemia, surgery, presence of Retinopathy of Prematurity (ROP), congenital abnormalities, cerebral complications, use of antibiotics included the known ototoxic, caesarean section, turbid or meconium amniotic fluid, premature rupture of membrane (PROM), neurologic disorders, and meconium aspiration syndrome. The maternal risk factors studied were the maternal infections, including Cytomegalovirus, Toxoplasma, Rubeola, and Candida albicans. The maternal diseases were included: pre-eclampsia, chronic hypertension, kidney disease, gestational diabetes, and lupus nephritis.

Before conducting research on patients about Early Detection of Hearing Impairment in Neonates with Dual/Multiple Toxoplasma, Rubella, Cytomegalovirus Infections, first obtain a declaration of informed consent as approval to participate in this research.

The tool for Distortion product otoacoustic emissions (DPOAE) examination, AuDX PRO Bio-logic SYSTEMS CORP type, was made in Germany. Before the examination, the patient's hair has been washed, and the patient's scalp must be free from skincare products. All neonates underwent an ear examination with headlamps and otoscopes in a quiet room, with a threshold of 2 dB. If the Meatus Acusticus Externus (MAE) gets the cerumen, it is cleaned (ear toilet). The OAE test was performed by placing earplugs in both ears, one ear at a time. The results were documented as either pass or refer. The neonates with OAE results were examined at the TORC serology laboratory. The study was approved by the Research Ethics Committee at Dr. Soetomo Hospital, Surabaya. The associations between potential risk factors and hearing impairment were initially analyzed by Fisher's exact test. The strength of the association was expressed as Odds Ratio (OR) with corresponding 95% Confidence Interval (CI). Spearman's correlation was used in order to obtain the correlation coefficient of hearing impairment and dual/multiple TORC infection. A p-value<0.05 was considered statistically significant. Multivariable logistic regression analysis was further performed if more than two risk factors were statistically significant.

Ethical Approval

This research was conducted after the ethical proposal was approved by the Committee of Ethics at Dr. Soetomo General Academic Hospital Center, with ethical clearance number 1478/KEPK/Ix/2019.

Results

Fifty infants were included in this study, 30 males (60%) and 20 females (40%). There are 7 infants (14%) classified as refer responses at OAE, while the others were normal. During the study, one of seven infants dropped out in the middle because the parents wanted to discharge the baby. Therefore, we could not perform the TORC examination for this one infant. In addition, only 6 infants participated in the complete TORC examination in this study. Of 6 infants, 5 had confirmed dual/multiple TORCs.

Forty-three babies (86%) presented with normal hearing on OAE testing. Prematurity was observed in 24 babies (48%). The babies born by cesarean section were 25 babies (50%). A total of 14 babies (28%) were born with maternal diseases during pregnancy, of whom 11 used medicines during pregnancy. Twenty-two babies (44%) were hospitalized in the NICU over 5 days. Six babies (12%) were observed with maternal infections. Nineteen babies (38%) were born with low Apgar scores. Twenty-one babies got supplemental oxygen (42%). Five infants (10%) were born with turbid or meconium amniotic fluid, and 23 babies (46%) had low birth weight (<2500 grams). Retinopathy of prematurity was presented in 4 babies (8%), premature rupture of membranes in 4 babies too, one infant (2%) had neurologic disorders, and 2 babies (4%) had meconium aspiration syndrome. None of the babies had a family history of hearing impairment, consanguinity, or twin pregnancy. Other factors of the neonate's classifications are presented in Table 1.

Table 1. Conditions observed in our sample by neonates with hearing impairment and normal hearing.

Risk factors	Hearing impairment N=7 (%)	Normal hearing N=43 (%)
Prematurity		
≤ 36 weeks	4 (57.1)	19 (44.2)
> 36 weeks	3 (42.9)	24 (55.8)
Length of stay in NICU		
>5 days	4 (57.1)	18 (41.9)
≤ 5 days	3 (42.9)	25 (58.1)
Maternal infections		
Yes	2 (28.6)	4 (9.3)
No	5 (71.4)	39 (90.7)
Apgar score		
Asphyxia	4 (57.1)	15 (34.9)
Non-asphyxia	3 (42.9)	28 (65.1)
Use of supplementation oxygen		
Yes	5 (71.4)	16 (37.2)
No	2 (28.6)	27 (62.8)
Turbid or meconium amniotic fluid		
Yes	1 (14.3)	4 (9.3)
No	6 (85.7)	39 (90.7)
Cerebral complications		
Yes	0 (0)	7 (16.3)
No	7 (100)	36 (83.7)
Hyperbilirubinemia		
Yes	2 (28.6)	20 (46.5)
No	5 (71.4)	23 (53.5)
Birth weight		
<2500 gram	5 (71.4)	18 (41.9)
≥2500 gram	2 (28.6)	25 (58.1)
Surgery		
Yes	1 (14.3)	8 (18.6)
No	6 (85.7)	35 (81.4)
Presence of retinopathy of prematurity		
Yes	2 (28.6)	2 (4.7)
No	5 (71.4)	(95.3)
Septicemia		
Yes	3 (42.9)	7 (16.3)
No	4 (57.1)	36 (83.7)
Use of antibiotics		
Yes	6 (85.7)	24 (55.8)
No	1 (14.3)	19 (44.2)
Use of ototoxic antibiotics		
Yes	5 (71.4)	19 (44.2)
No	2 (28.6)	24 (55.8)
Maternal use of medicines during pregnancy		
Yes	3 (42.9)	8 (18.6)
No	4 (57.1)	35 (81.4)
Caesarean childbirth		
Yes	3 (42.9)	22 (51.2)
No	4 (57.1)	21 (48.8)
Congenital abnormalities		
Yes	3 (42.9)	21 (48.8)
No	4 (57.1)	22 (51.2)
Premature rupture of membrane		
Yes	3 (42.9)	1 (2.3)
No	4 (57.1)	42 (97.7)
Meconium aspiration syndrome		
Yes	0 (0)	2 (4.7)
No	7 (100)	41 (95.3)
Neurologic disorders		
Yes	0 (0)	1 (2.3)
No	7 (100)	42 (97.7)

Data presented as number and percentage. Source: Own authorship.

Seven babies (14%) had a refer response on OAE, of whom 6 (12%) had positive TORC serology results. One neonate (16.67%) had a single TORC infection (CMV infection), and 5 babies (83.33%) had dual or multiple TORC infections (Tables 2 and 3). Among children with refer response, six babies (85.71%) had a unilateral response at OAE and one baby (14.29%) had a bilateral response at OAE (Table 2).

Table 2. Distribution of DPOAE examination (N=7).

OAE results	Total
Unilateral Right	4 (57.14%)
Unilateral Left	2 (28.57%)
Bilateral	1 (14.29%)
Total	7 (100%)

Source: Own authorship.

Infants with hearing impairment (n=7), use of antibiotics and ototoxic antibiotics were common findings in 5 subjects (71.4%), followed by history of oxygen supplementation, low birth weight (n=5, 71.4%), prematurity, hospitalization in NICU over 5 days, and low Apgar score (n=4,57.1%). Less common findings were septicemia, maternal use of medicines during pregnancy, cesarean childbirth, congenital abnormalities, and premature rupture of membranes (n=3, 42.9%). This was followed by hyperbilirubinemia, maternal infections, retinopathy of prematurity, and maternal diseases during pregnancy (n=2, 28.6%), turbid or meconium amniotic fluid, and surgery (n=1, 14.3%).

In this group, we did not observe any cases of cerebral complications, neurologic disorders, or meconium aspiration syndrome. Table 5 compares DPOAE findings with the risk factors in neonates. In babies with normal hearing function (n=43), antibiotic use was common in 24 subjects (55.8%), followed by cesarean childbirth (n=22, 51.2%), with p-values of 0.239 and 1.000, respectively. These two variables are not statistically significant. Less common findings followed by prematurity and hyperbilirubinemia (n=20, 46.5%) with p = 0.689 and p = 0.444, respectively. The remaining risk factors did not exhibit any statistically significant correlation (Table 3).

Table 3. Bivariate analyze of risk factors hearing impairment to DPOAE results.

Variable	DPOAE		p	OR (95% CI)
	Refer (N=7)	Pass (N=43)		
Sex				
Male	6	24	0.219	4.750
Female	1	19		(0.536-42.907)
Gestational age				
Premature	4	19	0.689	1.684
Term	3	24		(0.336-8.455)
Caesarean childbirth				
Yes	3	22	1.000	0.716
No	4	21		(0.143-3.589)
Maternal use of medicines during pregnancy	3	8	0.170	3.281
Yes	4	35		(0.610-17.650)
No				
Preeclampsia	0	1	1.000	-
Yes	7	42		
No				
Premature rupture of membrane	3	1	0.007*	31.5
Yes	4	42		(2.626-377.925)
No				
Birth weight	5	18	0.225	3.472
<2500 gram	2	25		(0.604-19.945)
≥2500 gram				
Apgar score	4	15	0.404	2.489
Asphyxia	3	28		(0.491-12.614)
Not asphyxia				
Use of supplementation oxygen	5	16	0.115	4.219
Yes	2	27		(0.731-24.339)
No				
Maternal infections	2	4	0.192	3.900
Yes	5	39		(0.563-27.029)
No				
Hyperbilirubinemia	2	20	0.444	0.460
Yes	5	23		(0.080-2.636)
No				
Use of ototoxic antibiotics	5	19	0.239	3.158
Yes	2	24		(0.551-18.114)
No				

Source: Own authorship.

We identified an increased risk of hearing impairment for one risk factor included in the analysis. Hearing impairment with confirmed cases of

dual/multiple TORC infection was statistically associated with premature rupture of membrane (OR 41; 95% CI 3,65 – 46,03; p=0.001) (Table 4).

Table 4. Bivariate analyze of risk factors hearing impairment to Dual/ Multiple TORC infection.

Variable	TORC infection		p	OR (95% CI)
	Yes (N=5)	No (N=45)		
Sex				
Male	4	26	0.636	2.923
Female	1	19		(0.302-28.286)
Gestational age				
Premature	4	19	0.167	5.474
Preterm	1	26		(0.566-52.969)
Caesarean childbirth				
Yes	1	24	0.349	0.219
No	4	21		(0.023-2.114)
Maternal use of medicines during pregnancy	2	9	0.301	2.667
Yes	3	36		(0.386-18.419)
No				
Preeclampsia	0	1	1.000	-
Yes	5	44		
No				41
Premature rupture of membrane	4	4	0.001*	(3,65 – 46,03)
Yes	1	41		
No				5.474
Birth weight	4	19	0.167	(0.566-52.969)
<2500 gram	1	26		
≥2500 gram				1.208
Apgar score	2	16	1,000	(0.182-8.002)
Asphyxia	3	29		
Not asphyxia				6.000
Use of supplementation oxygen	4	18	0,155	(0.619-58.135)
Yes	1	27		
No				-
Maternal infections	0	6	1.000	
Yes	5	39		
No				-
Hyperbilirubinemia	0	22	1.000	
Yes	5	23		
No				1.714
Use of ototoxic antibiotics	3	21	0.661	(0.261-11.264)
Yes	2	24		
No				

Source: Own authorship.

The other risk factors did not show an OR with a statistically significant value. Table 5 shows the correlation between hearing impairment on DPOAE testing and dual/multiple TORC infection (p = 0.001), with a correlation coefficient (R = 0.826).

Table 5. The correlation between DPOAE examination dual/multiple TORC examination.

Dual/multiple TORC examination	DPOAE examination		p
	Refer	Pass	
Dual/multiple TORC infection	5	0	0.001*
Non-dual/multiple TORC infection	2	43	
Total	7	**43**	

One infant had early discharge in the middle of study and the other one had a single TORC infection; *Fisher's exact test was used for the analysis. Source: Own authorship.

Discussion

Hearing impairment in neonates is a condition that significantly affects speech, language, and psychological development. That may have social consequences and auditory symptoms. This study aimed to determine the prevalence of hearing impairment in neonates with dual or multiple TORCH infections and to identify risk factors associated with hearing impairment. In our study, the prevalence of hearing impairment observed in neonates was 14% **[4]**.

The study lasted 4 months to determine the incidence of hearing loss and analyze the relationship between risk factors for hearing loss in infants at Dr. Soetomo Hospital. Based on the basic characteristics of the research subjects, men outnumber the research subjects. The basic characteristics of other research subjects are not the same as in some previous studies, which were predominantly premature infants, LBW, hyperbilirubinemia, use of ototoxic drugs, and postpartum infections. From 7 research subjects with DPAOE, results (hearing loss) were obtained from 5 research subjects with multiple TORC infections.

In this study, 6/7 research subjects had unilateral DPOAE results, and 1/7 had bilateral DPOAE results. In this study, the results are more consistent for the right ear than for the left (4/6 research subjects). The literature reports that, at the cochlear level, there is asymmetry between the right and left ears, with the OAE response higher in the right ear **[5]**.

We found that males were at greater risk of hearing loss than females, OR 4.75, 95% CI (0.53-42.91). These results are in accordance with studies in Israel **[6]** and Philippines **[7]** with men more at risk of hearing loss. The most common risk factors include premature birth, exposure to ototoxic drugs, LBW, and Apgar values <5 in the first minute. In the Bielecki et al. Study, ototoxic drugs were the most common risk factors, followed by preterm birth, LBW, and length of stay at the NICU. Severe asphyxia and mechanical ventilation are more common in the studies of Hille et al. (2007) **[8]**. It was found that although the proportion of infants with birth weight <1500 who have cochlear dysfunction is higher (50%), LBW is not a risk factor for cochlear dysfunction **[9]**.

Most of the neonates included in our study received ototoxic antibiotics; this was equally present among neonates with hearing impairment and in the normal-hearing population. Cesarean childbirth, septicemia, and surgery were more common in neonates with hearing impairment compared to normal-hearing neonates. This could be explained by systemic hypoperfusion, which may affect ear perfusion and contribute to inner cell death. Furthermore, septicemia and surgery may increase circulating reactive oxygen species (ROS), which are responsible for oxidative damage in the inner ear. In the case of maternal diseases, even if treated correctly, the risk of developing hearing impairment in our sample was slightly increased. This follows the alteration of normal maternal homeostasis and metabolism/metabolism that may lead to both pressure variations and increased ROS, capable of damaging the inner ear structures of neonates.

We did not observe an increased prevalence of

hearing impairment among babies hospitalized in the NICU for 5 days, who received antibiotic treatment, and who had low birth weight. These findings are in contrast to other authors' results, which observed an increased risk of hearing impairment in these babies. We attributed this finding to the small size of our sample. Similarly, no higher prevalence of hearing impairment was observed in neonates with low Apgar score and maternal infections. This may be correlated with the characteristics of our sample and with the management of neonates in our hospital. The control of infections with specific treatment administered from the early stage of pregnancy decreased the risk of viral infections, while mechanical ventilation with personal assistance (several daily checks) avoided rapid changes in oxygenation that might affect the inner ear structures.

In a Philippine study in 2000 involving 406 infants in the NICU, with gestational age <37 weeks, OR 0.76, 95% CI (0.50-1.15) **[10]**. Cochlear maturation and function occur optimally at 38 weeks' gestation, so that in premature babies, a smaller emission will be obtained on OAE examination **[11]**. In our study, preterm birth had a risk of 1.68 times hearing loss, 95% CI (0.34-8.46).

Our results indicate that the prevalence of hearing loss in newborns with gestational age <37 weeks is clearly high. Prematurity must be considered as a risk factor for hearing loss in the NICU population. These infants struggled because of their underdeveloped respiratory system; therefore, in this case, they need more and longer oxygen therapy. As a result of their weak immune system, they are also more susceptible to infections, so the risk of sepsis and antibiotic use will be higher **[12]**.

In a study conducted in China in 2010-2011, comparing infants born vaginally and by cesarean section, results showed that infants with cesarean section delivery had a greater risk of experiencing first OAE failure. Of 423 infants with cesarean section, 81 infants (21%) experienced a first OAE failure compared with 1037 with vaginal delivery, 74 (7.1%) of whom experienced a first OAE failure **[13]**. Patients with cesarean section labor may have problems with slow fluid absorption in the middle ear, thereby interfering with the transmission of sound through the middle ear **[13]**. But in our study, the type of cesarean section delivery associated with a lower risk of hearing loss was 0.72 (95% CI, 0.14-3.58).

Infants born to mothers with a history of drug use during pregnancy had a risk of 3.28 times experiencing cochlear dysfunction, OR 3.28, 95% CI (0.61-17.65). Explanation of how the drugs used by the mother during pregnancy can cause cochlear dysfunction most likely related to diseases suffered by the mother such as anemia, preeclampsia, pregestational diabetes, congenital heart disease, heart failure, and SLE. The 50 pregnant women who gave birth with complications of preeclampsia found that the prevalence of hearing loss in the group was 4% and was not found in the normotensive mothers group. Statistical analysis did not show a significant relationship between severe preeclampsia and hearing loss (p = 0.999) **[14]**. In this study, the same prevalence of 4% was also found in the group of women with preeclampsia who have hearing loss in their babies. The bivariate analysis also found no statistically significant relationship (p = 1.000). These findings are in line with our study.

Ongoing oxidative stress in severe preeclampsia causes endothelial dysfunction, which can disrupt blood flow and damage blood vessels not only in the placenta but also in maternal blood vessels, including cochlear blood vessels. In the cochlea, hypoxia can cause temporary or permanent dysfunction of both outer and inner hair cells and can even damage them, leading to hearing loss. This condition generally reduces or disappears entirely after termination of pregnancy **[15]**. This might explain the hearing loss in this study.

The analysis of the two relationships was significant (p = 0.00715). In our study, the results showed that mothers with difficult postpartum hemorrhage (PPH) labor had a greater risk than previous studies, with an OR of 31.5, 95% CI (2.62-377.92). The analysis of these two relationships in this study was also significant (p = 0.007). Babies with hearing loss may be at higher risk for an emergency delivery due to problems such as prematurity, PROM, and LBW. Olusanya et al. in 2005 reported several significant risk factors for hearing loss, such as young maternal age, delayed labor, prematurity, and premature rupture of membranes **[16]**. These factors also have a large role in the delivery process **[17]**.

In univariate analysis, birth weight <2500 grams has a risk of 3.47 (95% CI 0.60-19.95, p = 0.225). In a study conducted in Thailand in 2010-2012 with univariate analysis, data on birth weight <1500 grams RR 4.3, 95% CI (2.3-8.1), p <0.001, and on birth weight 1500-2500 grams RR 2.00, 95% CI (1.3-3.0), p = 0.003 **[18]**. The results of research in Turkey in 2009-2012 showed that 49 babies with birth weight <1500 grams, 13 (26.5%) of them experienced OAE referral, compared to 2235 babies with birth weight> 1500 grams, 349 (15.6%) of them experienced OAE referral, with the results of chi-square analysis p = 0.038. In a study by Korres et al. (2005), 6 of 19 infants with birth weights <1500 grams (31.6%) failed

the first TEOAE screening [19]. The prevalence of neonatal screening failure with very low birth weight is higher than that with normal birth weight due to the accumulation of fluid in the middle ear, resulting in conductive hearing loss [20].

Low Apgar scores at 1 and 5 minutes are recognized as the primary perinatal indicators associated with hearing impairment [21]. In a study conducted in Thailand in 2010-2012, using univariate analysis, data were obtained for Apgar values <6; RR 22.4, 95% CI (16-31.4), p <0.001 [18]. Meanwhile, our study found a different result with OR 2.48, 95% CI (0.49-12.61), p = 0.404. These results differ from those of previous studies in Thailand.

It has been reported in the literature that adequate oxygenation and perfusion are very important for cochlear function, and hypoxia can cause hearing loss. Our analysis shows no significant association between oxygen use and the incidence of hearing loss. In a study conducted in Iran in 2006-2007, 21 (17%) of 103 babies who received oxygen therapy had hearing loss12. Adequate oxygenation is essential for normal cochlear function. Hypoxia can cause irreversible damage to the cochlea, especially to outer hair cells [22]. In this study, 5 (10%) of 50 babies who received oxygen therapy had hearing loss.

Infants who experienced postpartum infections had a risk of cochlear dysfunction (DPOAE refer) of 5.7 times greater than study subjects who did not experience infections. In a study conducted by Poonual et al. (2016) in Thailand, the RR in the multivariate analysis was 1.8 (95% CI, 1.0-3.2; p = 0.045) [18]. In a study conducted by Karaca et al. (2014), 35 (11.9%) experienced OAE failures from 293 infants with hyperbilirubinemia [23]. Our study did not find a significant analysis for this comparison. But it might be due to the fewer samples and variation in the data. Theoretically, hyperbilirubinemia often occurs in neonates, usually mild and transient without further disability. However, neurological damage induced by bilirubin can occur in some infants. The auditory pathway is a sensitive part affected by bilirubin toxicity, and permanent disability can occur even with a slight increase in bilirubin levels [24]. The total bilirubin level, as a benchmark, is> 20 mg/dL, with 35% of infants with bilirubin levels experiencing hearing impairment [25].

The results of the study in Thailand found RR values in infants exposed to ototoxic drugs in the amount of 4.1, 95% CI (1.9-8.6), p <0.001 [18]. The combination of aminoglycoside and βlactam antibiotics is often used as a first-line antibiotic treatment in newborns. Unfortunately, these drugs can damage the cochlea and vestibular organs. These drugs cause irreversible damage to hair cells [26]. Gentamicin autotoxicity can be minimized by short-term therapy, monitoring blood levels, and dosage adjustments under certain conditions [27]. The use of ototoxic drugs is one of the most common risk factors found in several studies. However, in this study, the results showed that ototoxic drugs were associated with a 3.16-fold increase in hearing loss but did not show a statistically significant relationship (p = 0.239). The same opinion is also expressed by other studies, which suggest that ototoxic drugs are not the most frequent risk factors for hearing loss [28].

Aminoglycosides can cause hearing loss by damaging the cochlea or outer hair cells due to their concentration in perilymph. An animal study shows that aminoglycoside concentration and duration can cause hearing loss by increasing perilymphatic aminoglycoside levels. Other studies investigating ototoxic drugs without determining the type of drug, dosage, and duration of exposure did not find an association between ototoxic drugs and hearing loss [29,30]. Our study has limited sample variation, especially in confirmed cases of infants with dual/multiple TORC infections. It was presumed that this might be why, in this study, we could not obtain the OR for hearing impairment with dual/multiple TORC infection, although both variables are statistically correlated. Therefore, we encourage further research to study this associated with a larger number of samples.

Conclusion

In screening babies treated at Dr. Soetomo Hospital, it was found that 7/50 (14%) had hearing loss on OAE testing; 4 of them had multiple TORCH infections. In this study, the results showed that every baby with hearing loss will show a positive TORC serological test, especially with multiple infections. It was suggested repeating the OAE examination in referrals or in all infants at risk at 1 month of age. A follow-up study using a cohort perspective within 6 months to determine the association of other risk factors with hearing loss in a larger sample was needed.

CRediT

Author contributions: **Conceptualization-** All authors**; Investigation-** All authors; **Methodology-** All authors; **Project administration-** All authors; **Supervision-** All authors; **Writing - original draft-** All authors; **Writing-review & editing-** All authors.

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Not applicable.

Ethical Approval

This research was conducted after the ethical proposal was approved by the Committee of Ethics at Dr. Soetomo General Academic Hospital Center, with ethical clearance number 1478/KEPK/Ix/2019.

Informed Consent

Not applicable. This study was observational and cross-sectional.

Funding

Not applicable.

Data Sharing Statement

The data used in this study are available from the corresponding author upon reasonable request.

Conflict of Interest

The authors declare no conflict of interest.

Similarity Check

It was applied by Ithenticate[@].

Application of Artificial Intelligence (AI)

Not applicable.

Peer Review Process

It was performed.

References

1. Tim Survey Depkes RI, 1997. Survey Kesehatan Indera Penglihatan & Pendengaran 1993-1996. Ministry of Health, Republic of Indonesia, Jakarta.
2. Dhingra PL, Shingra S. Anatomy of ear, in: Disease of Ear, Nose, and Throat & Head and Neck Surgery. Elsevier, India, 2013, pp. 3–13.
3. Dewi N, Judarwanto W. TORCH Newborn Syndrome: Dampak infeksi kehamilan TORCH pada bayi. 2013, Grow up Clin. www.growupclinic.com.
4. Coenraad S, Goedegebure A, Van Goudoever JB, Hoeve LJ. Risk factors for auditory neuropathy spectrum disorder in NICU infants compared to normal-hearing NICU controls. Laryngoscope. 2011; 121: 852–855. https://doi.org/10.1002/lary.21430
5. Ari-Even Roth D, Hildesheimer M, Maayan-Metzger A, Muchnik C, Hamburger A, Mazkeret R, Kuint J. Low prevalence of hearing impairment among very low birthweight infants as detected by universal neonatal hearing screening. Arch. Dis. Child. Fetal Neonatal Ed. 2006; 91: 257–262. https://doi.org/10.1136/adc.2005.074476
6. Smolkin T, Mick O, Dabbah M, Blazer S, Grakovsky G, Gabay N, Gordin A, Makhoul IR. Birth by cesarean delivery and failure on first otoacoustic emissions hearing test. Pediatrics. 2012; 130. https://doi.org/10.1542/peds.2011-3179
7. Chiong CM. Early detection and screening for childhood deafness in the Philippines. Radboud University Nijmegen Medical Centre, Nijmegen, 2015.
8. Hille ETM, Van Straaten HLM, Verkerk PH, Van Straaten I, Verkerk P, Hille E, Baerts W, Bunkers C, Smink E, Van Elburg R, De Kleine M, Kok JH, Ilsen A, Visser D, Steiner K, De Vries LS, Weisglas-Kuperus N, Sprij A, Lopriori E, Brokx J, Gavilanes D, Geven W, Bos A. Prevalence and independent risk factors for hearing loss in NICU infants. Acta Paediatr. Int. J. Paediatr. 2007; 96: 1155–1158. https://doi.org/10.1111/j.1651-2227.2007.00398.x
9. Handoko WB. Pengaruh Bayi Berat Lahir Rendah Terhadap Fungsi Koklea Pada Bayi Baru Lahir di RSUD Dr. Soetomo Surabaya. Universitas Airlangga, 2019.
10. Chiong CM, Erasmo EG, Tirona-Remulla AN, Calaquian CME, Reyes-Quintos MRT. Neonatal hearing screening in a neonatal intensive care unit using distortion-product otoacoustic emissions. Acta Otolaryngol. 2003; 123: 215–218. https://doi.org/10.1080/00016480310000331
11. Tognola G, Parazzini M, De Jager P, Brienesse P, Ravazzani P, Grandori F. Cochlear maturation and otoacoustic emissions in preterm infants: A time-frequency approach. Hear. Res. 2005; 199: 71–80. https://doi.org/10.1016/j.heares.2004.08.005
12. Pourarian S, Khademi B, Pishva N, Jamali A. Prevalence of hearing loss in newborns admitted to neonatal intensive care unit. Iran. J. Otorhinolaryngol. 2012; 24: 129–134. https://doi.org/10.22038/ijorl.2012.185

13. Xiao T, Li Y, Xiao L, Jiang L, Hu Q. Association between mode of delivery and failure of neonatal acoustic emission test: A retrospective analysis. Int. J. Pediatr. Otorhinolaryngol. 2015; 79: 516–519. https://doi.org/10.1016/j.ijporl.2015.01.019
14. Taufan A, Bernolian N, Efendi Y, Bahar AGE. The risk of sensorineural hearing impairment in preeclampsia. Indones. J. Obstet. Gynecol. 2019, 179–182. https://doi.org/10.32771/inajog.v7i3.585
15. Olusanya BO. Perinatal profile of very low birthweight infants under a universal newborn hearing screening programme in a developing country: A case-control study. Dev. Neurorehabil. 2010; 13: 156–163. https://doi.org/10.3109/17518420903468472
16. Olusanya BO, Luxon LM, Wirz SL. Screening for early childhood hearing loss in Nigeria. J. Med. Screen. 2005; 12: 115–118. https://doi.org/10.1258/0969141054855274.
17. Amini E, Kasheh Farahani Z, Rafiee Samani M, Hamedi H, Zamani A, Karimi Yazdi A, Nayeri F, Nili F, Rezaeizadeh G. Assessment of hearing loss by OAE in asphyxiated newborns. Iran. Red Crescent Med. J. 2014; 16: 1–4. https://doi.org/10.5812/ircmj.6812
18. Poonual W, Navacharoen N, Kangsanarak J, Namwongprom S. risk factors for hearing loss in infants under universal hearing screening program in northern Thailand. J. Multidiscip. Healthc. 2016; 9: 1–5.
19. Korres S, Nikolopoulos TP, Komkotou V, Balatsouras D, Kandiloros D, Constantinou D, Ferekidis E. Newborn hearing screening: Effectiveness, importance of high-risk factors, and characteristics of infants in the neonatal intensive care unit and well-baby nursery. Otol. Neurotol. 2005; 26: 1186–1190. https://doi.org/10.1097/01.mao.0000184602.94677.41
20. Cristobal R, Oghalai J. Hearing loss in children with very low birth weight: current review of epidemiology and pathophysiology. Arch. Dis. Child. Fetal Neonatal Ed. 2008;93: F462– F468. https://doi.org/10.1038/jid.2014.371
21. Wilkinson AR, Jiang ZD. Brainstem auditory evoked response in neonatal neurology. Semin. Fetal Neonatal Med. 2006;11: 444–451. https://doi.org/10.1016/j.siny.2006.07.005
22. Rais-Bahrami K, Majd M, Veszelovszky E, Short BL. Use of furosemide and hearing loss in neonatal intensive care survivors. Am. J. Perinatol. 2004; 21: 329–332. https://doi.org/10.1055/s-2004-831887
23. Karaca ÇT, Oysu Ç, Toros SZ, Naiboğlu B, Verim A. Is hearing loss in infants associated with risk factors? Evaluation of the frequency of risk factors. Clin. Exp. Otorhinolaryngol. 2014;7: 260–263. https://doi.org/10.3342/ceo.2014.7.4.260
24. Olds C, Oghalai JS. Audiologic impairment associated with bilirubin-induced neurologic damage. Semin Fetal Neonatal Med. 2015;2:42–46. https://doi.org/10.1038/jid.2014.371
25. Akinpelu OV, Waissbluth S, Daniel SJ. Auditory risk of hyperbilirubinemia in term newborns: A systematic review. Int. J. Pediatr. Otorhinolaryngol. 2013;77:898–905. https://doi.org/10.1016/j.ijporl.2013.03.029
26. Wroblewska-Seniuk KE, Dabrowski P, Szyfter W, Mazela J. Universal newborn hearing screening: Methods and results, obstacles, and benefits. Pediatr. Res. 2017; 81: 415–422. https://doi.org/10.1038/pr.2016.250
27. Fuchs A, Zimmermann L, Graz MB, Cherpillod J, Tolsa JF, Buclin T, Giannoni E. Gentamicin exposure and sensorineural hearing loss in preterm infants. PLoS One 2016;11: 1–11. https://doi.org/10.1371/journal.pone.0158806
28. Bielecki I, Horbulewicz A, Wolan T. Risk factors associated with hearing loss in infants: An analysis of 5282 referred neonates. Int. J. Pediatr. Otorhinolaryngol. 2011;75: 925–930. https://doi.org/10.1016/j.ijporl.2011.04.007
29. Maharani A, Dawes P, Nazroo J, Tampubolon G, Pendleton N. Visual and hearing impairments are associated with cognitive decline in older people. Age Ageing 2018;47:575–581. https://doi.org/10.1093/ageing/afy061.
30. Schwarz Y, Kaufman GN, Daniel SJ. Newborn hearing screening failure and maternal factors during pregnancy. Int. J. Pediatr. Otorhinolaryngol. 2017;103:65–70. https://doi.org/10.1016/j.ijporl.2017.09.027