A Preliminary Attempt to Profile Tympanometric Measures in Infants Using High Frequency Probe Tones

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Abstract There is dearth of published data on high frequency tympanometric measures for infants in Indian context. Aim of present study was to profile Peak compensated static acoustic admittance (Ytm), Tympanometric peak pressure (TPP), Tympanometric width (TW) and Equivalent ear canal volume (Vea) in infants. Cross-sectional study on 50 infants with present TEOAEs and with risk indicators for hearing loss. Tympanometry was performed using GSI-Tympstar for 678 and 1000 Hz probe tones. Descriptive statistics were used to determine mean, SD and minimum and maximum for both genders. Using 678 Hz, Ytm ranged from 0.09 to 1.48 mmho (males) and 0.11 to 1.14 mmho (females), while with 1000 Hz ranged from 0.15 to 1.49 (males) and 0.13–1.61 mmho (females). Using 678 Hz, TPP ranged from –95 to 70 daPa (males) and –155 to 80 daPa (females), while with 1000 Hz ranged from –75 to 95 daPa (males) and –145 to 50 daPa (females). Using 678 Hz, TW ranged from 30 to 190 daPa (males) and 40–23 daPa (females), while with 1000 Hz ranged from 60 to 210 daPa (males) and 40–183 daPa (females). Using 678 Hz, Vea ranged from 0.11 to 1.7 mmho (males) and 0.14–2.5 mmho (females), while with 1000 Hz ranged from 0.14 to 2.0 mmho (males) and 0.14–3.6 mmho (males). This study was a preliminary attempt to profile the tympanic measures. Ytm values were lesser or similar to other studies, TPP and Vea values had

lower and narrow range, while TW were more than previous studies.

Keywords Peak compensated static acoustic admittance · Tympanometric peak pressure · Tympanometric width · Equivalent ear canal volume · Tympanometric measures in infants · High frequency tympanometry

Abbreviations

JCIH Joint committee on infant hearing

Introduction

Tympanometry is defined as the dynamic measure of acoustic immittance in the external ear canal as a function of changes in air pressure in the ear canal [1]. It is a safe, quick and objective test for detecting middle ear conditions [2] and therefore is an essential component in the audiological test battery for infants. Evidence suggests that tympanometric measures are age dependent [3, 4]. Acoustic admittance increases with age hence the need for age specific normative values [4, 5]. This could be due to reasons such as increase in admittance as the size of middle ear cavity increases [4] and that the middle ear system responds differently to changes in ear canal pressure in young infants compared to adults [6].

Conventional tympanometry with 226 Hz probe tone has provided significant contribution in the assessment of middle ear status in individuals older than 7 months of age [4, 7, 8]. However, the use of 226 Hz probe tone in infants less than 7 months of age leads to high false-positive and high false-negative rates [5, 9, 10].

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Studies have demonstrated the successful application of higher probe tone frequencies for infants yielding recordings that are more informative [11–18]. American Speech and Hearing Association in 2004 [19] and Joint Committee on Infant Hearing in 2007 [20] have recommended the addition of 1000 Hz into the middle ear assessment battery.

Studies have been reported on infants from American, Australian and African backgrounds using 1000 Hz tympanometry, where differences based on gender, left versus right ear, and age were noted [15, 21, 22] as well as difference for infants from Neonatal Intensive Care Unit [11, 16, 18].

Need of the Study

Studies have reported difference in tympanometric measures based on anatomical differences due to variable ethnicities, age, gender and frequency of probe tone. There is still insufficient profiling of normative range for tympanometric measures in the Indian context especially for infants having some risk indicators for HL. The aim of the present study was to profile the tympanometric measures of peak compensated static acoustic admittance, tympanometric peak pressure, tympanometric width and equivalent ear canal volume in individuals with risk indicators for HL from birth to 6 months of age using high frequency probe tones of 678 and 1000 Hz.

Method

A cross-sectional study design was used to study infants from the Neonatal Intensive Care Unit (NICU) of Kasturba Hospital, Manipal. The study was approved by the Institutional Ethics Committee of Kasturba Hospital (IEC Serial No. 254/2012).

Subjects

Infants in the age range from birth to 6 months age with no current or prior history of middle ear infection with normal hearing sensitivity as determined by the presence of TEOAEs in the presence of risk indicator/indicators for HL were included for the study.

A total of 102 ears of infants in the age range of birth through 6 months were recruited for the study over a 3 month period. For the final sample, only 100 ears (50 participants) were included, wherein 27 were male and 23 were female participants, as two ears did not fulfill the inclusion criterion of a pass result for TEOAE.

Instruments

Otodynamics ILO 292 Version 6 for Transient Evoked Otoacoustic Emission (TEOAE) and Grason-Stadler Tympanometer Version 2 Middle-Ear Analyzer for tympanometry were used for testing after calibration as per ANSI standards (ANSI S3.39, 1987) in a sound treated room.

Procedure

The medical records and clinical history were used as a reference to note the presence of any risk indicators for HL. Infants who fulfilled the inclusion criteria and whose parents or caretakers gave informed written consent were included in the study. Testing was carried out while the infant was asleep.

TEOAE screening was performed. An infant was considered to have passed the TEOAE screening test, if he/she had present TEOAE in three consecutive frequency bands with the signal to noise ratio ≥ 3 dB. Those infants who passed the TEOAE test were then subjected to tympanometry. Tympanometry was done by sweeping the pressure from +200 to –400 daPa at a pump speed of 50 daPa/sec using probe tone frequency of 678 and 1000 Hz, testing both ears in no specific order. As while performing tympanometry with 678 and 1000 Hz, the values for TPP, Ytm and TW are not obtained automatically, the examiner had to locate the peak with the help of a cursor on the screen.

Analysis

Descriptive statistics of mean, standard deviation, minimum and maximum values were obtained for each tympanometric measure for both 678 and 1000 Hz probe tones for both the genders. Statistical Package for the Social Sciences (SPSS) Version 16.0 was used for statistical analysis.

Results

The 50 participants were subdivided according to their gender. The male group consisted of 27 participants (mean age = 35.81 days) and the female group consisted of 23 participants (mean age = 58.87 days). The Fig. 1 shows the distribution of the risk indicator/indicators for HL in both genders.

It can be noted from Fig. 1 that a higher percentage (33.33 % males and 47.83 % females) of tested infants were preterm. The other risk indicators included hyperbilirubinemia, neonatal seizures, preterm delivery and hyperbilirubinemia, preterm delivery and mild respiratory distress syndrome, maternal rubella, meningitis, global developmental delay (GDD), global developmental delay and neonatal seizures and congenital pneumonia.

Fig. 1 Risk indicator for hearing loss **Table 1** Mean (Standard deviation), minimum and maximum values obtained for tympanometric measures using 678 and 1000 Hz probe tones for the male group

Tympanometric measure		678 Hz			1000 Hz		
		Mean (SD)	Min.	Max.	Mean (SD)	Min.	Max.
Peak compensated static acoustic admittance (mmho)	Right	0.35 (0.26)	0.09	1.48	0.54 (0.30)	0.15	1.42
	Left	0.32 (0.17)	0.09	0.65	0.56 (0.34)	0.19	1.49
Tympanometric peak pressure (daPa)	Right	−6.85 (37.99)	−95	70	−1 (36.55)	−75	50
	Left	−7.48 (40.1)	−95	60	2.70 (38.73)	−75	95
Tympanometric width (mmho)	Right	109.25 (35.32)	50	182	122.3 (28.15)	65	185
	Left	105.44 (39.17)	30	190	115.78 (35.09)	60	210
Equivalent ear canal volume (daPa)	Right	0.64 (0.47)	0.14	1.7	0.83 (0.66)	0.14	2.0
	Left	0.62 (0.43)	0.11	1.5	0.86 (0.66)	0.14	1.8

The Tables 1 and 2 shows the mean, standard deviation, minimum and maximum values for Tympanometric Measures such as peak compensated static acoustic admittance (Ytm), tympanometric peak pressure (TPP), tympanometric width (TW) and equivalent ear canal volume (Vea) using 678 and 1000 Hz probe tones for the male and female group respectively.

Discussion

The present study attempted to explore tympanometric measures for high frequency probe tones in infants with normal ear status as indicated by present TEOAE's in the presence of high risk indicators for HL.

Moraes et al. [23] used 678 Hz probe tone to evaluate tympanometric measures in healthy infants from zero to 3 months of age, and reported a mean Ytm of 0.55 mmho. In the present study for the same probe tone as seen in Tables 1 and 2, the mean Ytm value for male in right ear was 0.35 and 0.32 mmho for left ear.

Studies on infants using 1000 Hz probe tone have reported of variable findings of Ytm. Margolis et al. [16] studied NICU and normal infants reported of mean 2.2 and 2.7 mmho respectively. While Swanepoel et al. [22] who studied normal healthy infants reported mean 2.4 mmho Ytm values. The Ytm values found in the present study are much lesser as compared to these findings. Mazlan et al. [21] using 1000 Hz probe tone on healthy neonates

Table 2 Mean (Standard deviation), minimum and maximum values obtained for tympanometric measures using 678 and 1000 Hz probe tones for the female group

Tympanometric measure		678 Hz			1000 Hz		
		Mean (SD)	Min.	Max.	Mean (SD)	Min.	Max.
Peak compensated static acoustic admittance (mmho)	Right	0.36 (0.15)	0.16	0.63	0.72 (0.35)	0.13	1.61
	Left	0.46 (0.25)	0.11	1.14	0.69 (0.33)	0.21	1.42
Tympanometric peak pressure (daPa)	Right	−1.52 (41.17)	−120	80	0.65 (39.79)	−100	50
	Left	−12.82 (51.21)	−155	65	−7.09 (46.75)	−145	45
Tympanometric width (mmho)	Right	121.52 (31.73)	40	195	116.34 (25.80)	41	157
	Left	120.87 (31.41)	85	236	120.22 (28.50)	40	183
Equivalent ear canal volume (daPa)	Right	0.67 (0.55)	0.14	2.4	0.97 (0.90)	0.14	3.6
	Left	0.70 (0.60)	0.15	2.5	0.97 (0.82)	0.15	2.6

reported mean Ytm values at birth as 0.78 mmho; and at 6–7 weeks of age as 1.01 mmho.

In a study on Indian population, by Sood et al. [24] in healthy newborns, the mean Ytm using 1000 Hz was 2.08 mmho with a minimum value of 0.9 mmho and a maximum value of 3.4 mmho. The higher mean and the broader range of Ytm values obtained by them [24] as compared to the current study, may be due to difference in the age groups, or due to the presence of certain risk indicators for HL in the current study, or a combination.

There was an increase in mean Ytm values with increase in frequency of the probe tone [11, 23]. The mean Ytm values in infants obtained using high frequency probe tones are lower than those for adults which could be attributed to the mass-dominant middle ear system of the infant, resulting due to the anatomic and plasticity differences between infant and adult ears.

The range of TPP obtained in the current study using 678 Hz was less broad as compared to that obtained by Moraes et al. [23] that is, a minimum of −150 daPa and a maximum of 145 daPa. Swanepoel et al. [22] reported a minimum of −185 daPa and a maximum of 185 daPa. The range of TPP values obtained using 1000 Hz show a narrow range than those obtained by other studies [22, 23].

Margolis et al. [16] used 1000 Hz for full-term babies reported a wide range of TPP of −200 to 200 daPa values, which is consistent with the findings of other studies [22, 23]. However for NICU graduates the range was −188 to −93 daPa, which is much lesser than all the above findings, and is comparable to the trend observed in the current study for participants with risk indicators for HL. Sood et al. [24] used 1000 Hz probe tone on healthy newborns, reported a minimum value was −81 daPa and a maximum value was 58 daPa for TPP which is similar with the findings of the present study.

TPP has been regarded to be a less useful criterion for tympanometric assessment of infants due to large standard

deviations (SD) and large inter-subject variability. Mazlan et al. [21] used a 1000 Hz probe tone and obtained a SD of 44.76 daPa and a range of −88 to 98 daPa for TPP for neonates at birth, whereas the findings of the current study show a lesser SD but a slightly broader range. However, for infants at 6–7 weeks of age a much greater SD of 67.99 daPa and a much broader range of −254 to 80 daPa for TPP was obtained as compared to the current study.

The possible reasons for the narrow range in TPP values in the present study may be due to the presence of risk indicators for HL or differences due to ethnicity, which is unlike in the previous studies [21–23] on full-term infants. However, the study by Sood et al. [24] has been conducted on healthy neonates of Indian ethnicity, still the range for TPP was broader than obtained in the current study, while in the study by Margolis et al. [16] on NICU graduates, similar narrow range of TPP was obtained as in the current study, even though the ethnicities are not the same.

These differences may also be due to the age groups in the present and previous studies [16, 21, 22, 24] as maturational changes may affect the TPP. However, no significant age-effect for TPP has been reported [16, 22].

As observed in Tables 1 and 2, the mean TW for the female participants is slightly greater than male participants for both ears. There have been no reports in literature on the TW in neonates or infants, both normal healthy or with risk indicators for HL, using 678 Hz probe tones which could be due to 1000 Hz probe tone being used.

Kei et al. [15] used 1000 Hz probe tone for healthy neonates, obtained mean TW of 107.6 daPa for right ear and 97.7 daPa for left ear, wherein they reported a significant ear-effect, for right ears showing higher mean TW than left ears, however no gender-effect. Silva et al. [25] reported the mean TW obtained for normal healthy neonates using 1000 Hz was 99.49 daPa for both ears, with no ear-related or gender-related significance effects. The findings of the present study show slightly greater mean

values of TW for both ears compared to previous studies (Kei et al. [15] and Silva et al. [25]).

In studies on adults using 226 Hz probe tones, wider tympanometric widths have been reported for Asians as compared to Caucasians or African Americans [26–30]. The findings of the current study also reveal greater mean values for TW than those obtained by Kei et al. [15] and Silva et al. [25] on healthy neonates using 1000 Hz probe tone. The presence of risk indicators for HL, differences in the age groups, ethnicities or a combination of these factors could be the possible reasons for greater mean values obtained for TW using 1000 Hz probe tone.

It can be observed from Tables 1 and 2 that the maximum values obtained for Ve a using 678 Hz probe tone in female participants are much higher than male participants for both the ears. This may be attributed to the difference in mean ages for males (mean age = 35.81 days) and females (mean age = 58.87 days). These findings demonstrate a much lesser minimum value for Ve a, and also, a much narrower range of Ve a as compared to Shahnaz and Davies [28].

Even for the 1000 Hz probe tone, the maximum values for Ve a in females were much higher than males for both ears which may be attributed to the difference in mean ages for males (mean age = 35.81 days) and females (mean age = 58.87 days).

Smaller ear canal volumes have been reported for children and adults of Asian ethnicity in comparison to Caucasians or African-Americans [26–30]. The minimum values of Ve a in the present study were lesser than those obtained by Sood et al. [24] even when the participants belonged to the same geographical location which could be due to the presence of risk indicators for HL in the present study.

Conclusion

The present study is a preliminary attempt to profile the tympanometric measures of infants. The Ytm values were lesser or similar to other studies, TPP and Ve a values had lower and narrow range. TW as compared to other studies. Keeping in mind the existence of anatomical differences between individuals belonging to different ethnicities, it is important to consider clinical data appropriate for a given individual belonging to a particular ethnic group.

Compliance with Ethical Standards

Conflict of interest The authors reports of no conflict of interest and are solely responsible for the contents of this paper.

Informed Consent Informed consent was obtained from the parents of infants prior to testing.

Research Involving Human Participants and/or Animals This study does not involved any animal.

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