Auditory and Vestibular Research

Effect of Contralateral Ear Occlusion on Transient Evoked Otoacoustic Emission and Distortion Product Otoacoustic Emission Amplitudes in Newborns in Noisy Environments

Maryam Yarahmadi[a], Hasan Haddadzade Niri[a], Nariman Rahbar[a], Malihe Mazaher yazdi[a], Arash Bordbar[b], Mohammad Amin Sharafi[a]

[a] Rehabilitation Research Center, Department of Audiology, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran.

[b] Shahid Akbarabadi Clinical Research Development Unit, School of Medicine, Iran University of Medical Sciences , Tehran, Iran

Corresponding Author:

Hassan Haddadzade Niri

E-mail address:

haddadzadeniri.h@iums.ac.ir

ORCiD ID: https://orcid.org/0000-0002-4280-9401

Nariman Rahbar: https://orcid.org/0000-0002-7724-632X

Malihe Mazaher Yazdi: https://orcid.org/0000-0001-5165-9604

Arash Bordbar: https://orcid.org/0000-0001-6057-5744

Mohammad Amin Sharafi: https://orcid.org/0000-0002-8121-2317

Highlights:

- Occluding the contralateral ear could improve the amplitude of OAE in newborns
- NICU noise has greater effect on OAE amplitude compared to white noises

Abstract

Background and Aim: Background noise, especially in environments like neonatal intensive care units (NICUs), can compromise the accuracy of otoacoustic emission (OAE) testing by activating the medial olivocochlear (MOC) reflex, which suppresses OAE amplitudes. This study evaluated whether attenuating sound to the contralateral ear could improve OAE measurements in noisy environments.

Method: Thirty full-term newborns with no signs of hearing loss were enrolled. OAEs, including distortion product (DPOAE) and transient evoked (TEOAE), were recorded under three contralateral noise conditions: white noise at 50 and 60 dB SPL, and recorded NICU noise. The recordings were repeated after covering the contralateral ear with a soundproof headphone to attenuate incoming noise. OAE amplitudes were compared between uncovered and covered conditions using paired t-tests.

Results: After covering the contralateral ear, there was a slight overall enhancement of OAE amplitude across all noise conditions that showed statistical significance using a paired *t*-test. This improvement was more considerable in NICU noise than in white noise. OAE improvement in TEOAE was not as remarkable as in DPOAE

Conclusion: This method resulted in a modest improvement in OAE levels, likely by reducing the activation of the MOC reflex. Enhancing OAE amplitudes by attenuating contralateral noise, particularly in high ambient noise environments, could improve the accuracy of OAE testing. This may lead to a reduction in false positive results, consequently lowering the costs associated with further diagnostic evaluations and alleviating parental anxiety.

Keywords: auditory efferent system, olivocochlear system, newborns, transient evoked otoacoustic emission, distortion product otoacoustic emission

Introduction

Otoacoustic emissions (OAEs) result from an active mechanism in the cochlea[1], and can emit spontaneously or in response to an external stimulus[2,3]. OAEs provide valuable information about hearing loss, especially in newborns[4-6]. OAE serves as the initial step in identifying hearing loss and is widely recognized as a reliable hearing screening technique across many countries[7,8]. Significant hearing loss is reported to affect approximately 4.6 out of every 1,000 well-babies[9]. Undiagnosed hearing loss can significantly impair language development and cognitive abilities[10]. Early hearing screenings, such as transient evoked otoacoustic emissions (TEOAE), help mitigate the adverse impacts of hearing loss. Therefore, increasing the validity and accuracy of the OAE test has always been important. Nevertheless, OAE responses may be influenced by factors like background noise, the examiner's technique, or the presence of hearing loss itself. Additionally, the MOC reflex is one factor known to affect OAE amplitude[11].

The medial olivocochlear (MOC) reflex originates from the superior olivocochlear(SOC) and is activated in contralateral moderate noise[11-13]. This reflex can play a significant role in reducing acoustic trauma and helping speech perception in noisy environments, defined as "MOC unmasking"[14-15]. MOC fibers form synapses on outer hair cells (OHC) and engage an active cochlear mechanism through cholinergic synapses. This process inhibits amplification by inducing hyperpolarization in the OHCs, which, in turn, is expected to influence OAE amplitude. Notably, this reflex is observed in both adults and newborns[16-18]. Research indicates that the MOC reflex can diminish OAE amplitude in newborns by 0.3 to 2.7 dB, varying across different frequencies[19].

OAEs play a vital role in hearing screenings and diagnostic assessments. However, the MOC reflex can suppress OAEs and decrease their amplitude, potentially resulting in false positive outcomes, particularly in environments with high noise levels. Newborn screenings are often conducted in patient rooms, clinical settings, or neonatal intensive care units (NICUs), where sound levels can range from 54 to 83 dB SPL [20] and is high enough to trigger the activation of the MOC reflex. The false-positive rate of TEOAE in initial newborn hearing screenings has been reported to range between 1.2% and 19.5%[21]. False-positive results can impose additional burdens on healthcare systems and family finances, while also causing stress and anxiety for parents. Papsin et al.[22] employed a method to make a significant enhancement in OAE amplitude in adults. Previous research has shown that occluding the contralateral ear can mitigate MOC suppression and increase OAE amplitude. Considering the anatomical and developmental differences between adults and newborns, conducting a similar evaluation is essential to assess the practicality of this method in newborns. Should it prove effective in newborns, it could be implemented in screening protocols to enhance test reliability and minimize false-positive outcomes.

Methods

Subjects

In this study, 30 full-term newborns (48 ears) aged between 8 and 48 hours after birth were examined in a hospital setting. Some infants woke up during the testing procedure, leading to their exclusion from the study. One of the primary causes for this was probe displacement from one ear to the other. Parental consent was obtained for all participants, and the noise presented during testing was ensured to be safe for their hearing sensitivity.

All newborns had Apgar scores of at least seven, were not at risk of hearing loss, and had standard weights ranging from 2.5 to 4.0 kg. All newborns passed bilateral OAE screening to exclude the presence of hearing loss. Moreover, middle ear function was assessed and confirmed using wideband tympanometry (Interacoustics Titan, Denmark), thereby excluding any conductive abnormalities. None of the participants had a family history of hearing disorders.

Noises

Three types of noise were utilized in this study: white noise at 50 dB SPL, white noise at 60 dB SPL, and recorded NICU noise. The white noise signals were generated using Audacity software, while the NICU noise was recorded during the daytime in a typical neonatal intensive care unit. Unlike standard white noise, NICU noise exhibited more dynamic characteristics, with sound levels ranging from 53.5 to 84.9 dB SPL. The mean stimuli level was 71.5 dB SPL, with a rapid response time of 200 ms. To prevent the activation of the middle ear muscle reflex(MEMR), all noise levels during testing were kept below 75 dB SPL. Further details about the noise specifications are outlined in Table 1. All noise signals were calibrated using the B&K 2250 L Sound level meter(SLM) under controlled experimental conditions. Noise presentations occurred in a free-field setup, with the speaker positioned 1 meter away from the SLM at a 0° azimuth.

Procedure

To activate the MOC reflex, newborns were exposed to three types of noises. Initially, TEOAE and distortion product otoacoustic emission (DPOAE) measurements were conducted through diagnostic OAE (Otometrics, manufactured in Denmark) in a silent environment with ambient noise kept under 25 dB SPL. To minimize the impact of probe placement, all testing stages were carried out while the newborns were in sleep mode, with a single examiner performing the tests. The newborns had recently been fed to maintain a calm state. TEOAE responses were measured using click stimuli, while DPgrams were calculated as the simple average of emission amplitudes across all 13 frequencies. .

In the second step of the experiment, both TEOAE and DPOAE measurements were recorded in the noise present to evaluate MOC suppression on OAE amplitude. The noise was delivered through a speaker starting from 30 seconds prior to the test to activate the MOC reflex.

In the third step, while the noise was still playing, the contralateral ear was covered using a soundproof headphone (Baltic S41CE, manufactured in the UK). This setup was designed to attenuate incoming noise in contralateral ear and prevent the activation of the MOC reflex in the test ear. The attenuation levels across various frequencies, were sourced from the Baltic S41CE catalog. Additional verification was conducted in a pilot study using real ear measurements (Audidata Primus), establishing an average reduction of 22-23 dB. Following the occlusion of the contralateral ear, TEOAE and DPOAE tests were repeated under identical conditions.

The following steps were done in the study:

• TEOAE and DPOAE in quiet

• TEOAE and DPOAE in presenting 50 dB SPL and 60 dB SPL white noise with and without covering the contralateral ear

• TEOAE and DPOAE in presenting NICU noise with and without covering the contralateral ear

Statistical analysis

The data were analyzed using comparative and descriptive methods. A paired t-test was employed to assess differences in DPOAE and TEOAE amplitude values between the two conditions (with and without contralateral ear covering). A p-value of ≤0.05 was considered statistically significant. All statistical analyses were conducted using SPSS version 17. Additionally, the data in this study were found to follow a normal distribution.

Results

Contralateral ear occlusion led to small increases in TEOAE amplitudes and the greatest increase was observed at NICU noise in the left ear. For DPOAEs, contralateral ear plugging caused more noticeable amplitude increases compared to TEOAE. The largest average increase was seen at 60dB SPL white noise in the right ear.

Transient evoked otoacoustic emissions results

Changes in OAE levels were calculated by comparing conditions with the contralateral ear open versus occludedacross three noise types: 50 dB SPL white noise, 60 dB SPL white noise, and NICU noise.

In 50 dB SPL white noise, no significant differences were observed at most frequencies, except at 3000 Hz in the left ear (p=0.05) and 4000 Hz in the right ear (p=0.025). In the 60 dB SPL white noise condition, a statistically significant difference was found only at 1000 Hz in the right ear (p=0.015). For the NICU noise, significant differences were found at 1000 Hz in both ears (p-values: right = 0.001, left = 0.010), and at 2000 Hz and 4000 Hz in the left ear (p=0.033 and 0.002, respectively).

Overall, the increase in amplitude after contralateral ear occlusion was approximately 0.03 dB in the right ear and 0.02 dB in the left ear in 50 dB SPL white noise. In 60 dB SPL white noise, the average MOC suppression effect measured 0.32 dB in the right ear and 0.29 dB in the left ear. In NICU noise conditions, the enhancement reached 0.29 dB in the right ear and 0.58 dB in the left ear (Figure 1).

Distortion product otoacoustic emission Results

DPOAE results from all 30 participants are obtained throughcomparing OAE levels with the contralateral ear occluded and non-occluded across three different noise conditions. The measurements are averaged across all participants, and the differences between the two conditions are calculated. Statistical significance and corresponding *p*-values from paired *t*-tests are also included. DPOAEs were recorded using DPgrams as a function of f_2 ($2f_1$–f_2).

The results show the enhancement of OAE levels following contralateral ear occlusion in 50 dB SPL white noise. The results were not statistically significant across most frequencies, except at 800 Hz and 7998 Hz in the left ear. In 60 dB SPL white noise, more frequencies demonstrated significant improvements. Notably, a significant increase in OAE levels was observed at 1250 Hz in both ears (*P*-values: right = 0.001, left = 0.13), and at 1600 Hz, 2001 Hz, 6298 Hz, and 7998 Hz in the right ear (*P*-values: 0.011, 0.001, 0.018, and 0.014, respectively). =Analyzed data in NICU noise conditions, showing significant OAE amplitude enhancement at 996 Hz in both ears (p-values: right = 0.012, left = 0.016), at 1600 Hz and 2500 Hz in the right ear (*P*-values: 0.050 and 0.018), and at 1250 Hz and 5000 Hz in the left ear (*P*-values: 0.049 and 0.028).

The average difference between the open and plugged contralateral ear was 0.45 dB in the right ear and 0.48 dB in the left ear in 50 dB SPL noise. At 60 dB SPL, the measurements showed an improvement in OAE levels of

0.88 dB in the right ear and 0.57 dB in the left ear. Additionally, in NICU noise conditions, the enhancement was 0.60 dB for the right ear and 0.67 dB for the left ear (Figure 2).

Discussion

The impact of contralateral acoustic stimulation (CAS) on OAEs has been extensively studied in animal models[23]and experimental research. Surprisingly, these effects have not been thoroughly investigated in newborn hearing screening protocols[22]. Understanding CAS effects could enhance our understanding of cochlear mechanics and efferent system, potentially improving hearing screening procedures.

Background noise in OAE testing has long been a persistent challenge, particularly in newborn screenings. For valid and accurate results, ambient noise levels must remain below 65 dB A [7] as even moderate noise can significantly prolong test time [2,24].Although clinical OAE diagnostics are typically conducted in controlled, sound-attenuating booths, hospitals often present unavoidably noisy environments. A previous study has demonstrated that background noise at the maternal bedside can reduce TEOAE specificity to as low as 4.2% [2]. Moreover, OAE screening in the NICU has shown a false-positive rate of up to 8.5%[25].

One key factor contributing to reduced OAE amplitudes is the olivocochlear efferent system, particularly the medial olivocochlear (MOC) reflex. When activated by contralateral noise, the MOC reflex suppresses OAE responses, diminishing signal amplitude. This effect could be mitigated by attenuating noise exposure to the contralateral ear. The primary objective of this study was to develop a practical approach to enhance the reliability of OAE testing in newborns under real-world clinical conditions.

The results show consistency with Abdala et al. [1] demonstrating significant improvement in DPOAE responses within the 1500-3000 Hz range. Our results also showed partial agreement with Chabert et al. [18] particularly in detecting suppression effects in the 2000-4000 Hz region. While Papsin et al.[22] employed a single averaged value across the frequency range to compare OAE measurements, this study adopted a more precise approach. In contrast to the approach taken by Papsin et al., the present study employed a higher frequency resolution for OAE amplitude analysis, enabling statistical comparisons at each frequency by calculating the corresponding p-values. Notably, although some studies have proposed that MOC function may be absent in newborns [26], our results provide evidence of measurable MOC suppression effects even in this early developmental stage. The observed robust suppression in mid-frequency ranges may reflect the efferent system's role in speech perception, particularly within noise environments, as these frequencies align with critical components of the speech spectrum. Notably, the magnitude of suppression enhancement in this study exhibited a non-linear distribution across frequencies, consistent with the findings of Abdala et al. and Papsin et al.[22, 27]. In the present study, statistical significance was not achieved for most frequencies in either TEOAE or DPOAE measurements. This contrasts with the findings of Papsin et al., who reported significant amplitude enhancements in both TEOAE and DPOAE responses when using 55 dB SPL white noise contralateral stimulation. The discrepancy between findings may be attributable to developmental differences, as our neonatal population demonstrated different response patterns compared to the adults examined in Papsin et al.'s study.[22]. These discrepancies may be attributed to several factors: 1) age-related anatomical and physiological differences in middle ear development and ear canal characteristics, 2) maturation of the cochlear amplifier and transfer function[27], and 3) variations in measurement protocols between studies.

While statistical significance was not achieved at most frequencies, a consistent trend of amplitude enhancement was observed in both TEOAE and DPOAE measurements following contralateral ear occlusion using soundproof headphones (Figures 1-2). These findings align with previous reports indicating that MOC suppression effects in humans can be subtle, with amplitude changes as small as 0.6 dB[28]; therefore, improvement of OAE amplitude as much as 0.6dB is supposed to be a result of MOC reflex prevention even if it is not statically significant. Considering this criterion for MOC suppression, after plugging the contralateral ear versus the open condition, many frequencies showed enhancement in amplitude that can be defined as prevention of MOC reflex. This slight increase in OAE amplitude can make a remarkable change in the TEOAE screening test by just covering the contralateral ear. It wouldn't be a time-consuming or hazardous method and can be used in hospitals or any noisy test environments to reduce false positive results. In our experience, using this method led to less test time in OAE to pass, and it can be beneficial for clinicians who are working in the newborn screening field.

Our findings demonstrate noise-dependent variations in MOC reflex intensity. Consistent with previous reports[19], higher noise levels produced greater amplitude attenuation, while contralateral ear occlusion yielded more pronounced amplitude enhancement under these conditions. Specifically, 60 dB SPL white noise elicited significant amplitude increases at more frequencies following occlusion compared to 50 dB SPL, suggesting insufficient MOC reflex activation at the 50dB white noise in newborns, in contrast to Papsin et al.[22]. Contralateral ear occlusion produced significantly greater OAE amplitude enhancement in NICU noise environments compared to white noise conditions. This likely reflects its broader frequency spectrum (1000-8000 Hz)[29] and higher intensity levels. These results indicate that contralateral occlusion may be particularly beneficial in maternal bedside settings where noise peaks at 66-75 dB A [2]and NICU environments with noise levels reaching 81 dB SPL [20].

This study was conducted with a relatively small sample size, and all participants were less than 48 hours old. It is recommended that future research be carried out with a larger sample size and include newborns a few days postnatally. Further research is required to precisely evaluate the impact of MOC suppression on the false positive rate in neonatal hearing screening. Additionally, studies are recommended to assess the duration of OAE testing in noisy environments, such as NICUs, with particular attention to the effect of contralateral ear occlusion on test completion time.

Conclusion

Occluding the contralateral ear may help reduce the suppressive effects of the MOC reflex, improving OAE amplitude and enhancing test accuracy in noisy environments. This method has the potential to reduce false positives, minimize unnecessary follow-up testing, and ease parental concern.

Funding Statement

This work was found by the research committee at Iran University of Medical Sciences in grant agreement No IR.IUMS.REC.1401.597.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Author Contributions

MY: Material preparation, data collection, study design, drafting the manuscript, interpretation ; MSH: data collection MM: Data collection ; HHN: drafting the manuscript, interpretation, suprevision ; NR: drafting the manuscript , Data analyisis; AB: Data analysis. All authors read and approved the final manuscript.

References

1. Salina H, Abdullah A, Mukari SZ, Azmi MT. Effects of background noise on recording of portable transient-evoked otoacoustic emission in newborn hearing screening. Eur Arch Otorhinolaryngol. 2010;267(4):495-9. [DOI:10.1007/s00405-009-1080-y]
2. Zamiri Abdollahi F, Lotfi Y. Gender Difference in TEOAEs and Contralateral Suppression of TEOAEs in Normal Hearing Adults. Iranian Rehabilitation Journal. 2011;9(2):22-5.
3. Mazaheryazdi M, Sharafi MA, Akbari M, Choobdar FA. Comparing Auditory Brain Stem Responses and Transient Otoacoustic Emissions in Premature Infants with Auditory Developmental Delay: Evidence of Temporary Auditory Neuropathy. Iran J Child Neurol. 2023;17(4):35-44. [DOI:10.22037/ijcn.v17i4.42882]
4. Mazaheryazdi M, Akbari M, Abolhasan Choobdar F. Auditory and speech development in a 3-year-old boy with auditory neuropathy spectrum disorder. Aud Vestib Res. 2021;30(2):139-47. [DOI:10.18502/avr.v30i2.6099]

5. Khosravi N, Mazaheryazdi M, Kalani M, Khalesi N, Shakeri Z, Archang S, et al. Physiological and electrophysiological evaluation of the hearing system in low birth weight neonates treated with cholestin: a cohort study. Egypt J Otolaryngol. 2023;39:75. [DOI:10.1186/s43163-023-00425-z]
6. Kanji A, Khoza-Shangase K, Moroe N. Newborn hearing screening protocols and their outcomes: A systematic review. Int J Pediatr Otorhinolaryngol. 2018;115:104-9. [DOI:10.1016/j.ijporl.2018.09.026]
7. Jacobson JT, Jacobson CA. The effects of noise in transient EOAE newborn hearing screening. Int J Pediatr Otorhinolaryngol. 1994;29(3):235-48. [DOI:10.1016/0165-5876(94)90170-8]
8. Sabbagh S, Amiri M, Khorramizadeh M, Iranpourmobarake Z, Nickbakht M. Neonatal Hearing Screening: Prevalence of Unilateral and Bilateral Hearing Loss and Associated Risk Factors. Cureus. 2021;13(6):e15947. [DOI:10.7759/cureus.15947]
9. Wallhagen MI, Strawbridge WJ, Shema SJ. The relationship between hearing impairment and cognitive function: a 5-year longitudinal study. Res Gerontol Nurs. 2008;1(2):80-6. [DOI:10.3928/19404921-20080401-08]
10. Dhar S, Hall III JW. Otoacoustic Emissions: Principles, Procedures, and Protocols. 2nd ed. San Diego: Plural Publishing, Inc; 2018.
11. Lopez-Poveda EA. Olivocochlear Efferents in Animals and Humans: From Anatomy to Clinical Relevance. Front Neurol. 2018;9:197. [DOI:10.3389/fneur.2018.00197]
12. Haddadzade Niri H, Pourbakht A, Rahbar N, Haghani H. Brainstem Representation of Auditory Overshoot in Guinea Pigs Using Auditory Brainstem Responses. Iran J Child Neurol. 2021;15(2):41-56. [DOI:10.22037/ijcn.v15i2.26241]
13. Guinan JJ Jr. Olivocochlear efferents: Their action, effects, measurement and uses, and the impact of the new conception of cochlear mechanical responses. Hear Res. 2018;362:38-47. [DOI:10.1016/j.heares.2017.12.012]
14. Gkoritsa E, Korres S, Segas I, Xenelis I, Apostolopoulos N, Ferekidis E. Maturation of the auditory system: 2. Transient otoacoustic emission suppression as an index of the medial olivocochlear bundle maturation. Int J Audiol. 2007;46(6):277-86. [DOI:10.1080/14992020701261405]
15. Abdala C, Mishra S, Garinis A. Maturation of the human medial efferent reflex revisited. J Acoust Soc Am. 2013;133(2):938-50. [DOI:10.1121/1.4773265]
16. Durante AS, Carvallo RM. Contralateral suppression of linear and nonlinear transient evoked otoacoustic emissions in neonates at risk for hearing loss. J Commun Disord. 2008;41(1):70-83. [DOI:10.1016/j.jcomdis.2007.05.001]
17. Chabert R, Guitton MJ, Amram D, Uziel A, Pujol R, Lallemant JG, et al. Early maturation of evoked otoacoustic emissions and medial olivocochlear reflex in preterm neonates. Pediatr Res. 2006;59(2):305-8. [DOI:10.1203/01.pdr.0000196739.16060.0a]
18. Campos Ude P, Hatzopoulos S, Kochanek K, Sliwa L, Skarzynski H, Carvallo RM. Contralateral suppression of otoacoustic emissions: input-output functions in neonates. Med Sci Monit. 2011;17(10):CR557-62. [DOI:10.12659/msm.881981]
19. Aly HA, Ahmed AM. Effect of Noise on Neonatal Vital Data and Behavior in NICU. Clin Med Diagn. 2016;6(1):1-6. [DOI:10.5923/j.cmd.20160601.01]
20. Lotfi Y, Movallali G. A Universal Newborn Hearing Screening in Iran. Iranian Rehabilitation Journal. 2007;5(1):8-11.
21. Papsin E, Harrison AL, Carraro M, Harrison RV. Contralateral ear occlusion for improving the reliability of otoacoustic emission screening tests. Int J Otolaryngol. 2014;2014:248187. [DOI:10.1155/2014/248187]
22. Haddadzade Niri H, Rahbar N, Pourbakht A, Haghani H. Auditory Efferent System Influences the Auditory Overshoot Phenomenon- An Auditory Brainstem Response Study in Guinea Pigs. Basic Clin Neurosci. 2025;16(2).
23. Vishwakarma C, Mathur R, Sinha V, Vishwakarma R. Effects of background noise on transiently evoked otoacoustic emissions in newborn hearing screening. Indian J Otol. 2015;21(2):111-3. [DOI:10.4103/0971-7749.155296]
24. Kaveh M, Mirjalali SN, Shariat M, Zarkesh MR. Perinatal factors influencing the neonatal hearing screening results. BMC Pediatr. 2021;21(1):15. [DOI:10.1186/s12887-020-02476-0]
25. Morlet T, Hamburger A, Kuint J, Ari-Even Roth D, Gartner M, Muchnik C, et al. Assessment of medial olivocochlear system function in pre-term and full-term newborns using a rapid test of transient otoacoustic emissions. Clin Otolaryngol Allied Sci. 2004;29(2):183-90. [DOI:10.1111/j.0307-7772.2004.00786.x]

26. Abdala C, Keefe DH. Effects of middle-ear immaturity on distortion product otoacoustic emission suppression tuning in infant ears. J Acoust Soc Am. 2006;120(6):3832-42. [DOI:10.1121/1.2359237]
27. Prasher D, Ryan S, Luxon L. Contralateral suppression of transiently evoked otoacoustic emissions and neuro-otology. Br J Audiol. 1994;28(4-5):247-54. [DOI:10.3109/03005369409086574]Kellam B, Bhatia J. Sound spectral analysis in the intensive care nursery: measuring high-frequency sound. J Pediatr Nurs. 2008;23(4):317-23. [DOI:10.1016/j.pedn.2007.09.009]

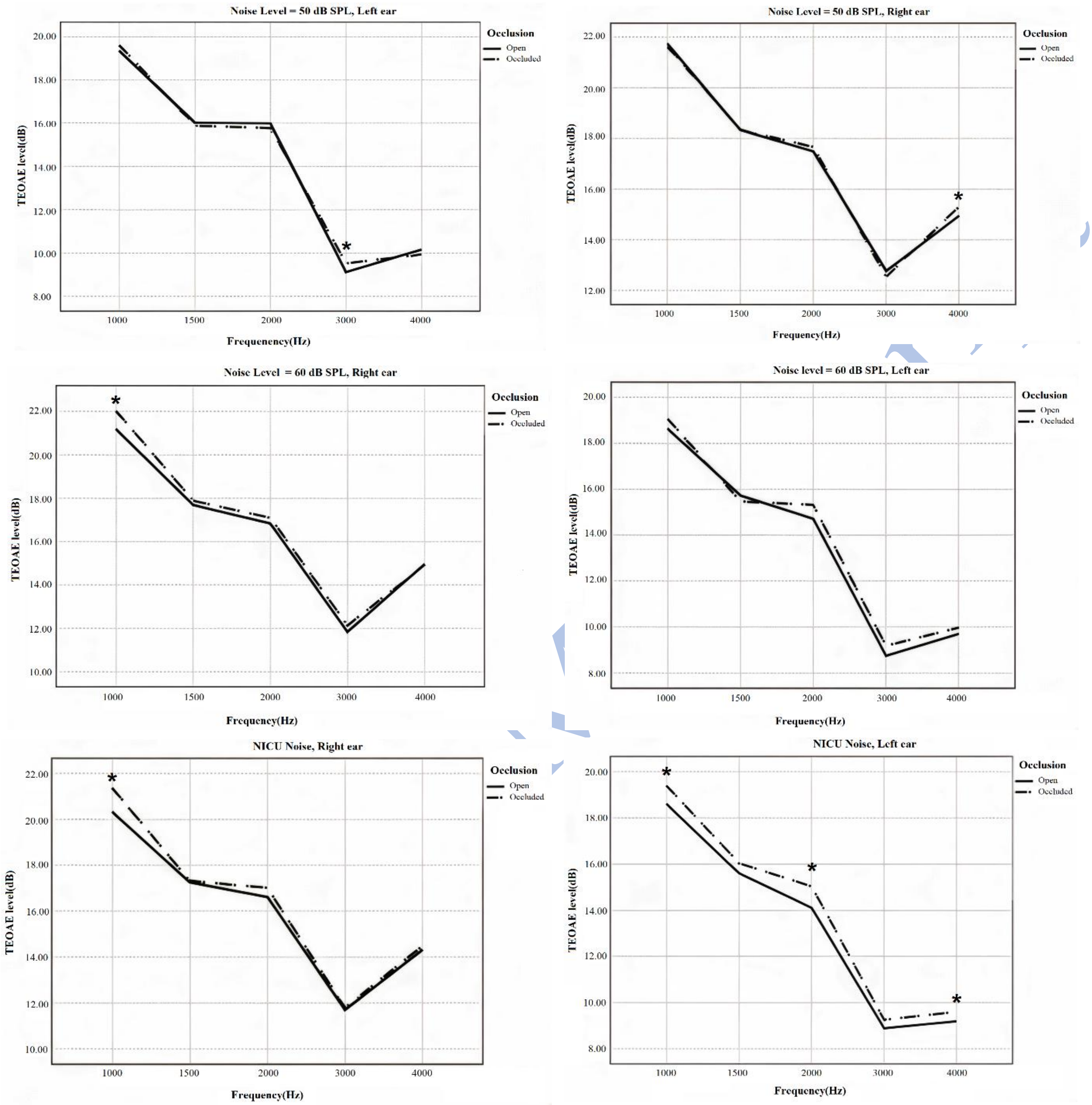

Figure 1. Transient otoacoustic emission amplitude versus Frequency(f2) line charts, averaged in 30 subjects with (dash line) and without (solid line) contralateral ear covering in 50,60dB SPL white noise and NICU noise In both ears.

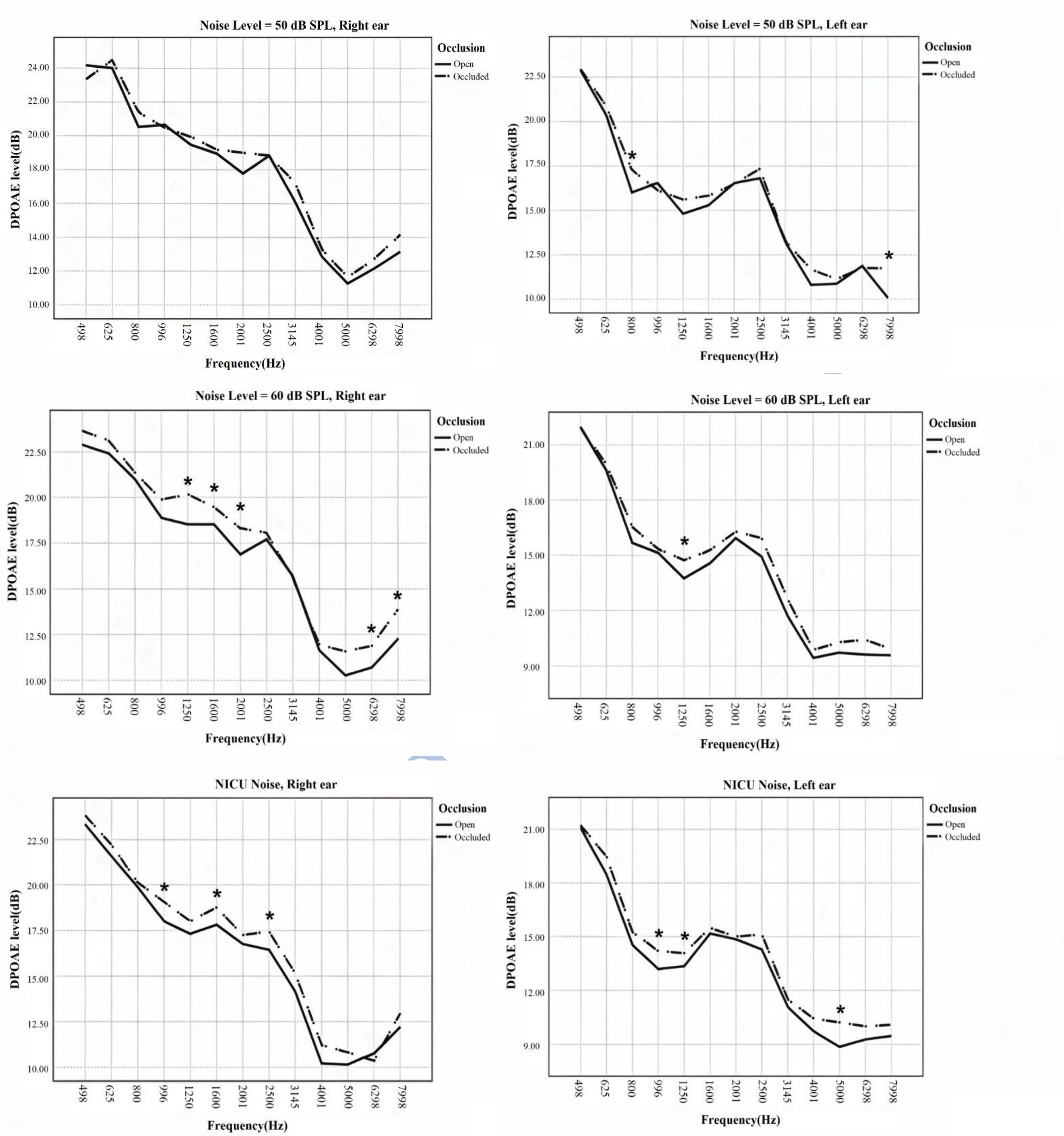

Figure 2. Distortion product otoacoustic emission amplitude versus Frequency(f2) line charts, averaged in 30 subjects with (dash line) and without (solid line) contralateral ear covering in 50, 60dB SPL white noise and NICU noise in both ears.