

High Frequency Tympanometry (1,000 Hz) for Neonates with Normal and Abnormal Transient Evoked Otoacoustic Emissions

Maryam Emadi¹, Mohammad Rezaei¹, Morteza Hamidi Nahrani¹, and Masoud Bolandi²

¹School of Rehabilitation Sciences, Hamadan University of Medical Sciences & Health Services, Hamadan,

²School of Rehabilitation Sciences, Shahid Beheshti University of Medical Sciences & Health Services, Tehran, Iran

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Address for correspondence

Maryam Emadi, Msc
 School of Rehabilitation Sciences,
 Hamadan University of
 Medical Sciences & Health Services,
 2 Shahid Fahmideh Avenu, Hamadan,
 Iran

Tel +8138381571

Fax +8138381572

E-mail maryam_e48@yahoo.com

Background and Objectives: This paper aimed at evaluating the characteristics of high-frequency (1,000 Hz) acoustic admittance (y_a) for the neonates with transient evoked otoacoustic emissions (TEOAE) as either pass or refer group. **Subjects and Methods:** Using a 1,000 Hz probe tone, 297 neonates (152 male, 145 female aged 0–104 days old) were evaluated. Tympanometric parameters admittance value at +200 dapa, middle ear admittance, and tympanometric peak pressure were calculated for each tympanogram. **Results:** The mean of y_a was 0.9678 mmho in the TEOAE for the pass group and 0.7229 mmho in the refer group. The mean of acoustic admittance at +200 (y_{200}) was 2.0657 in the TEOAE for the pass group and 1.7191 for the refer group. The mean of T_{pp} was 23/8591 in the TEOAE for the pass group and 59/7619 for the refer group. **Conclusions:** There were significant differences in the distribution of different types of tympanograms, the mean of y_a , tympanic peak pressure, and y_{200} between the TEOAEs for the pass and the refer groups.

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KEY WORDS: Infant hearing · Otoacoustic emissions · Tympanometry · Static peak admittance · Tympanic peak pressure.

Introduction

Tympanometry is one the most important audiological tests for the assessment of neonatal hearing screening programs. Accurate assessment of a newborn infant hearing can provide adequate rehabilitation if necessary. As slight and mild conductive hearing loss may confound the interpretation of the results, it is important to distinguish sensorineural from conductive hearing loss [1].

Newborns and infants with mild conductive hearing loss often fail in hearing screenings, resulting in higher false positive rates that may lead to increased anxiety for parents [1,2]. The structures of the outer and the middle ear get the structures of an adult's when the child is nine years old. During the first few months of life, the most rapid changes occur in

the outer and the middle ear; for example, the angle of the tympanic membrane increases relative to the ear canal and the middle ear cavity continues to grow [3]. In 2007, the Joint Committee on Infant Hearing (JCIH) declared that more than 95% of 1-month-old newborn infants had been screened and after subsequent rescreening, less than 4% of the newborn infants are referred for complete audiological evaluation [4]. By using otoacoustic emission (OAE) and auditory brainstem response, the reference range is 2–5%. Some of these referrals may have a congenital middle ear dysfunction (transient or permanent) [5]. Recent studies revealed that many of young infants, with hearing loss, have a mild to moderate conductive hearing loss [6].

A tympanometry measures the acoustic immittance in the external auditory meatus as a function of air pressure within the external auditory meatus. Tympanogram indicates how the immittance of the ear is altered when the ear canal pressure varies. Peak acoustic admittance (y_a) is composed of two major points, namely admittance of ear canal and admit-

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tance of the middle ear on the lateral surface of tympanic membrane (Y_{tm}) [7]. Conventional immittance evaluation of the middle ear functioning at 226 Hz probe tone is an effective measure of the middle ear function in adults and children; however, using this low frequency is not recommended for infants aged less than 7 months old, due to less sensitivity in identifying the middle-ear pathology [8,9]. Tympanometry with a higher probe frequency may be more sensitive to the middle ear disease in infants rather than that with 226 Hz, since the young infant's middle ear is more mass-dominated rather than a stiffness-dominated system [10,11]. Low-frequency probe tones are more sensitive to evaluate stiffness-dominated systems. Using high-frequency probe tones is suggested for evaluating a middle ear system that is mass-dominated as in the case of young infants [12,13]. Therefore, a number of clinical programs in several countries have included high-frequency tympanometry as a part of the screening protocol. Recent studies have shown promising preliminary results using a 1,000 Hz probe tone in treatment of the middle ear dysfunction for neonates [8,14,15]. However, the normative data for newborn infants have not been confirmed so far [16]. Studies have shown that infants without OAE response can have a normal tympanogram with 226 Hz test tone, even when there are conductive components. Thus, the application of the highest test tone (1,000 Hz) has been suggested by some authors as mild middle ear problems would not be detected by the 226 Hz probe [15].

The present study aimed at establishing normative data obtained from a large group of newborn babies to compare the middle ear admittance values between the infants who passed OAE and those that failed in OAE.

Subjects and Methods

Subjects

A total of 297 (152 male and 145 female) normal neonates, (589 ears), born at Fatemeh Hospital, Hamedan, Iran were evaluated by tympanometry and OAE screening. Some subjects could not be tested, or only one ear was tested, due to irritability and restlessness. The neonates were 1–104 days old [mean=10.58, standard deviation (SD)=13.82] and their weight 1,870–7,250 g (mean=3422, SD=758.48).

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.

The neonates admitted in intensive care unit or transferred from another institution after birth were excluded from the

project. Medical records included the following risk factors for sensorineural hearing loss identified in JCIH (2,000). 1) family history of genetic hearing loss, 2) intrauterine infection, 3) craniofacial anomaly, 4) birth weight less than 1,500 g, 5) hyperbilirubinemia requiring exchange transfusion, 6) bacterial meningitis, 7) administration of ototoxic drug, 8) apgar less than 0–4, 9) History of assisted ventilation, 10) clinical features associated with conductive or sensorineural hearing loss. The inclusion criterion for infants was their age (between 1 to 3 months old).

The visual inspection of ear was conducted to assess the appropriate probe size and to check the physical abnormalities of the outer ear. Transient evoked otoacoustic emission (TEOAE) and high-frequency immittance tests were performed.

Equipments and conditions

A GSI (Grason-Stadler Inc., Eden Prairie, MN, USA) me 1,001,086 Tymptstar Middle-Ear Analyzer (GSI Company, Minnesota, MN, USA) was used to record the immittance measures. A high-frequency probe tone of 1,000 Hz was utilized to measure Y-admittance tympanograms, with a positive to negative pressure sweep of 200 dapa at a pump speed of 50 dapa/s, as recommended for young infants [17]. TEOAE was performed with the Maico system (Maico Company, Berlin, Germany). Every day before the test, the device was calibrated by 2 cc coupler. This test includes the faster and less expensive OAE as the first test in newborns with no risk factors. The OAE test was done by an audiologist. Click stimulus was offered at the intensity of 83 dB SPL with rate of 50 per second. The time required for the test is about 1–3 min. The newborn should be quiet (preferably in sleep or while breastfeeding) and the ambient noise should be in the least amount possible. The pass criterion for TEOAE was 6 dB signal to noise ratio.

Results

The percentage of tympanogram types in participants are presented in Fig. 1. As shown in the figure, most frequent tympanogram in these infants was one peak type. The results show that 96.4% (568 ears) had one peak tympanogram, 0.8% (5.589) had bipeak, 2% (12.589) flat, and 0.6% (4.589) had unclassical tympanogram. Table 1 shows types of tympanograms according to passing or failing in TEOAE test. There were SD between the type of tympanograms distribution between the pass and refer groups.

The mean of acoustic admittance (ya) was 0.9678 mmho with 0.5225 SD in the TEOAE for the pass group and 0.7229

mmho with 0.6494 SD in the TEOAE for the refer group. The difference between the ya between the two groups was statistically significant.

The mean of the acoustic admittance at +200 (y200) was 2.0657 with SD 0.4785 in the TEOAE for the pass group and 1.7191 with SD 0.6282 in the TEOAE for the refer group. There was a significant difference between the two groups.

There was a significant difference in the tympanic peak pressure (Tpp) between the TEOAE for the pass and the refer group. The mean of Tpp was 23.8591 with SD 65.4879 in the TEOAE for the pass group and 59.7619 with SD 72.4581 in the TEOAE for the refer group (Table 2).

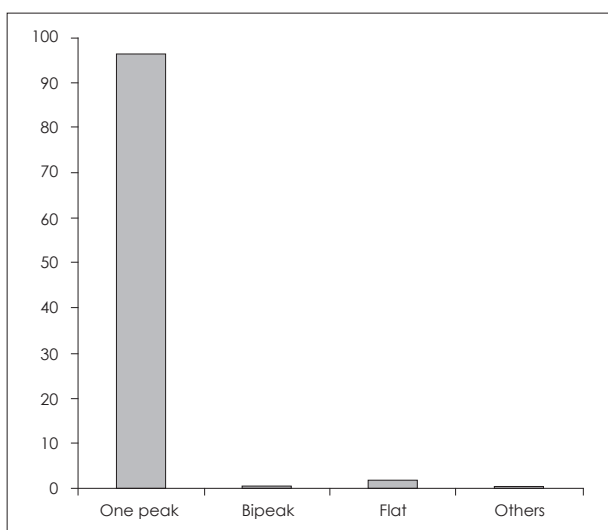


Fig. 1. Percentage of tympanograms for 297 participated infants.

The mean of ya was 0.9684 for the boys and 0.8681 for the girls. This difference was statistically significant. There was no significant statistical difference, based on Tpp, between the boys and the girls. There was also a significant difference between y200 as a function of gender (Table 3). The mean of y200 for the boys was 2.0857 with SD 0.5519 and 1.9042 with SD 0.4890 for the girls.

Discussion

The detection and follow-up of otologic diseases during the first months of life are important. The otologic assessment of the middle ear dysfunction in infants is more accurate when added to immittance test.

The main goal of this study was to obtain normative data of 1,000 Hz tympanogram in neonates, and the second goal was comparing the high-frequency immittance measures obtained from the pass TEOAE and the refer TEOAE test on neonates aged 0–3 months old. The results showed that most of the neonates had one peak tympanogram (96.4%) and 0.8% had bipeak, 2% flat, and 0.6% had unclassical type of tympanogram. These results were conform to the results by Kei, et al. [14] and Swanepoel, et al. [17] who reported a peaked tympanogram in 93.4% of 228 ears in neonates (1–4 weeks of age). The 1,000 Hz tympanometric peak in the present study and those reported by Kei, et al. [18] are also similar to a 678 Hz probe tone study results conducted on a group of 200 babies hospitalized in the neonatal intensive care unit, which indicated 91% of discernible peak tympano-

Table 1. Comparison types of tympanogrames according to pass or refer in TEOAE test

Variables	Pass	Fail	Total	R square	df	p-value
One peak	463 (81.8%)	103 (18.2%)	566	44.04	3	≤0.001
Bipeak	5 (100%)	0	5			
flat	2 (15.4%)	11 (84.6%)	13			
Unclassic	1 (25%)	3 (75%)	4			

TEOAE: transient evoked otoacoustic emissions

Table 2. Comparison normative tympanometry data according to pass or refer in TEOAE test

Variables	Number	Mean	SD	t	df	p-value
ya				0.243	587	≤0.001
TEOAE (pass)	472	0.967	0.522			
TEOAE (fail)	117	0.723	0.649			
Tpp				-35.90	575	≤0.001
TEOAE (pass)	472	23.85	0.442			
TEOAE (fail)	105	59.76	0.791			
y200				0.346	587	≤0.001
TEOAE (pass)	472	2.065	0.478			
TEOAE (fail)	117	1.719	0.628			

TEOAE: transient evoked otoacoustic emissions, Tpp: tympanic peak pressure, ya: acoustic admittance, y200: acoustic admittance at +200

Table 3. Comparison normative tympanometry data between gender

Variables	Number	Mean	SD	t	df	p-value
ya				2.189	587	≤0.001
Boy	301	0.968	0.587			
Girls	287	0.868	0.523			
Tpp				0.249	587	0.001
Boys	301	31.08	66.14			
Girls	287	29.66	70.33			
y200				4.21	587	≤0.001
Boys	301	2.08	0.551			
Girls	287	1.90	0.489			

Tpp: tympanic peak pressure, ya: acoustic admittance, y200: acoustic admittance at +200

grams.

The reasons for incidence of various types of tympanograms in the present study is unknown. The reasons may be normal variation within the population, a slight middle ear dysfunction unable to obliterate TEOAE, maturation delay of middle ear system of the neonates, the probe tone is not high enough for some neonates, inadequate probe seal, and movement artifacts.

The 1,000 Hz tympanometric peak for neonates in the this study and those reported by Kei, et al. [14] also conform to the 678 Hz probe tone study conducted on a group of 200 babies hospitalized in the neonatal intensive care unit, which indicated 91% of peak tympanograms in babies [18]. Double peaked tympanograms were also reported by Kei, et al. [14] in 1.2% of the peaked tympanogram ears while it was 6% in the current study. The higher incidence of double peaked tympanograms may be due to the larger neonatal age range in the current study (14 weeks) [15]. All double peaked tympanograms in the study by Kei, et al. [14] were accompanied by OAE pass results, corresponding to the high percentage of ears in the current study with OAE pass results. These results suggest that double peaked tympanograms are indicative of normal middle ear transmission and also conform to the previous reports suggesting that double peak tympanograms are not uncommon and are suggestive of normal middle ear transmission for 1,000 Hz probe tone measurements [19].

The mean peak-compensated static admittance value of neonates at birth in the present study was significantly higher (0.9678 mmho with SD 0.5225) in the TEOAE of the pass group than the TEOAE refer group (0.7229 mmho with SD 0.6494). The presence of normal OAE provides assurance of normal middle ear function although a small proportion of individuals with middle-ear pathology can pass the TEOAE test.

The significantly higher static acoustic peak admittance values for the boys can primarily be due to the difference in the middle ear and tympanic membrane sizes for female and

male ears [7]. This difference highlights the consideration of gender in establishing normative high-frequency tympanometry data. Statistically significant differences in the peak admittance values ($p < 0.05$) (t-test with pooled variance) for younger and older neonates indicate a general increase in admittance with increasing the age. However, this trend is observed mostly for ears of the males.

All double peaked tympanograms in the study by Kei, et al. [14] were accompanied by TEOAE pass results, corresponding to the high percentage of ears in the current study with TEOAE pass results [20]. These results suggest that double peaked tympanograms are indicative of normal middle ear transmission and also correspond to previous reports suggesting that double peak tympanograms are not uncommon and are suggestive of normal middle ear transmission for 1,000 Hz probe tone measurements [19].

The limitations in the present study are followed. First, high-frequency tympanometry may be affected by inability to get a perfect seal in tiny and soft external ear canal of neonates. Second, errors in measurements may also be related to the variations in high-frequency tympanometry results, as in some cases the probe had to be hand-held in the ears of the neonates.

In summery, the characteristics of high-frequency tympanograms for the neonates with normal and abnormal TEOAE results have been described in the present study. There was significant differences between the means of ya, Tpp, and y200 between the TEOAE pass and refer groups. The norm may be served as a guide for detecting the middle ear function in neonates. Correct identification of the middle ear position in neonatal period could direct timely and correct referrals to medical and audiological personnel, which that may lead to improved efficacy of neonatal hearing screening programs.

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Conflicts of interest

The authors have no financial conflicts of interest.

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