Aud Vest Res (2018);27(2):72-79.

RESEARCH ARTICLE

Effects of age, sex, ears, and weight on high frequency tympanometry 1000 Hz characteristics in neonates with normal transient evoked otoacoustic emission

Masoud Bolandi Shirejini[1*], Maryam Emadi[2], Athareh Farahani[3], Alireza Akbarzadeh Baghban[4]

[1]- Department of Audiology, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

[2]- Department of Audiology, School of Rehabilitation, Hamadan University of Medical Sciences, Hamadan, Iran

[3]- Department of Audiology, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran

[4]- Department of Basic Sciences, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Received: 16 Dec 2017, Revised: 4 Jan 2018, Accepted: 6 Jan 2018, Published: 15 Apr 2018

Abstract

Background and Aim: Middle ear of neonates is mass-dominant. Therefore, by increasing the frequency of probe tone from 226 Hz to 1000 Hz, middle ear abnormalities can be detected better. This study aimed to evaluate the effect of age, sex, ear and weight on the characteristics of 1000 Hz tympanometry in neonates.

Methods: A total of 255 neonates (136 boys and 119 girls) aged from 1 to 90 days, with normal transient evoked otoacoustic emissionat least in one ear were studied. Compensated static admittance at middle ear pressure (YPP) and admittance at pressure of +200 daPa (Y200) were measured with 1000 Hz tympanometry.

Results: Mean (SD) YPP and Y200 values were 0.97 (0.48) and 2.07 (0.46) mmho in the right ears and 0.98 (0.53) and 2.05 (0.48) mmho in the left ears, respectively. In both ears, gender had no significant effect on compensated YPP, but Y200 values were significantly different between girls and boys ($p<0.05$). Ear did not affect the YPP and Y200 values. There was also a linear relationship between age and weight with compensated YPP and Y200 values, so that compensated YPP and Y200 values increased with higher weight and age.

Conclusion: Age and weight by affecting the physical and impedance characteristics of ear canal and tympanic membrane, can also affect the characteristics of the high frequency tympanometry. Lack of gender effects on compensated YPP and its effect on Y200 can be attributed to the difference in compliance between tympanic membrane and ear canal in boys and girls.

Keywords: Newborns; age factors; sex factors; weight factors; acoustic impedance test

Citation: Bolandi Shirejini M, Emadi M, Farahani A, Akbarzadeh Baghban A. Effects of age, sex, ears, and weight on high frequency tympanometry 1000 Hz characteristics in neonates with normal transient evoked otoacoustic emission. Aud Vest Res. 2018;27(2):72-9.

[*] **Corresponding author:** Department of Audiology, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Damavand Ave., Tehran, 1616913111, Iran. Tel: 009821-77561721
E-mail: masoud.audio@yahoo.com

Introduction

A golden standard to check the function of the middle ear is myringotomy which evaluates middle ear cavity. Unfortunately, this method can only be performed under certain conditions, such as when middle ear effusion lasts [1]. Another test is the transient evoked otoacoustic emission (TEOAE) which is sensitive to middle ear abnormalities. Therefore, if a person has this disorder, and cannot pass myringotomy, to determine the normal function of the middle ear, TEOAE test can be a good substitute [2]. Therefore, in studies on normative high frequency tympanometry, neonates are studied who passed TEOAE test [3]. One of the limitations of the TEOAE test is elimination in moderate and higher sensory hearing losses (SNHL). Therefore, in this group of people, TEOAE test cannot be used to evaluate the middle ear abnormalities [4]. Note that passing on the TEOAE is not a golden standard in assessing the normal function of the middle ear of infants and adults, because TEOAE has been seen in some cases with middle ear disorders [1].

Middle ear of neonates is mass-dominant while middle ear of adults is stiffness-dominant. Also, low frequency probe tones are suitable for testing of high-stiffness system while high frequency probe tones are suitable for testing of high-mass system. Thus by increasing the frequency of the probe tone from 226 Hz to 1000 Hz, the anomalies of the middle ear can be detected better (For example, otitis media that is common in infants) [5-7]. Research shows that using low frequency probe tones for recording of tympanograms leads to higher false-negative responses, indicating low sensitivity for diagnosis of middle ear abnormalities of neonates [6,8,9]. The external ear canal wall has a resonance of about 0.3 kHz, which can change the volume of the ear canal. This finding suggests that the external ear canal wall of the neonates may show oscillatory behavior, that may affect the results if the tympanometry is performed with a 226-Hz probe tone [10].

Several reports suggest that children under six months, even with middle ear discharge, may have normal tympanograms with a 226-Hz probe tone, or may even have abnormal tympanograms in their healthy ears. Also after using the 226-Hz probe, it is not possible to correctly obtain the thresholds of acoustic reflex in this age group. Therefore, using tympanograms obtained by the 226-Hz probe tone yields unreliable results for the assessment of the middle ears of infants less than six months old [5,6,8,11]. In addition, conventional tympanometry (226 Hz) produces different shapes of tympanograms in infants compared to adults and older children [5,12,13]. The reasons for this abnormal tympanogram with a 226-Hz probe tone in infants are as follows: 1) inflation of ear canal walls, 2) excessive eardrum mobility, and 3) growth changes of the ear [7].

In neonates, to interpret the immittance results with a 1000-Hz probe tone, the age, sex, and weight have a significant effect on the characteristics of these tympanograms. Therefore, it is imperative to consider these criteria in obtaining tympanometric 1000 Hz norms [1,6,14]. According to previous studies in the field of multifrequency tympanometry, the effect of age, gender and ear are unclear; also there is no data about the effect of the infant weight. An article points to the effects of age and gender [15] but some studies reject these effects [16-19]. However, there are studies that refer to ear effect [1,20], for example there is an article that denies this effect [21].

Considering the different results of previous studies, this study aimed to investigate the effects of age, sex, ear (right and left) and weight factors on high frequency tympanometry (1000 Hz) characteristics in neonates with normal TEOAE.

Methods

Testing was performed by a clinical audiologist, assisted by master of audiology who had extensive training in TEOAE and immittance measures. The participants were tested individually in the presence of their parents in a quiet non-sound-treated room. TEOAE was given to 297 infants who were born at Fatemi Hospital in Hamadan. A total of 255 neonates (136 boys and 119 girls) between the ages of 1-90 days (mean=11.3, SD=13.15 days) and weight range of 1870-7250 gram (Mean=3432, SD=750.42 g) were studied. These neonates had a normal TEOAE at least in one of their ears. A total of 471 ears with normal TEOAE (231 right ears and 240 left ears) were studied to measure characteristics of 1000 Hz tympanometry. Characteristics of 1000 Hz tympanometry include the compensated admittance in the middle ear pressure (YPP) and the admittance at a pressure of 200 daPa (Y200). Medical and parental permissions were obtained before testing. All participants were full-term babies (38-42 week gestation) with an uneventful birth history and free from any pre-existing condition or a decisive history of risk factors, predisposing the individual to hearing loss. Medical records included the following risk factors for SNHL identified in Joint Committee on Infant Hearing (JCIH) (2000). 1) Family history of genetic hearing loss, 2) Intrauterine infection, 3) Craniofacial anomaly, 4) Birth weight less than 1500 g, 5) Hyperbilirubinemia requiring exchange transfusion, 6) Bacterial meningitis, 7) Administration of ototoxic drug, 8) Apgar scores less than 4, 9) History of assisted ventilation, and 10) Clinical features associated with conductive hearing loss (CHL) or SNHL [22].

The inclusion criterion for infants was their age (between 1 to 3 months old). Otoscopic inspection of the external auditory canal was performed to select the appropriate probe size and check the physical abnormalities of the outer ear. A GSI Tympstar Middle-Ear Analyzer (Grason-Stadler Inc, USA) was used to record the immittance measures. To record the tympanogram, the 1000-Hz probe tone was selected at a pressure range of +200 to -400 daPa and the pump speed of 50 daPa/s. The TEOAE test was measured by MICO (Maico Company, Berlin, Germany). Every day before the test, the device was calibrated in a 2 mL coupler. The intensity of 83 dB SPL and rate of 50 Hz were used to measure TEOAE. The test time was 1 to 3 minutes. The signal-to-noise ratio of 6 dB was selected as the acceptance criterion in the TEOAE test.

Nomination of the type of tympanograms (one-peak or two-peak) is determined by the appearance of tympanograms and the presence or absence of notch at the peak of tympanograms (middle ear pressure). So, at two-peak tympanograms a notch is seen at peak of tympanograms.

Data were analyzed using SPSS 23. Descriptive statistics such as mean and standard deviation ere used to describe the data. The Kolmogorov-Smirnov test was used to assess the normality of the data. In this study, the Independent samples t-test was used to examine the gender effect on tympanometric characteristics of 1000-Hz probe tone. The Pearson correlation test was used to determine the correlation of age and weight with tympanometric characteristics of 1000-Hz probe tone. Also paired sample t test was used to examine the ear effect.

Results

In this study, two types of one-peak and two-peak tympanograms were obtained using 1000-Hz probe tone from neonates with normal TEOAE. Regarding the right ears, 99.6% of the tympanograms were one-peak and 0.4% of them were two-peak. In the left ears, 98.4% of the tympanograms were one-peak and 1.6% of them two-peak (Fig. 1). Out of 471 ears, 466 ears (99%) had one-peak tympanograms and 5 ears (1%) had two-peak tympanograms. Based on the tests, 95^{th} and 5^{th} percentiles of YPP obtained from right ears of 231 infants with normal TEOAE were respectively 1.95 and 0.3 mmho. This indicates that in the right ear of 90% of infants, the YPP values were between 0.3 and 1.95 mmho. Also, 95^{th} and 5^{th} percentiles of YPP were obtained from the left ear of 240 infants with normal TEOAE, which were respectively 1.9 and 0.3 mmho. This indicates that in the left ear of 90% of infants, the YPP values were between 0.3 and 1.9 mmho. Generally, the compensated YPP values range from 0.3 to 1.9 mmho for both ears. In the absence of ear effect, Fig. 2 represents the 90% range for uncompensated YPP and Y200 of 471 ears used for describing normative tympanometric data.

The mean of compensated YPP and Y200 in the right ears with normal TEOAE were 0.97 and 2.07 mmho, respectively and in the left ears as 0.98 and 2.05 mmho, respectively. With regard to right ears, there is no significant difference between YPP of girls (mean=0.9, SD=0.44 mmho) and boys (mean=1.0, SD=0.52 mmho), ($p>0.05$). Also regarding the left ears, there was no significant difference between YPP of girls (mean=0.9, SD=0.51 mmho) and boys (mean=1.0, SD=0.55 mmho), ($p>0.05$). Regarding the right ears, Y200 values were

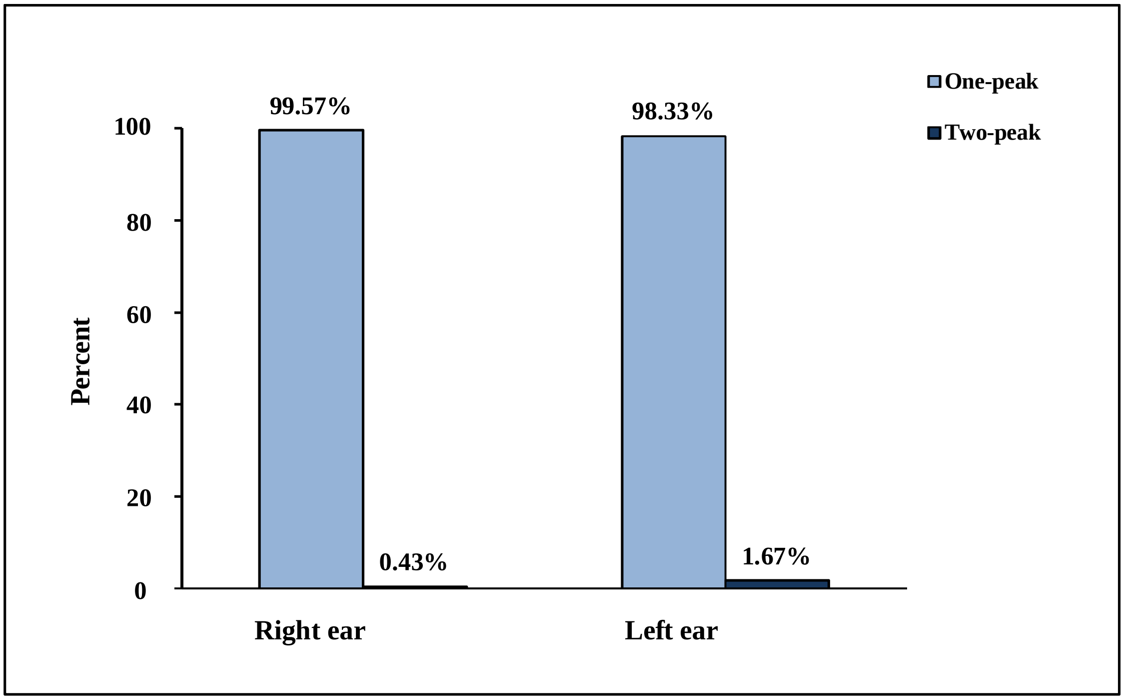

Fig. 1. Types of tympanograms at the right and left ears of all neonates.

significantly higher for boys (mean=2.1, SD= 0.49 mmho) compared to the girls (mean=1.9, SD=0.40 mmho), ($p<0.001$). Also regarding the left ears, Y200 values were significantly higher for boys (mean=2.1, SD=0.53 mmho) compared to the girls (mean=1.9, SD=0.41 mmho), ($p=0.037$).

A linear relationship was observed between age and YPP. We found a Pearson correlation of 0.143 ($p=0.033$) (2-sided) for right ears and Pearson correlation of 0.175 ($p=0.006$) for left ears. Also a linear relationship was observed between age and Y200. We found a Pearson correlation of 0.171 ($p=0.009$) for right ears and Pearson correlation of 0.202 ($p=0.002$) for left ears.

A linear relationship was observed between weight and YPP. We found a Pearson correlation of 0.139 ($p=0.035$) for right ears and Pearson correlation of 0.205 ($p=0.001$) for left ears. Also A linear relationship was observed between weight and Y200. We found a Pearson correlation of 0.288 ($p<0.001$) for right ears and Pearson correlation of 0.255 ($p<0.001$) for left ears.

To examine the ear effect, 216 neonates (115 boys and 101 girls) who had normal TEOAE in both ears were studied. Statistical analysis was conducted to compare the YPP and Y200 values of right and left ears. Based on the results, there was no significant difference between the YPP and Y200 regarding the right and left ears ($p>0.05$).

Discussion

In the present study, 90% of the compensated YPP values ranged between 0.3 and 1.9 mmho, which is consistent with the study findings of Shahnaz et al. [21] and Kei et al. [1]. In Shahnaz et al. study, 1000-Hz probe tone tympanometry was performed on 32-week old neonates and 90% of the compensated YPP range was reported to be around 0.1-1.5 mmho. Also, in Kei et al. study, which evaluated neonates aged from one to six days, these values ranged from 0.29 to 0.39 mmho. However, in Margolis et al.

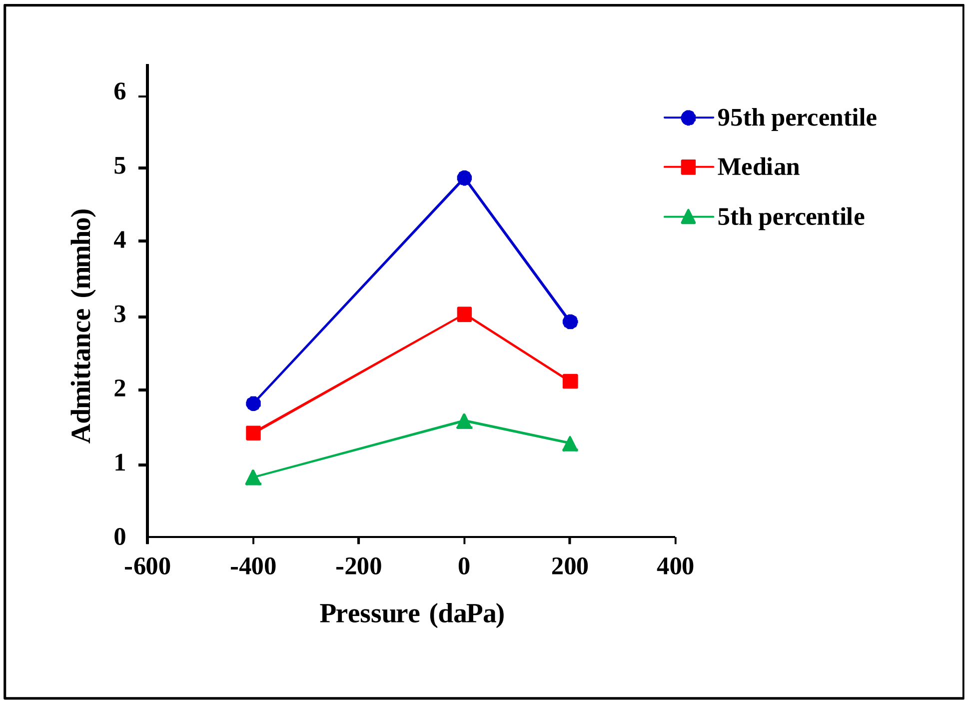

Fig. 2. Normative tympanometric values from 1 kHz tympanograms obtained from neonates.

study [23], 65 neonates up to four weeks old were studied by 1000-Hz probe tone tympan-difference can be attributed to the difference in calculating compensated YPP values. Because in our study, the compensated YPP was calculated from the pressure of +200 daPa, but in the study of Margolis et al., the used pressure in the calculation of compensated YPP values was -400 daPa.

In the present study the results of TEOAE test were normal in neonates with two-peak tympanograms, so in neonates under the age of three months, two-peak tympanograms, such as one-peak tympanograms, indicate the normal function of the middle ear. This finding is consistent with Swanepoel de et al. study [6]. In their study, 278 neonates were evaluated with 1000-Hz probe tone admittance. They observed that 94% of the 16 ears who had two-peak tympanogram, passed in the distortion product otoacoustic emissions (DPOAE) screening test. The reason for observing two-peak tympanograms in neonates with normal TEOAE can be ometry and 90% of the YPP values were between 0.6 and 4.3 mmho. The reason for this due to increased middle ear stiffness in older neonates. Because at the time of birth, the outer portion of the ear canal is relatively loose and fallen, and a half of the inner portion of the external ear canal is ossified in the first year of birth [5].

For better statistical analysis, the results were obtained by grouping the right and left ears. In the present study, there was no significant difference between right and left ears. This finding is consistent with the findings of Shahnaz et al. study [21] and contrasts with those of Dessai et al. study [20]. This difference could be due to different sample sizes (216 ears in the present study compared to 60 ears studied in the Dessai et al.). Since the values of the real ear to coupler difference (RECD) are also affected by the features of the middle ear and external ear canal [24]; therefore, to compare the difference between the right and left ears, the obtained RECD values from two ears can be compared. In the study of Munro and Howlin, it was found that the RECD obtained from the right and left ear did not differ significantly [25]. Thus, their study can also confirm that the compensated YPP and Y200 values are not affected by right or left ear.

In the study of de Moraes et al., middle ear and external ear canal admittance were obtained in neonates up to 3 months old using 226-Hz and 1000-Hz probe tones [26]. The findings suggest that by changing the frequency of probe tone from 226 Hz to 1000 Hz, compensated YPP values increased from 0.51 to 1.2 mmho and Y200 values from 0.64 to 2.59 mmho. As can be seen, by changing the frequency of the probe, the Y200 value changes are much more than compensated YPP (due to the high compliance of the ear canal relative to the eardrum). Assuming a high volume of the ear canal and middle ear cavity of boys compared to girls [27], it is possible to justify the greater effect of gender on Y200 than compensated YPP values using a 1000-Hz probe tones. Maybe for this reason in our study, gender has no significant effect on compensated YPP values, but Y200 has shown significant differences between boys and girls. This finding is consistent with Roush et al. [28] results. They found that gender had no effect on compensated YPP values in 88 neonates with a mean age of 5.2 months. Kei et al. evaluated Y200 and YPP compensated values in 122 infants aged one to six days [1]. According to the report, gender had no significant effect on Y200 and YPP. The reason for the lack of gender effects on Y200 values is the low birth age of infants compared to the samples in our study. In the study of Hanks and Rose, gender had no significant effect on compensated YPP and Y200 [19]. In our study, the reason for the lack of gender effects on the Y200 can be attributed to the use of 226-Hz probe tone in immittance evaluation.

It was also observed that in both ears, with increasing age and weight, the compensated YPP and Y200 values obtained with the 1000-Hz probe tone also increased. This finding is consistent with Roush et al. [28], Keefe and Levi [7], and Mazlan et al. [14] findings. Increased compensated YPP and Y200 with age can be due to the growth of the infant's ear. In particular, changes in the volume of the outer ear and middle ear cavity are high in the first year of life. Although the increase in the volume of the outer and the middle ear increases the compensated YPP and Y200 values, but as the baby grows older the reduction in mass (increase in stiffness) of the ear canal and middle ear has greater effect on these values [29]. To further discuss about the effect of age, we can refer to the study of Palva et al. The results of this study indicate that volume of mastoid antrum at birth is 1 to 1.5 cm^3, and mastoid cells grow to an average of 1 to 1.2 cm^3 each year up to the age of six [30]. Also, after the birth, the length and diameter of the Eustachian tube increases. Since the Eustachian tube connects the middle ear space to the nasopharynx [31], increasing the volume of the Eustachian tube can increase the volume of the middle ear. A study of weight effect can also be found in Judipour et al., [32]. This study was performed on 1712 newborn infants and the results indicate a positive linear correlation between neonate weight and head circumference ($p<0.001$). Accordingly, the weight effect on compensated YPP and the Y200 values can be attributed to an increase in the volume of the external ear canal and middle ear. Because of excessive fluid accumulation in the brain of people with hydrocephalus, they have a larger head circumference [33]. Therefore, to study the effect of weight on tympanometric characteristics, in the present study, all newborns lacked any criteria for hydrocephalus [34].

Conclusion

In both ears, gender had no significant effect on YPP values ($p>0.05$), but Y200 values in the girls and boys group were significantly different, which can be explained by the difference between the compliance of eardrum and external ear canal. However, the ear type (right/left) has no effect on compensated YPP and Y200 values. There was also a linear relationship between age and weight with compensated YPP and Y200 values, so that compensated YPP and

Y200 increased with increasing weight and age. It can be said that age and weight with their influences on the impedance and physical properties of the eardrum and ear canal, affect the high frequency tympanometry characteristics.

Acknowledgments

This work was supported by grant NO 9311145901 from Deputy of Research of Hamadan University of Medical Sciences.

Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Kei J, Allison-Levick J, Dockray J, Harrys R, Kirkegard C, Wong J, et al. High-frequency (1000 Hz) tympanometry in normal neonates. J Am Acad Audiol. 2003;14(1):20-8.
2. Emadi M, Rezaei M, Hamidi Nahrani M, Bolandi M. High frequency tympanometry (1,000 Hz) for neonates with normal and abnormal transient evoked otoacoustic emissions. J Audiol Otol. 2016; 20(3): 153–157. doi: 10.7874/jao.2016.20.3.153
3. Mazlan R, Kei J, Hickson L, Khan A, Gavranich J, Linning R. High frequency (1000 Hz) tympanometry findings in newborns: normative data using a component compensated admittance approach. Australian and New Zealand Journal of Audiology, The. 2009;31(1):15-23. doi: 10.1375/audi.31.1.15
4. Suckfüll M, Schneeweiss S, Dreher A, Schorn K. Evaluation of TEOAE and DPOAE measurements for the assessment of auditory thresholds in sensorineural hearing loss. Acta Otolaryngol. 1996;116(4):528-33.
5. Holte L, Margolis RH, Cavanaugh RM Jr. Developmental changes in multifrequency tympanograms. Audiology. 1991;30(1):1-24.
6. Swanepoel de W, Werner S, Hugo R, Louw B, Owen R, Swanepoel A. High frequency immittance for neonates: a normative study. Acta Otolaryngol. 2007;127(1):49-56. doi: 10.1080/00016480600740563
7. Keefe DH, Levi E. Maturation of the middle and external ears: acoustic power-based responses and reflectance tympanometry. Ear Hear. 1996;17(5):361-73.
8. Hunter LL, Margolis RH. Multifrequency tympanometry: current clinical application. Am J Audiol. 1992;1(3):33-43. doi: 10.1044/1059-0889.0103.33
9. Meyer SE, Jardine CA, Deverson W. Developmental changes in tympanometry: a case study. Br J Audiol. 1997;31(3):189-95.
10. Murakoshi M, Takeda S, Wada H. Analysis by finite element method of dynamic characteristics of the external ear canal in neonates. Journal of Biomechanical Science and Engineering. 2017;12(2):16-00596-16-. doi: 10.1299/jbse.16-00596
11. Alaerts J, Luts H, Wouters J. Evaluation of middle ear function in young children: clinical guidelines for the use of 226- and 1,000-Hz tympanometry. Otol Neurotol. 2007;28(6):727-32.
12. Keith RW. Impedance audiometry with neonates. Arch Otolaryngol. 1973;97(6):465-467. doi: 10.1001/archotol.1973.00780010479007
13. Sprague BH, Wiley TL, Goldstein R. Tympanometric and acoustic-reflex studies in neonates. J Speech Hear Res. 1985;28(2):265-72.
14. Mazlan R, Kei J, Hickson L, Stapleton C, Grant S, Lim S, et al. High frequency immittance findings: newborn versus six-week-old infants. Int J Audiol. 2007;46(11):711-7. doi: 10.1080/14992020701525858
15. Wiley TL, Cruickshanks KJ, Nondahl DM, Tweed TS. Aging and middle ear resonance. J Am Acad Audiol. 1999;10(4):173-9.
16. Margolis RH, Goycoolea HG. Multifrequency tympanometry in normal adults. Ear and Hearing. 1993; 14(6):408-13.
17. Holte L. Aging effects in multifrequency tympanometry. Ear Hear. 1996;17(1):12-8.
18. Shahnaz N, Davies D. Standard and multifrequency tympanometric norms for Caucasian and Chinese young adults. Ear Hear. 2006;27(1):75-90. doi: 10.1097/01.aud.0000194516.18632.d2
19. Hanks WD, Rose KJ. Middle ear resonance and acoustic immittance measures in children. J Speech Hear Res. 1993;36(1):218-22.
20. Dessai TD, Mereen RB, Anupama PS. Tympanometry in neonates- a comparative study. Acad J Ped Neonatol. 2017;3(1):555604. doi: 10.19080/AJPN.2017.03.555604
21. Shahnaz N, Miranda T, Polka L. Multifrequency tympanometry in neonatal intensive care unit and well babies. J Am Acad Audiol. 2008;19(5):392-418.
22. Weichbold V, Nekahm-Heis D, Welzl-Mueller K. Universal newborn hearing screening and postnatal hearing loss. Pediatrics. 2006;117(4):e631-6. doi: 10.1542/peds.2005-1455
23. Margolis RH, Bass-Ringdahl S, Hanks WD, Holte L, Zapala DA. Tympanometry in newborn infants--1 kHz norms. J Am Acad Audiol. 2003;14(7):383-92.
24. McPherson B, Smyth V, Scott J. External ear resonance as a screening technique in children with otitis media with effusion. Int J Pediatr Otorhinolaryngol. 1993;25(1-3):81-9.
25. Munro KJ, Howlin EM. Comparison of real-ear to coupler difference values in the right and left ear of hearing aid users. Ear Hear. 2010;31(1):146-50. doi: 10.1097/AUD.0b013e3181b8399b
26. de Moraes TF, Macedo Cde C, Feniman MR. Multifrequency tympanometry in infants. Int Arch Otorhinolaryngol. 2012;16(2):186-94. doi: 10.7162/S1809-97772012000200006
27. Palmu A, Puhakka H, Rahko T, Takala AK. Diagnostic value of tympanometry in infants in clinical practice. Int J Pediatr Otorhinolaryngol. 1999;49(3):207-13.
28. Roush J, Bryant K, Mundy M, Zeisel S, Roberts J. Developmental changes in static admittance and tympanometric width in infants and toddlers. J Am Acad Audiol. 1995;6(4):334-8.
29. Lindeman P, Holmquist J, Aberg B. Ear drum mobility and middle ear volume measured with tympanometry. Scand Audiol. 1984;13(3):147-50.
30. Palva T, Northrop C, Ramsay H. Spread of amniotic fluid cellular content within the neonate middle ear. Int J

Pediatr Otorhinolaryngol. 1999;48(2):143-53.
31. Adel Ghahraman M, Samimi Ardestani SH, Sadeghniiat Haghighi K. Eustachian tube dysfunction in patients with severe sleep disordered breathing: evidence from inflation-deflation test. Aud Vest Res. 2016;25(4):215-20.
32. Judipour Z, Alimalayeri F, Bagheri S, Bazzi A, Judipour M, Judipour M. [A Survey on anthropometric parameters of neonates at birth and some effective demographic factors in sistan region]. JIUMS. 2015; 23(4):106-13. Persian.
33. Bolandi Shirejini M, Farahani A, Nazeri A. The application of subjective visual vertical in balance system disorders. Aud Vest Res. 2018;27(1):1-11.
34. Hebb AO, Cusimano MD. Idiopathic normal pressure hydrocephalus: a systematic review of diagnosis and outcome. Neurosurgery. 2001;49(5):1166-84; discussion 1184-6.