Tympanometry in Jordanian adultotologically normal hearing using different probe frequencies

Hussein Alqassem *, Abedallah Kasem **, Kawther Amawi*, Zaidan Alkhamaiseh ****, Saed Al-Fawaeir*****.**

* Assistant Prof.Medical Allied Department Zarqa University,
** Assistant Prof. J Jordan University of Science and Technology
*** Associate Prof. Zarqa University Zarqa,
**** Associate Prof, Al-ahliyya Amman University
***** Assistant Prof, Jadara University,

Abstract

The present study was undertaken to assess and compare the results of multicomponent tympanometry for 226 Hz, 678 Hz, 800Hz and 1000 Hz probe tone in detecting middle ear pathology.

Subjects

70 ears of 70subject who are otologicallynormal, pure tone audiometry within normal, no middle ear problem, no exposure to noise were included in the present study for the investigation of differences among different probe tone frequencies .one ear is chosen for the measurements.

Key words: transient otoacoustic emission, stapedial reflex, normal hearing.

I. INTRODUCTION

Tympanometry was first developed in the 1950's by measuring the middle ear pressure. Over the years its contribution to clinical diagnosis has become well accepted and it is now a routine part of the audiological test battery (Harris et al. 2005). A tympanometer consists of an air pump, a probe with a loud speaker, a microphone and a manometer. The probe tip must provide a good sealing in the ear canal to form a hermetic seal to be formed, which is required to obtain the proper pressure in the ear. The air pump introduces air pressure changes in the ear canal and a probe tone is also sent into the ear canal. The probe mechanism contains a microphone and speaker, which emits a pure tone. The acoustic immittance of the ear is analyzed by continuously monitoring sound pressure levels in the ear canal with a probe microphone. The immittance at the Tympanic membrane (TM) is directly proportional to the sound pressure level of the probe tone in the ear canal.

The most commonly used probe tone has been 226Hz. This probe tone has some definitive advantages when testing the adult ear. That's because the adult middle ear system is stiffness-dominated (compliance) at this frequency and the effects of mass and friction are minor. Interpretation and presentation of the results in most instruments display only the compliance of the middle ear. Additionally, the compliance value is directly proportional to the closed air volume, and the external ear canal volume (ECV) is obtained. Multi-frequency tympanometry is based on the analysis of tympanograms at a wide range of frequencies between 226 and 2,000 Hz. The acoustic immittance is a term that encompasses impedance, admittance, and their components. The RF is described as the frequency at which each stiffness is equal. Tympanograms are used to identify middle earpathologies. Most commercial tympanometers offer a 226 Hz probe tone. Though it has been shown that other probe frequencies can obtain different results (Shurin et al. 1976, 1977).

II. METHODS AND MATERIALS

A. Participants

The study included 70 ears of 70 adults of both sexes (50 female, and 20 males, aged between 18 and 22 years), we used only one ear of each subjects who are graduate students at the university of Zarqa, speech and audiology department.

B. PROCEDUR

The status of the ears of each subject was assessed using otoscopic examination which is to insure evaluation of the ear tympanic membrane, and tympanometry. Tympanometry measurements were performed using a diagnostic Madsenzodiac optometric tympanometer. Ear canal pressure was swept in a positive-to-a negative direction from +200 daPa to −400 daPa. Examinations were performed twice at Zarqa university, speech and language department, for the reality and accuracy measurements was repeated twice. Tympanograms were recorded using four measurements frequencies: 226 Hz, 678, 800 and 1000 Hz, for each ear separately. All participants were taught not to move or do any maneuver during the test, and the probe frequency changed from 226 Hz to 1000 Hz without removing the probe and the results for each ear was recorded.

Parameters performed in this study were TPP (total peak pressure in (daPa), Era canal volume in ml, and static compliance (SC) in ml. The procedure instruction was given to the subjects included in this study. Our study examined the 3 parameters which are middle ear pressure (TPP), ear canal volume and static compliance. For 226 Hz this parameter was assessed using the standard normal range. The differences among the parameters compared to 226 Hz probe as follow:

The TTP was measured similarly to Roush et al., (1995) measurement where TTP for 226 Hz was0.4 dapa, for 678 Hz was 4.8 dapa, for 800 Hz was 3.4dapa and for 1000 Hz was 5.17dapa, (8) – from 0.2 to 0.7 mmho – while for 1000 Hz we adopted the criteria proposed by (Kei et al., 2003). An admittance between 0.39 and 2.12 mmho. Assessment of tympanogram shapes for 226 Hz was done according to the Jerger and Liden (1974) classification scheme. Of the seven types of tympanograms discussed in the literature, here we distinguished four: A, As, B, and E. The A-type tympanogram is presumed to come from ears with a normal sound conduction system, i.e., in ears without pathology of the middle ear. The A type is characterized by a tympanometry. Commonly, this type of result is indicating normal middle ear with no any problems. However, it can also be obtained in ears with normal middle ear function, especially in neonates. It is similar to the E-type tympanogram; whose shape resembles the letter M (it has two peaks). This result E shape is characteristic of a discontinuity in the ossicular chain, but is considered normal in newborns. The type B tympanogram appears as a flat tympanometric curveand was not included in our study as we are investigating the effect pf probe frequency in normal adults. the effect of type B and without a peak one cannot determine the middle ear pressure. This result may indicate inflammation of the middle ear (OMS).

For the probe frequency 226 Has the normal tympanograph type A. we used the classification of jerker et al. (1974). For the 678 Hz we used the classification by jerker and the results that all parameters were normal except for total peak pressure TPP which is higher compared with the results obtained using probe frequency 226 Hz. The 800 Hz probe frequency we used the classification of kei et al., (2003). the results showed no statistically differences between the probe frequency 678 Hz and 8000Hz the mean of both frequencies as follow for 678 Hz was 4.08, and for 800 Hz was 3.46.

For 1000 Hz we used the classification scheme proposed by Kei et al., 2003 which identifies just four types of tympanograms – type 1: single-peaked tympanogram (equivalent to type A of the Jerger classification), type 2: flat sloping tympanogram (equivalent to type B of the Jerger classification), type 3: double-peaked tympanogram (equivalent to type E of the Jerger classification), and type 4: other unclassified tympanograms (which could not be classified into any of the other categories – equivalent to type As of the Jerger classification). In the present study we have foun3d no significant differences among results obtained when using 678 and 800 and 1000 Hz. the significant was in the results obtained with probe frequency 226 Hz.

III. RESULTS

Table (1). Shows the mean values of the probe frequencies of tympanometry parameters of 70 ears for each measurement frequency.

Probe frequency (Hz)	**Total peak pressure (TTP)**	**Ear canal volume (ECV)**	**Static compliance (ST) ML**
226	0.4dapa	1.36 ML	0.82
678	4.8dapa	1.37 ML	2.1
800	4.5dapa	2.00 ML	1.98
1000	5.17dapa	0.23	1.69

Table (1) showed the different probe frequencies and the results for each probe frequency. The results from different probe frequency 226 Hz and the other 3 probe frequencies, this deference is statical significant The mean value of TTP for the probe frequency 226 Hz was 0.4 dapa, for 800Hz was 4.8 and for 1000 Hz was 5.17. The mean of TPP for 678 Hz was 4.8, and probe frequency was 4.8 dapaand for 1000Hz probe frequency. H z statistical analysis showed that the men (TPP) were similar in three measurements frequencies with no statistically significant differences. The 226 Hz probe was used as a reference for all measurements.

The effects of probe-tone frequency on admittance, its components, and the compensated phase angle in adults and healthy, full-term infants (average chronological age = 3 weeks) were investigated by Shahnaz, Miranda, and Polka (2008). In adults, when compensation was at the positive tail (+250 daPa), the compensated phase angle was positive at the low-mid probe-tone frequencies through 630 Hz, which is consistent with a stiffness-dominated middle ear. It was about 0° at 710 and 800 Hz, which is consistent with a middle ear at resonance (i.e., the mass and stiffness susceptance summing to yield a net susceptance of 0 mmho). Lastly, it was negative at frequencies over 800 Hz up to 1000 Hz, which is consistent with a mass-dominated middle ear.

In contrast, in infants, the compensated phase angle was positive at 226 Hz (still showing a net susceptance that is stiffness, but much smaller than in adults), negative at the higher frequencies through 560 Hz (consistent with a mass-dominated ear), about 0° at 610 through 800 Hz (consistent with middle-ear resonance), and then negative again at the higher probe-tone frequencies through 1000 Hz (consistent with a mass-dominated ear). These findings of a positive compensated phase angle with a small stiffness susceptance (positive compensation) at 226 Hz in infants are inconsistent with other studies that show the infant ear is mass dominated at low frequencies (Holte et al, 1997 Cavanaugh, & Margolis, 1991; Meyer et al., 1997). Although many articles cite Holte et al. (1991) in support of the conclusion that the infant ear is mass-dominated at low frequencies; Holte et al. (1991) stated that "several" (but not the majority) of "ears of neonates...showed negative admittance phase angles at all frequencies indicating a mass-controlled system" (p. 20) and "this suggests a greater contribution of mass and/or resistive elements for the youngest infants than in older infants and adults".

TTP values for the frequency probe are similar, and not statistically significant. TTP for 678 Hz,800 Hz, and 1000H are the same and there was no statical difference. Statistical analyses for the Ear canal volume showed that there were no significant differences, but it is noted that Canal volume for the probe frequency 800 Hz and 1000 Hz is higher than ear canal volume obtained with other probe frequencies. For Static compliance values in tympanograms for 226 Hz compared with 687Hz, 800, and 1000 Hz and the measurements showed that there werea deference's in the static compliance for 678, 800Hz and 1000Hz compared with probe frequency 226 Hz the differences are being between 226 Hz probe from one side and other probe frequencies 678, 800. And 1000. The research procedures were approved by the Ethics Committee of the Institute of audiology department at Zarqa university of Jordan.

Table (2) the mean value for the TTP probe frequency for 70 ears of 7o subjects	
Probe frequency (Hz)	(Total peak pressure). (dapa)
226	0.4dapa
678	4.8dapa
800	3.4dapa
1000	5.17dapa

Table 2 showed the mean value of TTP for the 70 ears of 70 subjects. It is noticed that the mean values for probe frequencies 678, 800, and 1000 Hz are not significantly differed. But when compared the mean frequency of the 226 Hz probe frequency showed a significant difference the differences being in 5.17dapa compared to o.4 of 226 Hz.

Table (3) showed the differences among different frequency probe 22, 678, 800 and 1000 Hz.	
Probe frequency (Hz)	Ear canal volume (ECV)
226 Hz	1.36ml
678 Hz	1.37ml
800 Hz	2.00ml
1000 Hz	0.23ml

It is apparent that in table 3 there were no any significant differences among all probe frequencies for ear canal volume.

Table (4). Showed the results of statistical compliance for all Frequencies probe.	
Probe frequency (Hz)	Static compliance (SC).
226Hz	0.82ml
678Hz	2.1ml
800Hz	1.37ml
1000Hz	1.69 ml

It is apparent that table 4 shows no Significant differences a among the means of different probe frequencies. the frequency is significant between probe frequency 678 and probe frequency 226 Hz. The static compliance for the probe frequency 678 is higher than for the probe frequency 226 Hz.

IV. DISCUSSION

Impedance audiometry is an important tool for assessing the middle ear, especially in newborns, in whom the incidence of middle ear pathology is very high. This study compares the parameters of tympanograms for 226 Hz,678, 800 and 1000 Hz.

The TTP for type A tympanograph single -peaked for 4 measurements frequencies showed a significant difference among 678Hz, 800Hz, and 1000 Hz in comparison with probe frequency 226 Hz the value for 226 Hz was 0.4 and for the 1000 Hz was 5. 17ml.no significant among probe frequencies 678 Hz, 800Hz and 1000 Hz. Total peak pressure for type A tympanograph for type A tympanogram (single-peaked) and 226 Hz ranged from 0.4 dap to 5.17 daPa, these values differ from the results obtained byrushel ea tal. who reported mean middle ear pressure (MEP) of 1.39 daPa. For 226 Hz, the total peak pressure value obtained by difference probe frequency the TPP value obtained in both studies were similar. Yerraguntla et al.(2018) obtained different results: the mean MEP in boys was 1 daPa in the right ear and 2.70 daPa in the left, and in girls 0.65 daPa and −7.09 daPa, respectively. Yang et al. (2020) found MEP values of 11.83 daPa, and Emadi et al. (2016) values of 23.86 daPa.

Middle ear pressure for type A tympanogram (single-peaked) and 226 Hz ranged from −63 daPa to 77 daPa, with a mean value of 19.6 daPa. These values differ from the results obtained by Resende et al., (2012) who reported mean middle ear pressure (MEP) of 1.39 daPa. For 1000 Hz, the MEP value obtained in both studies was similar.

The ear canal volume (ECV) for type A tympanogram (single-peaked) for both measurement frequencies showed no statistically significant differences. The mean ECV was 0.5 mL for 226 Hz and 0.4 mL for 1000 Hz. These results were similar to those reported by other authors Yerraguntlaet al., reported mean ECV values for 1000 Hz in boys of 0.83 daPa for the right ear and 0.86 daPa for the left ear and in girls 0.97 daPa bilaterally. Emadi et al. (2016) reported similar values. On the other hand, in a study published by Yang et al., 2020), the mean ECV for 1000 Hz was 0.71 mL.

Static susceptibility in our study material showed similar values for 1000 Hz to those obtained by Yang et al. (6). However, other authors have recorded different values with a markedly broader distribution for 226 Hz. At the same time, our mean static susceptibility for 226 Hz was noticeably different than values obtained by other researchers. In our study material, the most often registered tympanogram for both testing frequencies was the single-peaked type A

(56.7% for 226 Hz and 59.6% for 1000 Hz), which is in line with results obtained in other studies.

For 226 Hz, we recorded type E tympanograms (double-peaked) in 10.6% of ears. Many authors consider double-peaked tympanograms to be normal in children younger than 6 months. Li et al. have registered double-peaked tympanograms at 226 Hz in more than 47% of 408 ears they tested. We did not record any double-peaked tympanograms for 1000 Hz in our material, while Swanepoel et al. reported that type of tympanogram in 6% of ears they studied. Kei et al. reported a very low rate of double-peaked tympanograms, only 1.2%.

We have analyzed the frequency of occurrence of each tympanogram type for a 1000 Hz measuring frequency based on the type of tympanogram obtained using 226 Hz. The most frequently appearing tympanogram for 1000 Hz was type A, regardless of the tympanogram type present at 226 Hz. The largest proportion (62.7%) was paired with type A tympanogram at 226 Hz, which is confirmed in the literature. However, in our study, we registered twice as many single-peaked (type A) tympanograms for 1000 Hz paired with flat (type B) for 226 Hz as reported by Carmo et al. (2012). Moreover, we registered half as many type A tympanogram (single-peaked) for 1000 Hz when the tympanogram for 226 Hz in the same ear was type E (double-peaked).

If we analyze the rate of appearance of a specific type of tympanogram simultaneously for two measurement frequencies, we find that type A tympanograms (single-peaked) were present for both frequencies simultaneously only in 35.6% of cases and type B (flat) in 3.8% of cases. In a study by Liu et al. of a group of children younger than 6 months with secretory otitis, type B tympanograms (flat) were found for both frequencies simultaneously only in 21% of cases. Moreover, it has been shown that disease detectability using 1000 Hz is threefold the rate using 226 Hz. In normally functioning ears, type A tympanograms were registered in a similar number of children. Mutlu et al. (2015) has reported that with a measurement frequency of 1000 Hz, disease detectability increased twofold compared to 226 Hz. They also reported that type A tympanograms were present simultaneously at both frequencies in 30.7% of cases. For abnormal tympanograms (type Ad, As, B, or C), the simultaneous occurrence rate was 66%. Shi et al. (2016) reported similar results. At 226 Hz, they recorded type A tympanograms in 13.3% of cases but found only 8.9% of the single-peaked type at 1000 Hz.

Tympanometry curves for 226 Hz and 1000 Hz are different, and in newborns the 1000 Hz test tone revealed a higher rate of middle ear pathology. However, further studies are required to verify that 1000 Hz tympanometry is a high-sensitivity diagnostic method for middle ear problems in newborns.

V. CONCLUSION AND RECOMMENDATIONS

It is well known that the total susceptance is algebraic sum of positive (stiffness) and negative (mass) susceptance. Middle ear infection increases mass in the middle ear and reduces the resonant frequency. The results of the present study reinforce the concept that the reduced resonant frequency results in more dramatic changes for 1000 Hz tympanogram than 226 Hz tympanogram. These findings highlight the usefulness of high probe tone in detecting the alterations in the middle ear due to increase mass.

This study suggests that assessments of middle ear status are not consistent when frequencies of 226 compared with 678 Hz, 800 Hz and 1000 Hz are used. Moreover, in newborns, the rate of abnormal tympanograms is higher at 1000 Hz. Therefore, 1000 Hz seems to be a better frequency for assessing middle ear conditions. It is recommended that high frequency immittance measurements be included in a battery of test to identify any abnormality of middle ear. This study suggests that assessments of middle ear status are not consistent when frequencies of 226, 678, 800 and 1000 Hz are used. Moreover, in adults the rate of normal tympanograms is higher at 1000 Hz. Therefore, 1000 Hz seems to be a better frequency for assessing middle ear conditions. For better probe frequencies is to use 226 Hz the 226 probe frequency for middle ear pathology based on the result of the present study we recommend to test infants who are normally otological using probe frequencies 226, 678, 800 and 1000 Hz.

Recommendation for accurate and reliable tympanometry is to use the probe frequency 226Hz for best diagnosis especially for normal adults, and because width is absent when using 800 Hz, and 1000Hz. More research study is recommended in case of disorder.

ACKNOLWDGEMENT

We thank All subjects for their cooperation.

REFERENCES

(1) P.K. Harris, K.M. Hutchinson, J. Moravec**.** The use of tympanometry and pneumatic otoscopy for predicting middle ear diseaseAm. J. Audiol., 14 (1) (2005), pp. 3-13.

(2). Shurin et al 1976, 1977, MargolisMultifrequencytympanometry: current clinical applicationAm. J. Audiol.,

(3) J Kei, J. Allison-Levick, J. Dockray, R. Harrys, C. Kirkegard, J. Wong, M. Ma``urer, J. Hegarty, J. Young, D. Tudehope High frequency (1000 Hz) tympanometry in normal neonates J. Am. Acad. Audiol., 14 (1) (2003), pp. 20-28

(4) J. Jerker Clinical experience with impedance audiometer Arch. Otoloaryngol., 92 (1970), pp. 311-324. S.E. Meyer, C.A. Jardine, W. DeversonMDevelopmental changes in tympanometry: a case studyBr. J. Audiol., 31 (3) (1997), pp. 189-195,

(5) jerker Liden, E. Harford, O. Hallen Automatic tympanometry in clinical practiceAudiology, 13 (2) (1974), pp. 126-139. J. Glater Efficacy of 1000 Hz Tympanometry in Infants Birth to 4 Months of Age.

(6) R.H. Margolis, S. Bass-Ringdahl, W.D. Hanks, L. Holte, D.A. ZapalaTympanometry in newborn infants—1 kHz norm J. Am. Acad. Audiol., 14 (7) (2003), pp. 383-392.

(7) K. Yerraguntla, R. Kaur, R. Ravi A preliminary attempt to profile tympanometric measures in infants using high frequency probe tones Indian J. Otolaryngol. Head Neck Surg., 70 (2) (2018), pp. 188-193.

(8) N. Shahnaz. Multi-frequency tympanometry and evidence-based practice, American speech-language pathology and audiology (ASHA) perspectives on hearing and hearing disorders Research and Diagnosis, 1 (2007), pp. 2-12.

(9). K. Yang, Z. Liu Comparison of 1000 Hz-, 226 Hz-probe tone tympanometry and magnetic resonance imaging in evaluating the function of middle ear in infants Int. J. Pediatr. Otorhinolaryngol., 136 (2020), p. 110135.
Epub 2020 May 28.

(10) L.M. De Resende, J. dos Santos Ferreira, S.A. da Silva Carvalho, I. Simas Oliveira, I. Barreto Bassi Tympanometry with 226 and 1000 Hertz tone probes in infants, Braz J. Oto-Rhino-Laryngol., 78 (1) (2012), pp. 95-102, 10.1590/s1808-86942012000100015

(11) Roush, J. Bryant, K. Mundy, M. Zeisel, S. Roberts, J (1995). Developmental changes in static admittance and tympanometric width in infants and toddlers. J Amer Acad Audiol 6:334-338.

(12). Tympanometry with 226 and 1000 H ertz tone probes in infants, BrazJ. Oto-Rhino-Laryngol., 78 (1) (2012), pp. 95-102.

(13). M. Emadi, M. Rezaei, M.H. Nahrani, M. Bolandi High frequency tympanometry (1,000 Hz) for neonates with normal and abnormal transient evoked otoacoustic emissions J. Audiol. Otol., 20 (3) (2016), pp. 153-157.

(14) A. Mutlu, M. Durgut, M. Oztruk, M. Çağlar Buday, M. Topdag, M. İşeri Comprehensive study of 226-1000 Hz multifrequency tympanometry measures in infants J. Otolaryngol. ENT. Res., 2 (4) (2015), p. 130–133, 10.15406/joentr.2015.02.00030.

(15) K. Ozturk, S. Gode, F. Ogut, C. Bilgen, T. Kirazli The value of multifrequency tympanometry in the management of otitis media with effusion J. Int. Adv. Otol., 7 (1) (2011), pp. 4-8.

(16) M.P. do Carmo, M.G. Almeida, D.R. Lewis

226 and 1 kHz tympanometry in infants with risk indicators for hearing lossRev. Soc. Bras. Fonoaudiol., 17 (1) (2012), pp. 66-72, 10.

(17) D.Y. Shi, L. Zhou, Y.Y. Shang Audiological and otological status of 45 infants with cleft palate Zhongguo. Yi. Xue. Ke. Xue. Yuan. Xue. Bao., 38 (2) (2016), pp. 136-139, 10.3881/j.issn.1000-503X.2016.02.002

AUTHORS

First Author – Hussein Alqassem, Assistant Prof.Medical Allied Department Zarqa University.
Second Author – Dr Abedallah kasem, assistant prof. Jordan University of Science and Technology.
Third Author – Kawthar Amawi. Associate Prof. Zarqa University Zarqa.

Correspondence Author – Hussein Alqassem, Assistant Prof.Medical Allied Department Zarqa University.