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SURGICAL MEDICAL SCIENCES / CERRAHİ TIP BİLİMLERİ

Comparison of Wideband Tympanometry Measurements with Conventional Tympanogram Measurements in Normal Hearing Adults

Normal İşiten Yetişkinlerde Geniş Bant Timpanometri Ölçüm Değerlerinin Geleneksel Timpanogram Ölçümleri ile Karşılaştırılması

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Abstract

Objectives: The aim of this study was to compare the results of 226 and 1000 Hertz (Hz) tympanograms obtained from wideband tympanometry (WBT) and conventional tympanometry.

Materials and Methods: This prospective study was conducted on healthy individuals without any otological complaints. Each participant received pure tone audiometry, otoacoustic emission testing, conventional 226 Hz and 1000 Hz tympanometry and WBT. Tympanometric peak pressure, middle ear compliance, and ear canal volumes (Vol) were measured for each ear. The results of these parameters obtained from the two devices were evaluated separately for the right and left ears and compared statistically.

Results: The study included 62 healthy individuals (124 ears) aged 18-40 years. In terms of tympanometric peak pressure, the results were similar at 226 Hz but different at 1000 Hz. For compliance, the results were similar at 1000 Hz but different at 226 Hz. The measurement results of both devices for ear canal volume at both 226 Hz and 1000 Hz were statistically similar.

Conclusion: It was noted that there were frequency based differences in tympanometric peak pressure and compliance measurements between WBT and conventional tympanometry. Although WBT has several advantages over conventional tympanometry, the results of this study suggest that more normative data should be collected from different ethnicities and age groups for its widespread use.

Key Words: Wideband, Tympanometry, Compliance, Ear Canal Volume

Öz

Amaç: İki yüz yirmi altı Hertz (Hz) ile sekiz bin Hz arasındaki tüm frekansları kapsayan ve dar bant klik uyaran ile oluşturulan yüzlerce timpanogramın üç boyutlu analizini sağlayan yönteme geniş bant timpanometri (GBT) ismi verilmiştir. Bu çalışmada GBT ile elde edilen 3 boyutlu veriler içerisinden çıkartılacak 226 ve 1000 Hz timpanogramların geleneksel yöntemlerle elde edilen 226 Hz ve 1000 Hz timpanogramlar ile karşılaştırılmıştır.

Gereç ve Yöntem: Herhangi bir otolojik şikayeti olmayan sağlıklı bireyler üzerinde yapılan prospektif çalışmada, her katılımcıya saf ses odyometrisi, otoakustik emisyon testi, konvansiyonel 226 Hz ve 1000 Hz timpanometri ve GBT uygulandı. Her kulak için timpanometrik tepe basıncı, orta kulak kompliyansı ve kulak kanalı hacimleri (Vol) değerlendirildi. İki timpanometriden elde edilen bu parametrelerin sonuçları sağ ve sol kulak için ayrı ayrı değerlendirildi ve istatistiksel olarak karşılaştırıldı.

Bulgular: Çalışmaya 18-40 yaş arası 62 sağlıklı birey (124 kulak) dahil edildi. Timpanometrik tepe basıncı açısından sonuçlar 226 Hz'de benzerdi, ancak 1000 Hz'de farklı sonuçlar elde edildi. Kompliyans açısından sonuçlar 1000 Hz'de benzerdi ancak 226 Hz'de farklı sonuçlar elde edildi. Kulak kanalı hacmi için her iki cihazın ölçüm sonuçları hem 226 Hz hem de 1000 Hz'de istatistiksel olarak benzerdi.

Sonuç: GBT ve konvansiyonel timpanometri arasında timpanometrik tepe basıncı ve kompliyans ölçümlerinde frekansa dayalı olarak farklılıklar olduğu kaydedildi. GBT'nin geleneksel timpanometriye göre çeşitli avantajları olmasına rağmen, bu çalışmanın sonuçları, yaygın kullanımı için farklı etnik kökenlerden ve yaş gruplarından normatif verilerin toplanması gerektiğini göstermektedir.

Anahtar Kelimeler: Geniş Bant, Timpanometri, Kompliyans, Kulak Kanal Hacmi

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Introduction

Tympanometry is the measurement of middle ear elasticity (compliance) due to pressure changes in the outer ear canal (1). This measurement provides valuable data in terms of the middle ear functions in different pathologies. For this purpose, tympanometric evaluations have been performed for more than 50 years, so called conventional tympanometry (CT). CT is often performed with a 226 Hertz (Hz) probe tone.

Wideband tympanometry (WBT) is a relatively new technique, which covers frequencies between 226 Hz and 8000 Hz, providing three-dimensional (3D) analysis of hundreds of tympanograms obtained with narrow-band click stimuli (2). High frequency probe tones are more valuable in pathologies that cause increased mass effect in the middle ear. Therefore, the results of WBT are becoming more important in the differential diagnosis of otosclerosis, ossicular chain disruptions, primary cholesteatoma, middle ear tumors and fibrous dysplasia.

Despite its advantages in differential diagnosis, the use of WBT is still not very common in clinical practice. Measurements that were obtained with WBT are more complex and difficult to understand than standard single probe tone tympanometry. In addition, the low number of standard results and the benefits of WBT and the limited number of studies are probably restricting the use of WBT in clinics (3).

In this study, we aimed to compare the results of CT and WBT in terms of 226 and 1000 Hz tympanograms in healthy ears.

Materials and Methods

Study Design and Setting

This prospective study was conducted with voluntary participants who applied to the outpatient clinic of the Department of Otorhinolaryngology in a tertiary setting.

Participants and Eligibility Criteria

The study included 62 healthy individuals (124 ears) without any otological complaints. All subjects with a history of otological disease, tympanic membrane pathology and/or previous otological surgery were excluded.

The criteria for subjects to participate in the study were as follows:

• Absence of any pathology in the external auditory canal, tympanic membran and middle ear on otoscopic examination.

• Absence of a history of hearing loss.

• Absence of a history of ear surgery.

• Middle ear pressure within the limits of +/- 50 daPa and Jerger Type A tympanogram trace.

• Bilateral air bone gap at 500, 1000, 2000 and 4000 Hz is <10 decibels hearing level (dBHL).

• Bilateral airway hearing tresholds <25 dBHL in 250-8000 Hz.

• Otoacoustic emission (OAE) of 3 dB or more from at least three of 1000, 1500, 2000, 4000 and 6000 Hz frequency bands in distortion product OAE emission (DPOAE) measurements.

• OAE of 3 dB or more from at least three of 1000, 1500, 2000§ and 4000 Hz frequency bands in transient evoked OAE (TEOAE) measurements.

Intervention and Outcome Measures

Each participant was performed pure tone audiometry (PTA), DPOAE, TEOAE, conventional 226 Hz and 1000 Hz tympanometry and WBT. Tympanometric peak pressure (TPP), compliance, and ear canal volumes were measured for each ear. These parameters, measured with CT and WBT, were evaluated separately for the right and left ears and the results from the two devices were compared statistically.

WBR is preffered for its high performence in classfying conductive loss ears, as determined by the best performing surrogate gold standards (DPOAE, TEOAE).

PTA

Following the routine otolaryngological examination of the individuals, air thresholds at 250, 500, 1000, 2000, 4000, 6000 and 8000 Hz and bone thresholds at 500, 1000, 2000 and 4000 Hz were determined. GSI Audiostar Pro clinical audiometer (Grason-Stadler, Denmark), TDH 50P supra-aural headset and B71 bone vibrator were used. Thresholds are determined by the Hugson-Westlake Procedure.

OAE

Bilateral DPOAE and TEOAE measurements were performed using the Otodynamics ILOv6 292 OAE measurement system (Otodynamics, United Kingdom) and recorded by EZ-Screen Software interface.

Immitansmetric Measurements

Bilateral conventional immitansmetric measurements were performed by GSI TympStar Pro (Grason-Stadler, Danimarka) device. WBT measurements were performed by Interacoustics TITAN WBT (Interacoustics, Denmark). CT and WBT were performed in the 200 to -400 daPa pressure range. The probe tone intensity levels for 226 and 1000 Hz obtained with the tympamometry were 85 and 75 dB SBS respectively. WBT measurements covering the frequency range of 226-8000 Hz were made with a click stimulus which was a 2 ms duration, 94 dB SBS intensity level and 21.5 Hz frequency.

TPP, compliance and ear canal volumes were measured for each ear and transferred to the SPSS (Statistical Package for the Social Sciences, version 20.0, SPSS Inc., Armonk, NY, USA) programme. These parameters obtained from the two devices were then compared statistically.

Statistical Analysis

The statistical analyses were done with IBM Statistical Package for the Social Sciences software for Windows version 22.0 (IBM SPSS Corp.; Armonk, NY, USA). Results are expressed as numbers and percentages for categorical and as mean +/- standard deviation for quantitative variables. The difference between the two quantitative dependent variables was evaluated using the paired samples t-test if normal distrubution was achieved or the Wilcoxon signed-rank test if not provided. The difference between the categories of the qualitative variable, which has two categories as a quantitative variable, was examined using Student's t-test if normal distrubition was provided, or Mann-Whitney U test if not provided. The relationship between the two quantitative variables was examined using Pearson if the normal distrubition was obtained or the Spearman correlation coefficient if not provided. The statistical significance level was identified as 0.05.

Ethics committee approval was received for this study from the Institutional Review Board of Başkent University Faculty of Medicine (approval date: 23.01.2019, approval number: KA18/441-19/17).

Results

A total of 62 patients (36 male and 26 female) with a mean age of 28.2 (range 18-40 years) were included in the study. A complete otorhinolaryngological examination was performed on each volunteer.

Measurements at 226 Hz with CT and WBT are presented in Table 1. The results were similar between the two different devices for TPP. However, the TPP was measured different at 1000 Hz (Table 2). For compliance, CT and WBT results were different at 226 Hz (Table 3) but similar at 1000 Hz (Table 4). The ear canal volume measurements at 226 and 1000 Hz with CT and WBT were statistically similar (Tables 5 and 6).

Table 1: TPP at 226 Hz measured with CT and WBT

	Right		Left	
	CT 226 Hz	WBT 226 Hz	CT 226 Hz	WBT 226 Hz
Mean	-8.33 (±8.11)	-8.04 (±7.75)	-7.41 (±10.94)	-5.90 (±12.41)
p-value	0.785		0.048	

CT: Conventional tympanometry, WBT: Wideband tympanometry, Hz: Hertz

Table 2: TPP at 1000 Hz measured with CT and WBT

	Right		Left	
	CT 1000 Hz	WBT 1000 Hz	CT 1000 Hz	WBT 1000 Hz
Mean	-9.32 (±8.01)	-12.04 (±7.75)	-7.31 (±10.94)	-5.65 (±12.41)
p-value	<0.001		<0.001	

CT: Conventional tympanometry, WBT: Wideband tympanometry, Hz: Hertz, TPP: Tympanometric peak pressure

Table 3: Compliance at 226 Hz measured with CT and WBT

	Right		Left	
	CT 226 Hz	WBT 226 Hz	CT 226 Hz	WBT 226 Hz
Mean	0.60 (±0.20)	0.54 (±0.18)	0.55 (±0.17)	0.49 (±0.14)
p-value	<0.001		<0.001	

CT: Conventional tympanometry, WBT: Wideband tympanometry, Hz: Hertz

Table 4: Compliance at 1000 Hz measured with CT and WBT

	Right		Left	
	CT 1000 Hz	WBT 1000 Hz	CT 1000 Hz	WBT 1000 Hz
Mean	1.23 (±0.50)	1.30 (±0.57)	1.17 (±0.44)	1.21 (±0.48)
p-value	0.26		0.51	

CT: Conventional tympanometry, WBT: Wideband tympanometry, Hz: Hertz

Table 5: Ear canal volume at 226 Hz measured with CT and WBT

	Right		Left	
	CT 226 Hz	WBT 226 Hz	CT 226 Hz	WBT 226 Hz
Mean	1.20 (±0.24)	1.23 (±0.24)	1.24 (±0.33)	1.29 (±0.32)
p-value	0.49		0.23	

CT: Conventional tympanometry, WBT: Wideband tympanometry, Hz: Hertz

Table 6: Ear canal volume at 1000 Hz measured with CT and WBT

	Right		Left	
	CT 1000 Hz	WBT 1000 Hz	CT 1000 Hz	WBT 1000 Hz
Mean	1.12 (±0.23)	1.10 (±0.24)	1.14 (±0.25)	1.16 (±0.27)
p-value	0.84		0.49	

CT: Conventional tympanometry, WBT: Wideband tympanometry, Hz: Hertz

Discussion

In this study, we aimed to compare 3 different parameters obtained from CT and WBT at 226 and 1000 Hz in healthy ears. WBT results were extracted from 3D data. According to the results of the research, ear canal volume measurements in both devices have similar results in both frequencies. However, there were, frequency based, significant differences in terms of TPP and compliance values. Depending on these results, it is thought that data obtained with these devices may vary based on the parameters and frequency.

Each audiometric test evaluates a specific frequency range in the auditory system. In CT, testing battery include a single probe tone with a frequency which is generally 226 Hz. One of the most important reasons for using the 226 Hz tympanometry is the ease of calibration. Since the admittance of 1 cm^3 of air at 226 Hz is equal to 1 mL, the frequencies here proceed in multiples of 226 Hz. Research indicates that the use of CT may provide limited or incorrect information in various situations. In a study evaluating patients with otosclerosis, it was reported that normal (type A) tympanometry results were obtained in almost all ears (4). Another condition is that similar graphs can be seen in conventional 226 Hz tympanometry in ossicular chain discontinuity and the flaccid tympanic membrane. The neonatal patient group is another situation where the use of 226 Hz tympanometry is limited. In approximately half of this patient group, false results can be obtained (4). It is a matter of debate which probe tone will be used on children of 4-8 months. In such cases, 226 Hz and 1000 Hz tympanograms are measured separately in many clinics.

To overcome these limitations, multifrequency tympanometry technique was introduced. This method allows for the evaluation of frequencies between 226 and 2000 Hz at 50 Hz intervals. However, frequencies over 2000 Hz still remained in the dark area.

WBT is developed with the idea of testing a wider frequency band by changing the stimulus type. The aim is to test the middle ear between 226-8000 Hz. Pure tone of 85 dB sound pressure level (SPL) at 226 Hz is used as the stimulus in CT. In WBT, a narrow band click stimulus is to be tested 226-8000 Hz. In order to have the same amount of energy, 96 dB SPL stimulation is used in infants and 100 dB SPL in adults. After the test, a 3D graphic is obtained (Figure 1).

Since click stimulus is used, many tympanograms can be obtained simultaneously in this graph. This is actually a chart created by combining hundreds of tympanograms. This chart can be viewed from 2 different planes, pressure and frequency. In these planes, it is possible to see the peaks with the maximum permeability at each frequency. It is not correct to make interpretation about admittance since a pure signal is not mentioned here. Admittance at each frequency will vary. For this reason, it is more feasible to express the values as the energy of the sound in WBT. Thus, admittance is replaced by the term "absorbance" in WBT, which is expressed as a percentage.

One of the biggest advantages of WBT and the main feature of this research is that many frequencies can be evaluated by performing a single test. WBT gives information about resonance frequency (RF) in different frequencies, which is used in the differential diagnosis of many diseases as mentioned earlier. Differential diagnosis of ossicular chain discontinuity with flaccid membrane or follow-up of patients with otosclerosis are some of the examples which RF evaluation provides important information. Previous studies show that; RF decreases in mass-dependent pathologies and increases in those related to stiffness. In a recent study, Niemczyk et al. (5) reported how important WBT results are in the diagnosis of patients with otosclerosis. While interpreting WBT, absorbance graph is often used (Figure 2). Another notable feature of WBT is that it can be measured both with and without pressure. Being able to measure without pressure is important for early absorbance after tympanoplasty and/or ossicular chain reconstruction.

In cases where the stiffness effect increases and the mass is constant in the middle ear, it is observed that RF increases and the absorbance graph collapses especially at low frequencies.

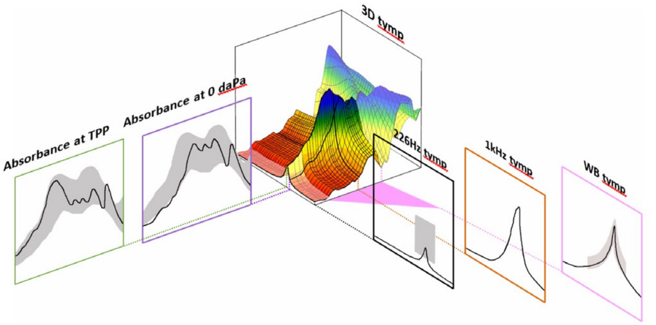

Figure 1: Wideband tympanometry

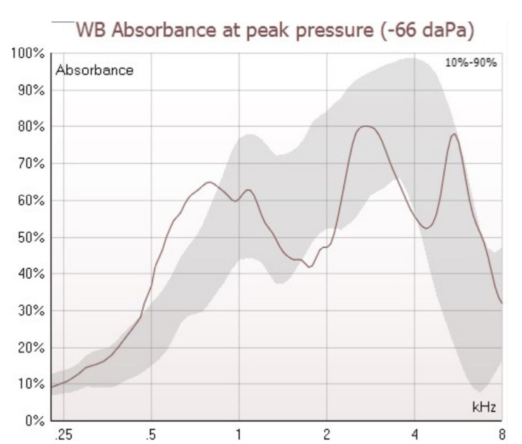

Figure 2: Absorbance graphic in wideband tympanometry

On the contrary, when there is a pathology concerning mass, a collapse should be expected at high frequencies. The normative data about Türkiye in 2015 was published by Polat et al. (6). It was noted that their data were similar to the values published from other parts of the world.

It is known that the outer ear canal is more susceptible for collapse, especially in the first year of life. There are some studies that suggest that middle ear pathologies are diagnosed more effectively using WBT in this period of life. The study of Prieve et al. (7) was conducted on 4-8 months old babies and it was reported that 2 tympanograms obtained in conventional way can be created at once and faster by applying WBT. Apart from all these, various studies have been published to suggest that WBT offers more reliable data in the evaluation of middle ear effusions than CT (8). In addition, more accurate and less artifact graphics are obtained with wideband average tympanogram (9).

Allowing RF measurement of the middle ear is another advantage of WBT over CT. Valvik et al. (10) reported that mean middle ear RF value was 1049 Hz (350-1750) in healthy adults. Sezin et al. (11) reported the mean middle ear RF value as 999.6 Hz (±134.9) in the healthy adults. Polat et al. (6) reported the mean middle ear RF value as 964.66 Hz (±233.94) in their normatization study on healthy individuals (5). Since the use of WBT has become increasingly widespread in recent years, the number of studies reporting normative data from different countries is increasing (12,13).

On the other hand, it should be kept in mind that WBT is a relatively new diagnostic tool. CT is a reliable test in audiology practice for more than half a century. Numerous studies from many countries to date have provided normative data flow in many different pathologies for CT. As is known, normative data analysis is crucial for the correct evaluation of a test result. In this respect, data should be collected from many different countries and from different centers in the same country. These measurements must be repeated at different times in order to eliminate seasonal and temporal interactions. In addition, in order for normative data analysis to be stronger, tests should be repeated on a very high number of patients. For instance, Shahnaz and Bork (14) evaluated TPP, admittance and ear canal volume in 53 patients. This research was carried out on adult Chinese people. The authors of the study emphasized that there may be variability in tympanometry values, possibly due to ethnicity, physiological and anatomical variations. One of the most important explanations for this difference is that the outer ear canal volume of people belonging to the yellow race is smaller than the caucasians (14). Volumetric changes in the outer ear canal, especially in the 0-2 age period, may cause differences in tympanometric studies. As it is known, the length and volume of the outer ear canal increase with age (15). While there is no significant difference in the dimensions of the semicircular canals and cochlea between the newborn and adults, this situation is not similar for the middle ear cavity, and the immitansmetry studies support this hypothesis (16,17). The stiffness of the outer ear canal, which is softer at birth, and the similar changes in the tympanic membrane explain the difference in measurements between newborns and adults (18).

Above all, even measurements of a newborn and 2-years-old healthy baby may not be similar. Therefore, in an area where tissue softness is at the forefront, it is a great advantage to be able to make measurements of immittance audiometry without pressure. WBT can provide clinicians more accurate results at this point compared to conventional 226 and 1000 Hz tympanometers.

There are several studies containing normative data on WBT. Among these, Polat et al. (6) evaluated 110 young participants (mean 21.1 years old) with WBT and reported an average RF 964 Hz, compliance 0.54 mL, TPP-6.71 daPa, outer ear canal volume 1.04 cc and gradient 95.61 daPa. It has been reported that there is a significant relationship between gender and absorbance values in the frequency range of 3100-6900 Hz (5). This relationship was also emphasized in another study examining the correlation of gender and absorbance values (19). Another important normative data study conducted in our country was published by Ozgur et al. (20) on 150 healthy individuals in 5 different age categories. As a result of this study, the mean RF value of the middle ear was measured as 330 Hz in the newborn and 1050 Hz above the age of 45. Frequency specific average absorbance values were 61.4% at 1000 Hz, 49.1% at 4000 Hz, and 56.4% at 8000 Hz. However, as mentioned above, more patients and studies are required to get more reliable results.

While the results of this study reported compatibility between WBT and CT in some parameters, frequency-specific differences were found in parameters such as compliance and TPP. New studies should be performed with more patients in the future in order to eliminate these differences and to get a more accurate opinion on the subject. Objective information and expert opinions in many studies in the literature show that WBT is advantageous compared to CT in many parameters. Based on this, it can be predicted that WBT will be used more in the near future and will be included in the routine test battery for many pathologies, probably eliminating the need for CT. Multicentre/multinational studies on the subject will help to overcome the problem of standardization and ensure faster and accurate data flow for patients.

Study Limitations

We think that more normotive data should be collected from different ethnicities and ages to use wideband tympanometry.

Conclusion

In sum, we can conclude that WBT has several advantages over CT. However, it is still too early to eliminate the use of CT. We think that more normative data should be collected from different ethnicities and age groups for its widespread use.

Wideband tympanometry is a relatively new technique, which covers frequencies between 226 Hz and 8000 Hz, providing 3D analysis of hundreds of tympanograms obtained with narrow-band click stimuli.

Wideband tympanometry is becoming more important in the differential diagnosis of otosclerosis, ossicular chain disruptions, primary cholesteatoma, middle ear tumors and fibrous dysplasia.

Wideband tympanometry has several advantages over CT. However, it is still early to eliminate the use of CT. We think that more normative data should be collected from different ethnicities and age groups for its widespread use.

Ethics

Ethics Committee Approval: Ethics committee approval was received for this study from the Institutional Review Board of Başkent University Faculty of Medicine (approval date: 23.01.2019, approval number: KA18/441-19/17).

Informed Consent: The authors certify that they have obtained all appropriate patient consent forms.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: E.O., M.A., Concept: E.O., S.T.Y., S.E., Design: S.T.Y., S.E., Data Collection and Processing: E.O., M.A., H.S.A., Analysis or Interpretation: E.O., M.A., S.E., Literature Search: E.O., H.S.A., Writing: E.O., H.S.A.

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