

A comparison of otoacoustic emissions examination results as early hearing screening in normal and infants at risk of hearing loss



Rosa Falerina^{1*}, Puguh Setyo Nugroho¹, Nyilo Purnami¹, Fatimah Azizah Salsabila²

ABSTRACT

Background: A child's ability to speak must be supported by a good hearing function. With early detection of hearing loss, it is hoped that intervention can be made promptly, thus improving the quality of life (QOL) of children with hearing loss at birth. The purpose of this study was to compare the otoacoustic emissions (OAE) examination results in infants with and without risk.

Method: The OAE examination was conducted on 60 newborns with and without risk factors in the nursery room and ORL-HNS outpatient unit. For all the newborns aged > 24 hours and before being discharged from the hospital with inclusion criteria, the OAE examinations were performed and repeated when they were 1 and 2 months old. Furthermore, the comparison of OAE results on newborns with and without risk factors aged > 24 hours, 1 month, and 2 months were statistically analyzed.

Results: A Friedman statistical analysis test was then conducted to examine the correlation between the results of the first, second, and third OAE examinations. The first, second, and third OAE examination results of newborns with and without risk factors were compared, significant differences were found with a p-value of 0.0111 ($p < 0.05$).

Conclusion: The newborn hearing screening using OAE should be performed for all newborns (Universal Newborn Hearing Screening) and serially to minimize the number of higher referrals to health facilities to improve an individual's quality of life in the future.

Keywords: Newborn screening, hearing loss, otoacoustic emissions, health services, quality of life.

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¹Department of Otorhinolaryngology, Head and Neck Surgery, Faculty of Medicine, Universitas Airlangga – Dr. Soetomo General Academic Hospital Center, Surabaya;

²Faculty of Medicine, Universitas Airlangga, Surabaya Indonesia;

*Corresponding author:

Rosa Falerina;
Department of Otorhinolaryngology, Head and Neck Surgery, Faculty of Medicine, Universitas Airlangga – Dr. Soetomo General Academic Hospital Center, Surabaya;
rosa.falerina@fk.unair.ac.id

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INTRODUCTION

Auditory perception is one of the senses that plays an important role in communication. A good hearing function and way of speaking will result in good communication as well. Speaking is an essential ability that humans only possess.^{1,2} The process of hearing and speaking begins from the moment a baby is born. So, if hearing loss occurs early on, there will be a speech problem.^{3,4}

Congenital hearing loss is defined as a hearing loss that occurs at birth caused by damaged and sensorineural outer hair cells (OHCs) of the snail shell (cochlea).⁵ The outer hair cells of the snail shell serve as cochlear amplifiers allowing sound waves to reach the brain stem.⁶ The congenital hearing loss incidence rate is 1 to 3 per 1000 births without risk and increases to 2 - 4 per 100 high-risk births.⁷ Hearing in children plays an important role in learning to speak and acquire a

language as well as for socializing and cognitive development.⁸ Those included in the high-risk group are newborns with one or more of the following: anatomical abnormalities of the head and neck, syndromes related to congenital deafness, low birth weight (LBW), bacterial meningitis, hyperbilirubinemia requiring blood transfusion, severe asphyxia, administration of ototoxic drugs, use of mechanical breathing aids/ventilation for more than 5 days, mothers suffering from TORCH during pregnancy, and family history with deafness, have a greater risk of damage to cochlear OHCs.⁹⁻¹⁴

A 2007 Joint Committee on Infant Hearing (JCIH) suggested that OAE be included in the gold standard test for newborn hearing screening in addition to Automated Auditory Brainstem Response (AABR). The OAE test is used to assess the function of the cochlear OHCs in newborns. An OAE is a sound generated

from a snail shell (cochlea) and can be captured with a microphone placed in the ear canal. It is produced by the contraction of the outer hair cells of the cochlear. The OHCs serve to increase the vibration effect of travelling waves allowing them to produce sharper and higher peaks to stimulate the inner hair cells of the snail shell better for further neural decoding purposes.^{5,11} Such emissions can be inspected using an OAE tool. If the cochlear OHCs operate properly, the emissions will be able to return to the tool so that the result will be displayed as a "PASS" (success). Otherwise, the emissions will fail to return if it is damaged, resulting in a "REFER" (failure). This examination is quite effective, simple, and does not take long, making it non-invasive. In addition, some researchers claim the sensitivity of OAE tools ranges from 85 to 95%, with a specificity of 90% or higher.^{5,11,15,16}

According to the JCIH 2007

recommendations, it is important to do a hearing screening examination with OAE for every newborn before leaving the hospital or health care, which can be repeated at 1 month of age, and diagnosis enforcement of hearing loss at the age of 3 months. It is hoped that interventions can be made on newborns with hearing loss when they are 6 months old.^{6,8,17,18}

A study to compare the results of the OAE serial examinations at birth > 24 hours, 1 month old, and 2 months old needs to be done. It is also hoped that by detecting early hearing loss in all newborns before 3 months, if there is a hearing loss before they turn 6 months old, it will be possible to act promptly. The study results can be utilized as a guide for health services to improve the QOL of hearing-loss children through early detection and intervention. Therefore, this study aimed to compare the OAE examination results in infants with and without risk.

METHODS

The study involved 60 newborns in the nursery room from December 2020 to July 2021. With the following inclusion criteria: newborn with and without risk, birth age > 24 hours, and parental agreement to participate in this study. If the newborn had atresia or stenosis of the ear canal on one side and a respiratory tract infection and fever, they were ruled out. The OAE examinations were carried out three times at different periods: when the newborns were > 24 hours in the nursery room, and 1 month old and 2 months old at the ORL-HNS outpatient unit.

Determining whether or not a risk factor was based on the anamnesis of the parents and their newborn's medical record. The risk factors include one or more: anatomical abnormalities of the head and neck, syndromes associated with congenital deafness, LBW (< 2500 grams), bacterial meningitis, use of ototoxic drugs, premature (pregnancy < 37 weeks), hyperbilirubinemia requiring exchange blood transfusion, asphyxia, ventilator use, mothers suffering from TORCH during pregnancy, and family history with deafness. An Otoscopic examination of the baby's ear canal was performed to determine whether the ear canal and eardrum were suitable for the

OAE examination or not. All results were then recorded on the data collection sheet. Furthermore, the Ethics Committee of Universitas Airlangga Academic Hospital Surabaya has approved the study protocol.

The OAE examination was performed by trained health workers using the Distortion Product Otoacoustic Emissions (DPOAEs) ERO-SCAN tool with various probe size options. It was accomplished by a soft probe of the baby's ear canal length. As long as the baby is quiet, it can be placed on the mattress or carried. If the baby is having a phototherapy session, then wait until it is finished. The parents were given the OAE results and an OAE examination evaluation control letter in a month at the ORL-HNS outpatient unit. The examination took around 5 to 10 minutes for both ears. If the outcome was a "PASS," it did not need to be repeated; otherwise, it should be repeated up to 2 times and could only be recorded after it was finished. If one side passed and the other was a "REFER," the refer would have been written in conclusion.

The statistical analysis was carried out using GraphPad Prism software version 8. Friedman's test was also used to compare the results of a serial OAE examination on newborns aged > 24 hours, 1 month, and 2 months. Meanwhile, the *p*-value was < 0.05, which was considered statistically significant.

RESULTS

The study sample comprised 60 at-risk and non-risk newborns aged > 24 hours, with 26 males (43%) and 34 females (57%) (Table 1).

The risk variables include: premature in 12 babies (20%), LBW in 14 babies (23%), asphyxiation with poor apgar scores in 8 babies (13%), and 1 baby receiving treatment with a ventilator. None of them had a history of hyperbilirubinemia requiring exchange transfusion, mothers with TORCH during pregnancy, and history of deafness in the family (Table 2).

The findings of 60 newborns were examined serially at the ages of > 24 hours after birth, 1 month, and 2 months. The first OAE examination was done at the age of > 24 hours yielded "PASS" results in 11 newborns (18%) and "REFER" results in 49 newborns (82%). The second

examination was performed at the age of 1 month, yielded "PASS" results in 22 newborns (36%) and "REFER" results in 38 newborns (64%). The last examination was done at the age of 2 months, yielded "PASS" results in 58 newborns (96%) and "REFER" results in 4 newborns (4%) (Table 3).

A comparative statistical test was carried out between the first, second, and third OAE examination results. The Kolmogorov-Smirnov (K-S) test was also used to assess whether or not the homogeneity of sample data was normally distributed. As a result of the data not being normally distributed, a comparison test utilizing the Friedman test was done. The comparison of the first, second, and third OAE examination results of newborns with and without risk factors obtained significant differences with a *p*-value of 0.0111 (*p* < 0.05).

DISCUSSION

The purpose of newborn hearing screening is to find the prevalence of hearing loss in newborns so that intervention may begin as soon as feasible. Therefore, it has the potential to improve the communicative, cognitive, and social skills of those who have hearing loss. Hearing screening is

Table 1. Characteristics of the patients.

Category	Value
Sex, n (%)	
Male	26 (43)
Female	34 (57)
Total	60 (100)

Table 2. Examination result of the patient.

Category	Value
Risk Factors, n (%)	
No-Risk Factors	30 (50)
With Risk Factors	30 (50)
Gestational Age, n (%)	
Premature (<37 weeks)	12 (20)
Full Term	44 (73)
Post Term (>42 weeks)	4 (7)
Birth Weight, n (%)	
Normal	46 (77)
LBW (<2500 grams)	14 (23)
Apgar Score, n (%)	
Normal (7-10)	52 (87)
Abnormal (<6)	8 (13)

Table 3. Comparison of the first, second, and third OAE examination results of all newborns with and without risk factors.

	Result	n (%)	High-Risk Newborns	No-Risk Newborns
1 (> 24 hours), n (%)	Pass	11 (18)	2 (7)	9 (30)
	Refer	49 (82)	28 (93)	21 (70)
2 (1 month), n (%)	Pass	22 (18)	5 (17)	17 (57)
	Refer	38 (64)	25 (83)	13 (43)
3 (2 months), n (%)	Pass	58 (96)	28 (93)	30 (100)
	Refer	2 (4)	2 (7)	0 (0)

Friedman test *P*-value of 0.0111 ($p < 0.05$), significantly different

divided into two ways: for all newborns (universal screening) and for those who are at high risk (targeted/risk screening).^{1,8,19} It is defined as a hearing examination of all newborns before being discharged, or up to 1 month old if delivered outside the hospital. According to the JCIH's Early Hearing Detection & Intervention (EHDI) program's Principles and Guidelines, every baby born before the age of 1 month gets a hearing screening, and every one of them taken before the age of 3 months gets a hearing evaluation so that those with hearing loss can be intervened before they turn 6 months.¹⁹ Those at high risk will be monitored regularly every 6 months for 3 years. The gold standard inspection tools that JCIH recommends are OAE and Automated Audiometry Brainstem Response AABR.⁸ By conducting hearing screenings in the hospital or before the babies are released, it is possible to prevent late evaluation of newborns' hearings, resulting in late hearing loss detection in babies and children.^{5,17-21}

In this study, a hearing screening with DP OAE was performed in all newborns from December 2020 to July 2021, matching the inclusion criteria. A total of 60 newborns were obtained, 30 of whom had risk factors, and the other 30 did not. The first OAE examination results were "REFER" in 49 newborns (82%) and "PASS" in 11 newborns (18%). In Hassan et al. research, 500 newborns aged > 24 hours with and without risk factors received OAE examination results, with 94.8% of them having passed, and 10.4% had "REFER" results with high-risk factors.¹⁵

False refer incidence rates in newborns aged > 24 hours can occur due to the presence of residual amniotic fluid in the ear canal or the tympanic cavity during

the examination, poor selection of probes, and less peaceful examination rooms.^{20,22,23} That is when repeated OAEs examinations at 1 month and 2 months come in handy. In this study, 49 newborns (82%) received "REFER" results in the OAE examination at the age of 1 month, which dropped to 38 newborns (64%), and at the age of 2 months dropped again to 2 newborns (4%). Moreover, the evaluation of OAE examination at the age of 1 and 2 months may minimize the number of higher baby referrals to health facilities thus, can save costs.²² A follow-up examination with ABR was performed on a newborn who had a "REFER" result on the third examination. All newborns, especially those with high-risk factors, will be monitored periodically every 6 months until they turn 3 years old.^{9,24}

This study's results revealed that the OAE examination of the female group had more "PASS" than the male group. Carvallo et al., in their study, also have more "PASS" results in the female group of newborns. That could be due to the high tendency of OAE amplitude in them.²² Hassan et al in 2017, in their research, explained that the high tendency of OAE amplitude in female newborns could be caused by a shorter cochlea length than males, allowing OAE stimulation to be received more quickly by the cochlear OHCs.¹⁵

Premature (gestational age < 37 weeks) is one of the hearing loss risk factors. From this study, 12 premature newborns with the first OAE result 100% "REFER" were obtained and from 44 full-term newborns, we obtained 11 newborns (25%) had passed, and 33 others (75%) had "REFER" results. The immature cochlear OHCs could cause a high number of "REFER" in premature newborns; therefore, the OAE examination needed to be repeated.²²

The results of this study on the OAE examination showed that there was an increase of "PASS" result in 1 newborn (8%), and on the third examination, 100% successfully passed. Carvallo et al., in their study, mentioned that there is a significant difference in OAE examination results between full-term and premature newborns.²²

LBW is also one of the high-risk variables of hearing loss compared to babies with no-risk factors. Those with LBW have a risk of developing hypoxia or acidosis and have regular metabolic functions. That is what affects hearing.^{20,25} In this study, 14 newborns (23%) were born with LBWs. At the first OAE examination, there was only 1 of them received a "PASS" result. The following examination yielded 2 "PASS" results, and in the third examination, 13 of them had passed. The newborns with high-risk factors who continued to fail (refer) were subjected to the ABR examination. In their research, Cristobal & Oghalai (2008) discovered that most LBWs with "REFER" results of the OAE examination on the follow-up with ABR apparently suffered from conductive hearing loss, which the presence of middle ear effusion might cause, and healed themselves within a few weeks.¹⁰

Low Apgar scores can affect the outer hair cells of the cochlear. In this study, newborns with low Apgar scores (< 6) were acquired as many as 8 newborns (13%). The first OAE examination resulted in 8 newborns with "REFER" results; followed by 3 newborns with "PASS" results in the second examination; 100% had passed in the third examination. Zang et al. research in 2007 stated that in infants aged 6 months with a history of low Apgar scores and perinatal hypoxia, the DP OAE examination results were obtained at a lower frequency of 1 - 4 kHz than a normal group.²⁶ Poonual et al. in 2016, found that there were 3,210 newborns aged 3 months with a risk factor of LBW history (< 2500 grams), Apgar score < 6, craniofacial abnormalities, sepsis, and use of ototoxic drugs, with 135 of those (4.3%) had "REFER" results on the OAE examination.¹²

From this study, 30 newborns were found to be at high risk (50%) and from

the third OAE examination at the age of 3 months obtained 2 newborns who remained to had “REFER” results (6%) in which require a follow-up hearing evaluation with ABR. In the Sreedharan et al. 2020, out of 500 newborns were at high risk on their first OAE examination, where 210 of them (42%) received “REFER” results and 290 (58%) had “PASS” results. On the second OAE examination (1 month later), obtained 40 newborns (8%) still had “REFER” results and 460 newborns had “PASS” results.²⁷ So that, the examination, especially on newborns with a “REFER” result, must be checked serially. It should be performed each month to diagnose enforcement to be done before the age of 6 months and hope that intervention can be carried out immediately so that the newborn’s listening and the speaking process can fit children their age.

Not all health facilities, especially in Indonesia, have an Auditory Brainstem Response (ABR) examination tool, so that serial OAE examinations are considered useful in reducing infant referral rates for ABR examinations. The limitations in this study were that during the ABR examination, sometimes the patients were uncooperative and some did not even come, so the secondary data obtained was incomplete.

CONCLUSION

The OAE examination can be performed on all newborns for hearing screening to assess the OHCs. With early detection of hearing loss, the interventions can be implemented sooner so that it is hoped to improve the communication, cognitive and social skills of children. In addition, the OAE examination needs to be done serially, especially for newborns with “REFER” results on their previous examinations.

The newborn hearing screening is recommended for all newborns with and without risk factors when they are > 24 hours. Furthermore, it is suggested to evaluate the OAE examination on individuals aged 1 month and 3 months, diagnose enforcement, and intervene before they reach 6 months.

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ETHICAL STATEMENT

Ethics Committee of Universitas Airlangga Academic Hospital Surabaya has approved the study protocol with ethical number 189/KEP/2020.

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CONFLICT OF INTEREST

No conflict of interest is found in this manuscript.

AUTHORS CONTRIBUTION

RF responsible for concept of the study, design of the study, statistical analysis, and manuscript review. PSN responsible for concept of the study, design of the study, and manuscript editing. NP responsible for concept of the study, manuscript preparation, manuscript editing, and manuscript review. FAS responsible for data analysis and statistical analysis.

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