NORMAL TYMPANOMETRIC WIDTH IN SULAYMANIYAH GOVERNORATE - KURDISTAN REGION- IRAQ

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ABSTRACT

Background

Tympanometry is the objective dynamic measurement of acoustic admittance of the middle ear cleft as a function of changes in air pressure in the external ear canal. Tympanometric width (TW) is the width of the tympanogram in daPa measured at half of the height from the peak to tail specify that the tail value is to be estimated from the tympanogram at +200 daPa.

Objectives

To evaluate the normal TW in the Sulaymaniyah governorate.

Materials and Methods

It is a prospective comparative clinical study undertaken in Kurdistan audiology center & pediatric teaching hospital in Sulaymaniyah governorate. Tympanometry test utilized for normal hearing participants after exclusion associated ear diseases. The clients were included after taken informed consent, divided into two groups according to their age, group A; age (2-7) years, group B; age (8-60) years. Then the clinical data retrieved from the tympanogram results and statistical analysis were done

Results

268 patients of either sex (128 males & 140 females) included in the study, there were higher width values in (2-7 years) age group in comparison with (8-20 years) age group with a $p < 0.001$, which is statistically significant.

Conclusion

The data generated in this study provide the beginnings of a normal database for the Sulaymaniyah governate population. TW 210 daPa and 175 daPa in normal population age groups of (2-7 years) and (8-60 years) respectively, considered as abnormal. Although there were no interaural or gender differences in TW, further future work in all age levels is advocated.

Keywords: *Tympanometry, Tympanometric width, Compliance of the middle ear system, Ear canal volume.*

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INTRODUCTION

Acoustic immittance is a common term that refers to either acoustic impedance or admittance or both. About the auditory system, the acoustic admittance is identified as a measure of the ease with which the probe tone energy flows into the middle ear system; However, the acoustic impedance is the inverse of acoustic admittance in which is the opposition to the flow of energy [(1)]. Whenever the acoustic wave hits the normal eardrum, part of it will transmit through the middle ear to the cochlea, and the remaining of the waves reflects out the external auditory canal through the middle ear system impedance function which carried out by; Mass is represented by the (weight of ossicles & tympanic membrane) which is very little, friction is primarily due to (seven suspensory ligaments, two muscles which support the ossicular chain) and stiffness has the most prominent role in the middle ear, it mainly occurs at footplate of stapes where a large resistant component must be overcome to move the fluids of the cochlear duct. So middle ear impedance is stiffness dominant [(2)].

Current clinical acoustic admittance measures can be broadly separated into three general areas:

1. Tympanometry measures.
2. Acoustic reflex measures & reflex decay.
3. Eustachian tube function. [(1)]

Since the early 1970s, where tympanometry was introduced by Jerger [(3)], it has been performed routinely in the clinical setting. Tympanometry is an objective dynamic measurement of acoustic admittance of the middle ear cleft as a function of changes in air pressure in the external ear canal. It refers to measures of acoustic admittance that are taken at various pressure points; these values are graphed to form a tympanogram. The objectivity of tympanometry or is result accuracy based on the calculations, not dependent upon a response from the patient [(3)].

Although tympanometry provides valuable information regarding the middle ear transmission system, three limitations should be realized:

1. A unique tympanometric pattern does not exist for every possible middle ear disorder.

2. The most lateral pathology, or the pathology directly affecting the eardrum, will have the dominant effect on the measured input admittance even when the pathology is inconsequential to the hearing status. Therefore, is not a measure of the admittance of pathology affecting the entire middle ear system. Because of this, the exact structure producing the conductive pathology cannot always be identified with tympanometry.

3.Substantial variability occurs in tympanometric values, often with substantial overlap between normal and diseased middle ear systems.

Even with these limitations, tympanometry, used in conjunction with otoscopy, a pure tone audiogram, and acoustic reflex measures can provide valuable, augmentative information that is not otherwise available [(1)].

One challenge is determining the causes of middle ear pathology is that there is not always a direct relationship between the effect of the pathology on the tympanogram and the auditory thresholds shown on the audiogram [(4)].

Accurate tympanometry measurements necessitate the following; careful otoscopic evaluation of the ear canal to ensure that there is a clear path to the eardrum, appropriate probe ear tip selection and during the test, it is important not to speak, move, swallow, or startle. All these actions can alter the pressure in the middle ear and invalidate the results. At the same time, tympanometry is contraindicated in recent stapedectomy or any other middle ear surgeries, discharging ear and discomfort (e.g., severe otitis externa, herpes zoster oticus) [(5)].

Most tympanometries used 226 Hz for measurement. The Tympanometer has a hand-held probe that is inserted into the ear. Inside the probe are four holes containing the loudspeaker, microphone, pump, and acoustic reflex measurement (Figure 1).

A tympanogram provides several parameters of information including:

1. Compliance of the middle ear system (eardrum movement)
2. Ear canal volume.
3. Middle ear pressure (normally equal to atmospheric pressure in healthy ears).
4.W idth = Gradient [6-8].

The last parameter of the tympanometry, the tympanometric gradient or width (TW) is the major focus of this paper to provide the normative values within the Sulaymaniyah governate population. TW is a measure of the relative sharpness of the tympanometric peak and measured at half of the height from the peak to tail specify that the tail value is to be estimated from the tympanogram at +200 daPa [4]. as shown in figure 1.

Tympanometric width is measured in deca Pascale (daPa) and has a low correlation with tympanometric amplitude (Compliance), on the other hand, middle ear effusion can widen the tympanogram without substantially reducing the height [1, 9-11].

Although the general application of tympanometric width is in identifying pathologies that increase the width, especially otitis media and sensitivity to middle ear diseases that are not detected by other immittance measures such as otosclerosis which can narrow the tympanometric width, There is still uncertainty about the cut-off value for determining normal and pathological conditions, especially in the adult because of the low prevalence of middle ear disease in the adult population [1, 12, 13].

MATERIALS AND METHODS

This is a prospective comparative clinical study conducted in Kurdistan audiology center & pediatric teaching hospital in Sulaymaniyah governorate within 8 months from (1st of November 2012 to 1st of July 2013), the study was approved by the Ministry of Health (MOH) Ethical Committee.

268 clients (participants) of Sulaymaniyah governorate residents, from the city center and the surrounding rural areas, were included in the current study after taking informed consent. Participant's age has been selected between (2-60 years) old included through the following criteria: All participants present with normal hearing which defined as follows; for age 6-60 years old, audiometric thresholds < 10 dB hearing loss (HL) for tones of 500, 1000, 2000, and 4000 Hz on pure tone audiometry (PTA), and those for < 6 years old with normal auditory brainstem response (ABR) test. Each participant had normal otoscopic findings (i.e., normal tympanic membrane appearance, as well as being free of ear-canal debris, drainage, middle ear liquid, or any structural abnormalities) and denied any recent or current history of otic disease or disorder. Exclusion criteria: Clients after careful clinical examination who presented with external auditory canal, middle ear, and inner ear deformities or diseases and out of the selected age range were excluded from the study.

The studied clients distributed into two groups were categorized according to the age distribution: (Group A; 2-7 years old), Group B; 8-60 years old). Tympanometry study applied for each client using the device tympanometer (Impedance meter) Maico MI34 brand, Germany origin model 2011 (Serial number: 9915751) with the following technical specification:

1. Features

- Fast, automatic tests - Tympanogram in 3 seconds.
- Ipsi- and contralateral reflex testing with 4 frequencies.
- Reflex decay testing.
- Eustachian tube function test for intact and perforated eardrums.
- Handheld, adjustable probe for diagnostic and screening purposes.

2. Specification

- Probe frequency, intensity: 226 Hz, 85 dBSPL
- Pressure range: from + 200 to - 400 daPa.
- Volume range: 0, 1 to 6,0 ml.
- Test time < 3 seconds.

For the 8-60 years group given appropriate instructions to avoiding swallowing, moving, speaking & startling to prevent invalid results. The same instructions were given to the 2-7 years group given except for those small age children not cooperative with the test, we advised one of the parents to sit the child on his or her lap.

The procedure of Tympanometry

A non-invasive test can quickly and easily be performed on patients of any age, from infants to adults and the result records only take about 3 seconds for both ears. The probe with an appropriate ear tip is positioned at the opening of the ear canal.

When a tight seal is obtained between the probe tip and the ear, a known quantity of sound energy (low pitch tone 226 Hz) is introduced to the ear through the loudspeaker while the air pressure is changed within the sealed canal from a positive value (+200daPa) to a negative value (-400daPa) Deca Pascals or daPa is a measurement of air pressure; whereby, Pressure of 1.02 mm H20 = 1.00 daPa. Then the microphone measures the amount of sound that is reflected from the eardrum during the pressure sweep. This information is then displayed in the graph.

The amount of sound energy transmitted is equal to the amount of sound energy introduced, minus the amount of sound energy that returns to the probe microphone.

Statistical analysis

Each returned questionnaire was given an identity number (ID). Before data entry and analysis, the questions of the study were coded. The data was entered into a Microsoft Excel Spreadsheet, after data cleaning; the data was transported into SPSS (Statistical Package for the Social Sciences-version 21.0) package software program for statistical analysis. Descriptive statistics (numbers, percentages, range, minimum, maximum, means, and standard deviations) were calculated for all variables, as well as analytical statistics was done to find the relations between variables by using the appropriate statistical T-test, P-value < 0.05 was considered as significant.

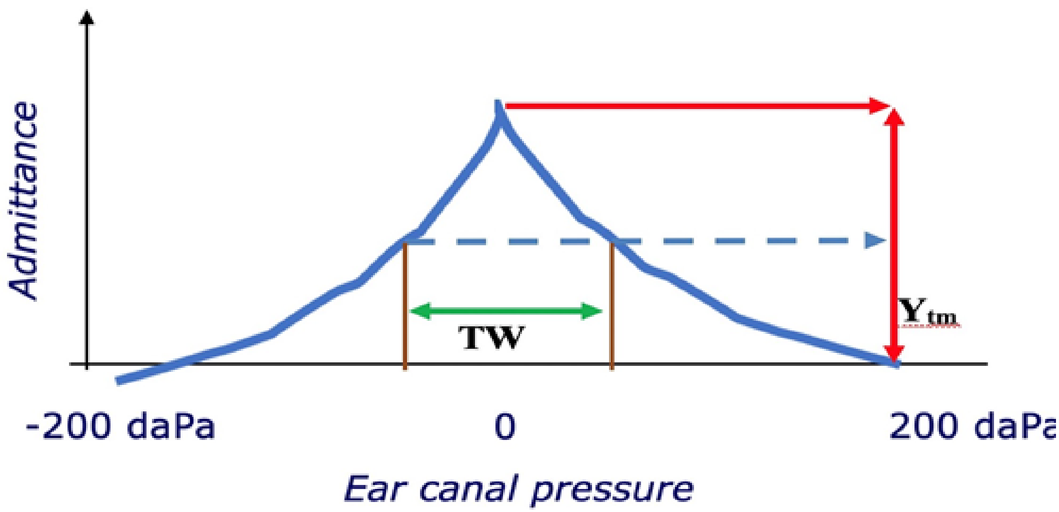

Figure 1. Illustrate the tympanometric width (TW) measurement graph.

RESULTS

In the present study, the 268 clients of either sex [128 males (47.6%) & 140 females (52.4%)] with male to female ratio 1:1.09 were included and distributed into two groups according to the age range as follows; Group A (2-7 y); 100 clients, (37%) & Group B (8-60 y); 168 clients (63%).

The mean of the tympanometric widths records for 100 cases of group A were 96.18, 96.86 daPa for both right and left ear respectively and for the rest 168 clients of group B were 77.10, 78.94 daPa for both right and left

ears respectively and the comparison between both groups revealed significant statistical differences a with a p value < 0.001 as shown in table 1.

The mean & standard deviation of right ear tympanometric width for 128 males were (83.72, 26,48) & for 140 females were (84.59, 31.71) in both A and B groups respectively. While in the left ear the mean & standard deviation of width were (86.80, 30.16) & (84.49, 28.47) for the same numbers of males & females in both groups respectively. Therefore, there is no statistical significance difference value observed between the mean of tympanometric width of both male & female cases (p-value = 0.735 in right ear & 0.363 in left ear) as shown in table 2.

Table (3) concentrate on the minimum, maximum & mean of the tympanometric width ranges in 90% of cases of both age groups for both sides. In (2-7 years) age group A, the right ear means was 97.20, minimum & maximum limit was 62, 206 respectively, while the left ear mean was 98.09, minimum 72 & maximum limit was 214 and. In (8-60 years) age group B, the right ear means was 76,41, minimum & maximum limit were 52, 172 respectively while the left ear mean was 77.95, minimum 56 & maximum limit was 178, and P-value between the sides for both groups are 0.673, 0.324 respectively which are not significant, and it's 0.001 between statistically significant age groups.

Table 1. Statistical analysis of TW in both age groups (100%).

Ears	Age groups	N	Mean	Std. Deviation	P values
RT ear width	2-7	100	96.18 daPa	28.31	< 0.001
	8-60	168	77.10 daPa	27.58	
LT ear width	2-7	100	96.86 daPa	26.98	< 0.001
	8-60	168	78.94 daPa	28.58	

Table 2. Statistical analysis of TW measures according to gender and side.

Both age groups (100%)	Gender	Mean	N	Std. Deviation	P values
RT width	Male	83.72 daPa	128	26.48	0.735
	Female	84.59 daPa	140	31.71	
LT width	Male	86.80 daPa	128	30.16	0.363
	Female	84.49 daPa	140	28.47	

Table 3: Statistical analysis of TW measures for participants in both groups according to age, side (means, 90% range, P value).

Group	Side	Range	Minimum	Maximum	Mean	Std. Deviation	P values	
Group A 2-7 years (%90 of cases)	RT	144 daPa	62 daPa	206 daPa	97.20 daPa	28.399	0.673	0.001
	LT	142 daPa	72 daPa	214 daPa	98.09 daPa	27.40 3		
Group B 8-60 years (%90 of cases)	RT	120 daPa	52 daPa	172 daPa	76.41 daPa	26.95	0.324	
	LT	122 daPa	56 daPa	178 daPa	77.95 daPa	27.97		

Table 4: Comparison of TW means, and 90% ranges for participants in different studies according to age, gender (male, female and combined across) gender.

Study	no	sex	Age (y)	TW (daPa)	
				mean	90% range
Koebsell & Margolis 1986	88	B	3.7-5.8	133	80-200
De Jonge 1986	83		22		60-160
Margolis &Heller 1987	47	M		105	
	42	F		95	
	92	B	2.8-5.8	100	59-151
Margolis &Heller 1987	49	M		79	
	38	F		74	
	87	B	19-61	77	51-114
Margolis and Goycoolea 1993	14	M			
	14	F			
	28	B	19-48	106	42-183
Nozza 1992	130	B	6-15	104	60-168
Roush et al. 1995	1827	B	.5-6-7	148	102-204
Wiley et al 1996	825	M	48-90	73	35-125
	1322	F	48-90	76	40-120
	2147	B	48-90	75	35-125
Holte 1996	136	B	20-90	84	38-141
Roup et al 1998	51	M		60	35-87
	51	F		74	45-107
	102	B	20-30	67	36-95
De Chicchis 2000			2-2.11	130	
	221	B	3-3.11	138	
			4-4.11	128	
Our study	128	M		85.5	
	140	F		84.5	
	268	B	2-7/8-61	98/77	67-210 / 54-175

DISCUSSION

This study provides a set of tympanometry data (TW) collected from 268 Iraqi Kurdistanian clients with normal hearing and normal middle ear function. Precautions were made to minimize sampling bias and ensure the included subjects did have normal hearing and middle ear function.

Despite previous studies have reported normative data for tympanometric width in different communities, up to our knowledge this is the first study that has been done in Iraq. In the current thesis, we stressed screening of the TW parameter normative data through statistical analysis of the screened criteria of age, gender and side.

Participants < 2 years of age were excluded from the study because the external and middle ear systems vary significantly in their acoustic response properties over the first 2 years after birth. Physical changes in the external and middle ear after birth that could account for the acoustic changes include Size increase of the external, middle ear cavity and mastoid, change in the orientation of the tympanic membrane, fusion of the tympanic ring, decrease in the overall mass of the middle ear (due to changes in bone density, loss of mesenchyme), tightening of the ossicular joints, closer coupling of the stapes to the annular ligament and formation of the bony ear canal wall [9]. High-frequency tympanometry (1000Hz) is advocated in the infant because an infant middle ear is a mass-dominated system that has a lower resonant frequency compared to the adult middle ear, which is a stiffness-dominated system at low frequencies (226Hz) [14, 15]

In the current study, we stressed the effect of the age on TW, the recorded data of the TW mean in both age groups showed higher record in the smaller age group as follows; 96 and 77 daPa in (2-7y) (8-60y) respectively, the difference is significant statistically (P > 0.001), and it is in harmony to (American Speech-Language-Hearing association 1990) [16] child & adults normative means TW data (100, 80 daPa) respectively.

In comparison to countless articles that also focused on the effect of age on TW (Koebsell & Margolis 1986; Margolis and Heller 1987; Wiley 1996; Nozza 1992; de Jonge 1986; Roup 1998; Margolis and Goycoolea 1993; Holte 1996; Roush J 1995; De Chicchis 2000) [10-12, 17-23], as shown in table 4 it appeared that the disparity in the age group results attributed to the anatomic and physiologic changes in the developing ear from childhood to adult age has its significant reflection on the physical properties of middle ear system.

Although some small age differences have been reported for child and adult groups, any clinically significant differences appear to be masked by the large range of normal variability. The concern regarding the large age range which previously recorded by Margolis and Heller (1987) [11] data (ASHA, 1990 interim norms) [16] was noted in the current study, where the large age range in group B (8-60), which may have resulted in bias normative values for some adult age and it is considered one of the main limitations in the current paper.

In the present study, no significant gender differences were observed for TW normative data measurement. Although almost all previous investigators (Margolis and Heller 1987; Margolis and Goycoolea 1993; Holte 1996; Wan and Wong 2002) [11, 20, 24] consistent with our findings, other reports were recorded by (Wiley et al 1996; Roup et al 1998) [12, 19] noted a slight gender difference in TW measures. This disparity even if present may be due, at least in part to differences in sample size across studies, and gender effects are clinically insignificant and do not warrant the added inconvenience of separate norms for males and females. Roup et al [19], Margolis and Goycoolea [20] studies were based on a smaller sample relative to the present study (128 male/140 female) and the work of Wiley et al. [12] (825 males /1322 females) and it is noted in comparison to the Roup et al [19] were recorded smaller TW values in both male and female (60, 74) in comparison to our study (84.5, 85.5) respectively as shown in Table 4.

The present study revealed no significant interaural difference in the 90 % of TW mean for both age groups (A, B) with a P-value of 0.673, 0.324 and it is agreed by Margolis and Goycoolea (1993) [20]. However, Kei J et al (2003) [25] noted a significant ear effect, with right ears showing significantly higher mean TW in the neonatal population which may be related to the age group wherein neonate facing difficulties in inserting the probe due to very small canal especially if not right-handed examiner trying to do it.

Although race comparison effect on TW is not stressed in the current thesis, some authors investigated it. Two studies comparing Caucasian and Chinese adults concluded that an increase in TW in Chinese adults could be attributed to smaller body size (Wan and Wong, 2002 [24], Shahnaz and Davies, 2006 [26]. Wan and Wong (2002) [24], pointed out that 48% of Chinese children failed tympanometry screening when norms developed on Caucasians were used.

The differences in TW values across some studies, although significant, were small and likely of little importance in clinical applications. If screening criteria were based on age, gender, and side data, the small differences in the overall means of the two samples, likely attributable to age differences, would have minor effects on clinical screening decisions.

Limitations

We should point out that many limitations present in the current study as follows;

Although, the mean difference between both age groups was significant, an effort to further explore the clinical feasibility of having multiple age-specific normative data groups especially for the adult population.

We neither excluded subjects who had suffered from otitis media during early childhood nor subjects that had tympanostomy tube placement performed previously. The effect of previous otitis media and tympanostomy tube placement is therefore unknown and could be a subject for further research.

Tympanometric width is measured separately from other parameters where the normative data correlation is a valuable instrument in clinical application.

Conclusion and Recommendation

The data generated in this study provide the beginnings of a normal database for the Sulaymaniyah governate population and further future work to investigate other parameters and screening the correlation between them to rule out it is clinical applications.

Tympanometric width exceeding 210 daPa and 175 daPa in normal population age groups of (2-7 years) and (8-60 years) respectively, considered as abnormal.

Although there were no interaural or gender differences in tympanometric width in tested limited age groups, the issue of side or gender effects at all age levels should be stressed in future research on diagnostic measures that are most sensitive to hearing disorders and pathologies.

Compliance with ethical standards

Conflicts of interest

The authors declare that they have no conflict of interest.

Ethical approval

All procedures performed in studies involving human participants were following the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent

For this type of study formal consent is obtained

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