Research Type: *Original Research*

Multifrequency tympanometry

Multifrequency tympanometry findings in Newborns and Infants

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Abstract

Objectives: We aimed to evaluate the correlation between transient otoacoustic emission and multifrequency tympanometry measurements in the ages of 0-28 weeks neonates and infant group in this study.
Materials and Methods: In this study, 245 right and left ears, screened by transient otoacoustic emission were evaluated in Hacettepe University Audiology and Speech Pathology Department. Tympanometric and transient otoacoustic emission measurements were applied after otoscopic examination. During analysis, SPSS 13,0 statistics programme was used. Ethics Committee approval was taken for this study. (Date of ethics committee approval:24.05.2007; LUT 07/43-18).
Results: Although there were not any significant difference in tympanometric peak pressure, we just found significant difference in left ears according to static acoustic admittance who passed and who did not pass transient otoacoustic emissions in 226-678-1000 Hz probe tones. Also we found significant difference in tympanometric types in babies who passed and who did not pass transient otoacoustic emission.
Conclusion: The use of 226 Hz probe tone tympanometry to detect middle ear dysfunction particulary for ages less than seven months may produce contradictory test outcomes**.** Our results indicated that 1000 Hz probe tone tympanometry is valid and efficient way in evaluating middle ear status in newborns and infants below the ages of 28 weeks.

Keywords: Acoustic impedance test; infant; newborn; otoacoustic emission

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Multifrekans Timpanometri

Yenidoğan ve İnfantta Multifrekans Timpanometri Bulguları

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Özet

Amaç: Bu çalışmada 0-28 hafta arasındaki yenidoğan ve infant grubunda Transient Oto-akustik Emisyon (TEOAE) ve Multifrekans Timpanometri (MFT) arasındaki ilişkinin değerlendirilmesi amaçlanmıştır.
Gereç ve Yöntem: Bu çalışmaya Hacettepe Üniversitesi Tıp Fakültesi Kulak Burun Boğaz Anabilim Dalı Odyoloji ve Konuşma Bozuklukları Ünitesinde işitme taraması yapılan ve 0-28 hafta arası 245 kulak sağ ve sol olarak aynı gün değerlendirmeye alındı. Bebeklere otoskopik muayene yapıldıktan sonra impedansmetrik değerlendirme ve TEOAE ölçümü yapıldı. Analizler yapılırken SPSS 13,0 istatistik programı kullanıldı. Çalışma için Etik Kuruldan onay alındı (Etik kurul onay tarihi: 24.05.2007; LUT 07/43-18). .
Bulgular: TEOAE 'dan geçen bebeklerde her iki kulakta 226-678 ve 1000 Hz prob tonda timpanometrik tepe basınç değerleri açısından anlamlı fark bulunmazken, sol kulakta statik admitans değerleri açısından anlamlı fark elde edildi. TEOAE'dan kalan bebeklerde ise sadece sol kulakta timpanometrik tepe basınç değerlerinde anlamlı fark bulundu. TEOAE'dan geçen ve kalan bebeklerde timpanogram tiplerine göre anlamlı fark saptandı.
Sonuç: 226 Hz prob ton kullanılarak yapılan orta kulak fonksiyon değerlendirmelerinin, özellikle yedi aydan küçük bebeklerde çelişkili test sonuçları vermektedir. Çalışmamızda 28 haftadan küçük yenidoğan ve infant grubunda alçak frekans timpanometri kullanımının yetersiz olduğu, 1000 Hz prob ton kullanımının ise daha güvenilir ve odyolojik test bataryasının önemli bir parçası olduğu düşünülmektedir.

Anahtar kelimeler: Akustik impedans test; infant; yenidoğan; otoakustik emisyon.

Sorumlu Yazar: Nezehat Özgül Ünlüer, Hacettepe Üniversitesi, Tıp Fakültesi Fizik Tedavi ve Rehabilitasyon Anabilim Dalı, 06100 Sıhhiye/Ankara 03123051356.

Introduction

In order to determine the sensitivity of hearing both in newborns and infants, both behavioral and electrophysiological test methods are used (Jacobson and Jacobson, 2004). Otoacoustic emission test (OAE), auditory brain stem response (ABR) and tympanometry are among the primarily used objective methods. The transient otoacoustic emission (TEOAE) measurement is preferred especially in hearing screening of newborns since it is easier to use and the duration of the test is shorter (McKinley, Grose, and Roush, 1997; Doyle, Rodgers, Fujikawa, and Newman, 2000). Tympanometric evaluation is carried out routinely in many clinics during audiological and otological evaluation. Clinical acoustic immitance measurements are frequently made with low frequency probe tones such as 220 Hz and 226 Hz (Fowler and Shanks, 2002). The reliability of middle ear function evaluations measured using 226 Hz probe tone frequency were found to be controversial especially in infants younger than 7-8 months (Hall and Mueller, 1998). It was shown that multi-frequency tympanometry (MFT) carried out using 500 Hz or over probe tones yielded more accurate results clinically, particularly in infants (Purdy and Willams, 2000). MFT is a test method that takes measurements between the frequencies of 200-2000 Hz probe tone, enables acoustic immitance measurement at many probe tone frequencies, and evaluates the resonance frequency of middle ear. The most commonly used frequencies are 600/678, 800, and 1000 Hz probe tone (Shanks, Wilson, and Cambron, 1993; Wiley and Fowler, 1997). The aim of the present study is to evaluate the relation between TEOAE and MFT in newborn and infant groups between 0-28 weeks.

Materials and Methods

One hundred twenty five newborns and infants between the ages of 0-28 weeks, born at the Hacettepe University and underwent hearing screening in Audiology and Speech Pathology Unit, were included in the present study. Evaluations were made both on right and left ears at the same day, resulted in a total of 245 ears. In the initial evaluation all infants who passed the TEOAE test and underwent the otoscopic examination were included in the study. Cases who failed the TEOAE test underwent the Auotomated Auditory Brainstem Response (A-ABR) test in order to determine if they have any risk factors in terms of hearing loss. Five ears who failed the A-ABR test were excluded from the study. Signed informed consent forms were obtained from families for the participation of the babies in the study (Approval date of ethics committee: 24.05.2007; LUT 07/43-18). For the reliability and convenience of measurements, newborns and infants

were evaluated in a relaxed state, or during sleep in their beds or the lap of their mothers. Information on etiological factors was obtained from the families of all newborns and infants and was recorded to information forms for each baby. Table 1 demonstrates the distribution of etiological factors for newborns and infants, and Table 2 shows the age range, delivery week, and weight at birth of newborns and infants.

Newborns included in the study underwent the following evaluations:

Evaluation of hearing screening with TEOAE

Evaluation of TEOAE in newborn and infants was made with GN *Otometrics MADSEN Accuscreen PRO* screening emission device at the volume of 40dB SPL with non-linear 60 Hz click stimulus. According to the size of external auditory canal, measurements were made with 3mm or 4mm probe tip, and results were automatically evaluated as passed or failed. If the baby failed the TEOAE test, A- ABR was carried out.

Evaluation of hearing screening with A- ABR

All A-ABR measurements were made using the 35dB nHL narrow band click stimulus with Madsen Accuscreen Pro-screening ABR device. Results of the measurement were obtained automatically as passed or failed.

Multi-frequency tympanometric evaluation

MFT evaluation was carried out with GSI TympStar Version 2 Middle Ear Analyzer. In the automatic evaluation, pressure varying between +200 and -400 daPa was used. It was performed at 200/600 dapa/second speed and from positive to negative. Tympanogram types were interpreted according to the Liden and Jerger classification system. Type A refers to normal middle ear function; Type B refers to situations where peak value cannot be obtained; Type C is the tympanogram type with amplitude at negative or positive middle ear pressure (Martin and Clark, 2003); and Type D is the tympanogram with double peaks at normal middle ear pressure. Atypical tympanogram is a type of tympanogram which does not suit any of the A, B, C, and D tympanogram types seen in high frequency probe tones (Fowler et al, 2002; Kei et al, 2003; Baldwin 2006). By using 226-678-1000 Hz probe tones, tympanometric peak pressure values, static admittance values, and tympanogram types of all subjects were obtained.

Table 1: The distribution of etiological factors in newborn and infants

GENDER	**Number (n)**
Female	65
Male	60
RISK FACTORS	
Hearing loss in the family	9
Marriage between relatives	9
Genetic anormaly	-
Admission Intensive Care Unit	4
Ototoxic drug use	3
Incubator	17
Oxygen deficiency	-
Operation	2
Phototherapy	6

Table 2: Age range, delivery week and birth weight values in newborn and infants

	Minimum-Maximum	**Mean ± SD**
	(n: 125)	
Birth weight (g)	1700-4700	3210 ± 521
Delivery date (weeks)	38-41	38.20 ± 0.98
Chronological age (weeks)	1-28	11.10 ± 9.23

Statistical evaluation of data

Statistical analyses were performed using the SPSS software version 13. Shapiro-Wilk test was used to investigate normality of the distribution of continuous variables. The

descriptive statistics were given as the mean ± standard deviation or median (minimum-maximum) for continuous variables, and as the number of patients and percent value (%) for categorical variables. Proportions of patients were presented using cross tabulations. The Chi-square test or Fisher's exact test (when chi-square test assumptions do not hold due to low expected cell counts), where appropriate, was used to compare these proportions in different groups. A p-value of less than 0.05 was considered to show a statistically significant result. Friedman tests were conducted.

Results

One hundred twenty five newborn and infants at the age of 0-28 weeks delivered at the Hacettepe University and who underwent the screening test at the Audiology and Speech Disorders Clinic were used in the study. Results were reported for over 245 ears for right and left ears separately. Findings obtained from infants included in the study are presented below. In Table 3, the number of infants passing or failing the TEOAE test is given.

Multi-frequency tympanometry findings

Multi-frequency tympanometry findings of infants who passed the TEOAE test: Ears passing the TEOAE test, static admittance values, and tympanometric peak pressure values were obtained at 226-678 and 1000 Hz probe tones, and demonstrated in Table 4 and 5.

Table 3: The number of ears which passed or failed the TEOAE measurement

	The number of ears that passed the TEOAE (n)	**The number of ears that failed the TEOAE (n)**
Right ear	109	16
Left ear	105	15

Table 4: Static admittance (mmho) and tympanometric peak pressure values (daPa) at 226-678 and 1000 Hz probe tones for infants who passed theTEOAE at right ear

MF Probe tone	**SA(mmho) Mean±SD**	**F**	**P**	**TPP(daPa) Mean±SD**	**F**	**P**
226Hz	0.81±0.63			-16.9± 82.98		
1000Hz	1.22±2.94			1.50± 67.10		

MF:Multifrequency, SA:Static Admittance, TPP:Tympanometric Peak Pressure

For infants who passed the TEOAE test at the right ear, no significant difference was found between the static admittance values and tympanometric peak pressure values at 226-678-1000 Hz probe tone frequencies.

Table 5: Static admittance (mmho) and tympanometric peak pressure values (daPa) at 226-678 and 1000 Hz probe tones for infants who passed the TEOAE at left ear

MF Probe tone	**SA(mmho) Mean±SD**	**F**	**P**	**TPP (daPa) Mean±SD**	**F**	**P**
226Hz	0.82±0.61			-11.95±83.0		
678Hz	0.67±0.50	4.21	0.01*	-11.08±94.27	0.37	0.68
100Hz	0.93±0.73			-2.70±75.90		

*p<0.05

MF:Multifrequency, SA:Static Admittance, TPP:Tympanometric Peak Pressure

For infants who passed the TEOAE test in the left ear, in the comparison of static admittance values at 226-678-1000 Hz probe tone frequencies, a significant difference was found between 678-1000 Hz (p=0.01) while no difference was found in tympanometric peak pressure values.

Multi-frequency tympanometry findings of infants who failed the TEOAE test: For ears that failed the TEOAE test, static admittance values and tympanometric peak pressure values obtained at 226-678, and 1000 Hz probe tone frequencies are demonstrated in Table 6 and 7.

Table 6: Static admittance (mmho) and tympanometric peak pressure values (daPa) at 226-678 and 1000 Hz probe tone frequencies for infants who failed the TEOAE at right ear.

MF Probe tone	**SA(mmho) Mean±SD**	**F**	**P**	**TPP(daPa) Mean±SD**	**F**	**P**
226Hz	0.71 ± 0.43			-41.87 ± 121.10		
1000Hz	1.64 ± 0.58			-148.00 ± 249.91		

MF:Multifrequency, SA:Static Admittance, TPP:Tympanometric Peak Pressure

For infants who failed the TEOAE test in the right ear, no significant difference was found in static admittance and tympanometric peak pressure values at 226-678-1000 Hz probe tone frequencies.

For infants who failed the TEOAE test in the left ear, no significant difference was found between static admittance values at 226-678-1000 Hz probe tone frequencies.

In the comparison of tympanometric peak pressure values in the left ear of the same subjects at 226-678-1000 Hz probe tone frequencies, a significant difference was found between 226 and 1000 Hz frequencies ($p=0.02$).

The comparison of multi-frequency tympanometry type: In right and left ears passing or failing the TEOAE test, multi-frequency types were compared at 226-678, and 1000 Hz probe tone frequencies and are shown in Table 8 and 9.

Table 7. Static admittance (mmho) and tympanometric peak pressure values (daPa) at 226-678 and 1000 Hz probe tone frequencies for infants who failed the TEOAE at left ear.

MF Probe tone	**SA(mmho) Mean±SD**	**F**	**P**	**TPP(daPa) Mean±SD**	**F**	**P**
226Hz	0.92 ± 0.60			11.33 ± 46.15		
1000Hz	1.66 ± 0.50			-130.00 ± 179.73		

* $p < 0.05$

In the MF tympanometric evaluation made at right ears of the subjects passing or failing the TEOAE test at 678 and 1000 Hz probe tone frequencies, a significant difference was found between different tympanogram types (p=0.00).

In the MF tympanometric evaluation made at left ears of the subjects passing or failing the TEOAE test at 1000 Hz probe tone frequency, a significant difference was found between different tympanogram types (p=0.00).

Table 8: The comparison of MFT types in right ears passing or failing the TEOAE

		TEOAE					
		Passed		Failed		X^2	p
Right ear		**N**	**%**	**N**	**%**		
	Type A	79	86.8%	12	13.2%		
	Type B	4	80.0%	1	20.0%		
226 Hz	Type C	0	0%	1	100.0%	6.25	0.17
	Type D	25	92.6%	2	7.4%		
	Atypical	1	100%	0	0%		
	Type A	87	93.5%	6	6.5%		
678 Hz	Type B	4	40.0%	6	60.0%		
	Type C	4	80.0%	1	20.0%	18.17	0.00*
	Type D	2	100.0%	0	0%		
	Atypical	12	80.0%	3	20.0%		
	Type A	105	93.8%	7	6.2%		
1000 Hz	Type B	1	12.5%	7	87.5%	34.18	0.00*
	Type C	2	66.7%	1	33.3%		
	Type D	1	100.0%	0	0%		
	Atypical	0	0%	1	100.0%		

*$p<0.05$

Table 9: The comparison of MFT types in left ears passing or failing the TEOAE

		TEOAE					
		Passed		Failed		X^2	p
Left ear		**N**	**%**	**N**	**%**		
	Type A	76	88.4%	10	116%		
226 Hz	Type B	3	100.0%	0	0%	0.68	0.69
	Type D	26	83.9%	5	16.1%		
	Type A	85	90.4%	9	9.6%		
678 Hz	Type B	4	66.7%	2	33.3%		
	Type C	4	50.0%	1	50.0%	7.25	0.08
	Type D	2	75.0%	1	25.0%		
	Atypical	12	85.7%	2	14.3%		
	Type A	99	90.8%	10	9.2%		
1000 Hz	Type B	2	33.3%	4	66.7%		
	Type C	1	50.0%	1	50.0%	14.85	0.00*
	Type D	2	100.0%	0	0%		
	Atypical	1	100.0%	1	0%		

*$p<0.05$

Discussion

Tympanometry is the dynamic measurement of acoustic immitance with functional changes in the air pressure in external auditory canal. Tympanometry is used to determine the presence and potential cause of middle ear diseases(Wiley et al, 1997). While, in the early period, acoustic immitance in devices was evaluated with only a single frequency probe tone, more recently MFT devices, which can take measurements at two or more probe tone frequencies, have been started to be used[8]. In MFT devices, as high frequency, 660, 678 and 1000 Hz probe tones are present. According to the Joint Committee on Infant Hearing (Joint Committee on Infant Hearing, 2000), acoustic immitance is an important part of audiological test battery in babies. Immitance related

to mass and stiffness depends largely on frequency (Margolis and Hunter, 1999). At 226 Hz probe tone frequency, in middle ear system, a stiffness effect is seen while with high frequency probe tones, a mass effect becomes more marked (Wiley et al, 1997; Stadler and Garson, 2003). Higher sensitivity of high frequency tympanometry in babies compared to adults is attributed to mass effect at middle ear of babies. Therefore, it is stated that high frequency probe tone is more reliable in the babies for evaluating middle ear systems.

In the present study, for newborn and infants passing from the TEOAE test, a significant difference was found between 678 and 1000 Hz probe tone frequencies in terms of static admittance values in the left ear ($p=0.01$). Kei et al (10) stated in their study on 1-6 dayold healthy newborns that when 1000 Hz probe was used, static admittance value in the right ear was significantly higher. In the study of Margolis et al (2003), it was found that for infants passing from the otoacoustic emission, there was an increase in static admittance values at the 1000 Hz probe tone. In the present study, no statistically significant difference was found between tympanometric peak pressure values of infants passing the TEOAE test. However, it was seen that as probe tone frequency increased, tympanometric peak pressure had more positive values. In the evaluation of babies failing the TEOAE test, it was established that there was no significant difference between 226-678 and 1000 Hz probe tone with regard to static admittance values; however, in the left ear, a significant difference was found between 226 and 1000 Hz probe tones in terms of tympanometric peak pressure values ($p=0.02$). In the literature, it is mostly stressed that tympanometric peak pressure values are not much preferred for determining the normal range of tympanogram in hearing screening program, and that it is more important in the monitorisation of middle ear effusion (Edward, 2004).

In the current study, for the comparison of MFT types, no difference was found between babies who pass or fail the TEOAE test at 226 Hz probe tone in terms of MFT types; however, in the immitance evaluation made at 678 and 1000 Hz probe tones in the right ear and the 1000 Hz probe tone in the left ear, a significant difference was found in MFT types ($p< 0.05$). It is thought that this difference may be due to the fact that Type A tympanogram is more common in babies passing the TEOAE test and type B typnaogram is more common in those failing the TEOAE test. In the present study, when the 678 Hz probe tone was used in babies passing the TEOAE test, Type A tympanogram was found at the rate of 93.5% in the right ear and 90.4% at the left ear. When the 1000 Hz probe tone was used, the rate of type A typanogram was 93.8% and 90.8% at right and left ears

respectively, which is consistent with the results reported by other studies. In the study of Kei et al (2003) on 170 healthy newborns at the ages of 1-6 days who passed the TEOAE test, in the evaluation made using the 1000 Hz probe tone, Type A tympanogram was obtained in 92.2% of newborns. In the study of Garcia et al (2009), for infants passing or failing the TEOAE test, no statistically significant correlation was found between the TEOAE measurement and the 226 Hz probe tone. They evaluated the groups in themselves, and found normal tympanogram at the rate of 50% in the right ear of babies who pass or fail the TEOAE test. In the left ear, the rates of normal tympanogram in those who pass or fail the TEOAE test were respectively 52.9% and 47.1% (Garcia, Azevedo, and Testa, 2009). In the present study, when the 226 Hz probe tone was used, for infants who passed the TEOAE test, double peak tympanogram was obtained at the rate of 92.6% at the right ear and 83.9% at the left ear. In the study of Kei et al (2003) on 170 healthy newborns at the ages of 1-6 days who passed the TEOAE test, when the 226 Hz probe tone was used, double peak tympanogram was obtained at the rate of 47.5%. This difference was thought to be related to the fact that infants have smaller age range. In the study of Baldwin (2006) with infants between 2-21 weeks, tympanograms were interpreted using two different classification systems. According to the Liden/Jerger classification system, compared to 226-678, and 1000 Hz probe tones, atypical tympanogram was obtained at a higher rate at the 678 Hz probe tone. But, when the Marchant classification system was used, some of the tympanograms considered atypical at 678 probe tone were interpreted as normal, indicating that the interpretation of atypical tympanograms change with the classification system used. Similarly, in the present study, when the Liden–Jerger classification system and the 678 probe tone frequency were used in infants passing or failing the TEOAE test, atypical tympanograms were hence obtained at a higher rate compared to others.

Clinical experiences and studies reported in the literature demonstrate that high frequency immitance measurements made using the 1000 Hz probe tone yield more reliable results in differentiating false positive screening results related to the middle ear pathology or the transient middle ear effusion (Margolis et al, 1999; Garcia et al, 2009; Swanepoel, Werner, Hugo, Louw, Owen, et al, 2007). Accurate evaluation of the status of middle ear in newborn and infancy period plays an important part in increasing the efficacy of audiological and otological evaluation. In the literature, there are studies, including the studies on MFT, that consider diverse age groups (Baldwin, 2006; Margolis et al, 2003; Swanepoel et al, 2007; Alaerts, Luts, and Wouters et al, 2007; Calanruccio,

Fitzgerald, and Prieve, 2006). However, studies specifically on newborn and infants between 0-28 weeks are scarce. The majority of recent studies consider the use of low frequency tympanometric evaluation in infants until 7-8 months inadequate for screening programs and diagnosis (Hunter and Margolis, 1992; Keefe, Bulen, Arehart, and Burns, 1993).

Conclusion

The results of our study suggest that low frequency tympanometry use is inadequate in the newborn and infant group younger than 28 weeks and that the 1000 Hz probe tone frequency is more reliable and can be an important part of otological test battery.

Conflicts of interest

The authors have no funding or conflicts of interest to disclose.

Disclosure Statement

The authors declare there are no conflicts of interest regarding the data presented in this study.

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