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The influence of tympanometric curves on the results of otoacoustic emissions

A influência das curvas timpanométricas nos resultados das emissões otoacústicas

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ABSTRACT

Purpose: To analyze distortion product evoked otoacoustic emissions in normal-hearing adults aged between 18 and 50 years old, and to associate the results with the findings of tympanometry. **Methods:** 27 medical records were selected of adults with the following conditions: normal hearing; without auditory complaint; with type A, Ad or Ar tympanometric curve; with presence of acoustic reflexes; with no complaint of tinnitus or frequent exposure to high sound pressure levels; with minimal auditory rest of 14 hours at the time of the test, and who had undergone distortion product evoked otoacoustic emission (DPOAE) testing. The results of otoacoustic emissions were analyzed considering the results of the tympanometric curves presented by these individuals. For the data analysis, non-parametric tests were applied, and the level of significance was 5%. **Results:** The results of otoacoustic emissions of 54 ears were analyzed. There was a greater occurrence of the type A curve in individuals without auditory complaints. Regardless of side, most ears whose response was present in the DPOAE test also presented normal tympanometric curve. There was a positive correlation between DPOAE amplitude and middle ear volume for the 6000Hz frequencies ($p = 0.048$) and a tendency to significance at 4000Hz ($p = 0.054$). **Conclusion:** There was a higher occurrence of otoacoustic emissions present in normal-hearing individuals and type A tympanometric curve, and the amplitude of DPOAE at 6000Hz was smaller in normal-hearing individuals and type Ar or Ad tympanometric curve.

Keywords: Amplitude; Hearing; Auditory tests; Acoustic reflex; Acoustic impedance tests; Spontaneous otoacoustic emissions

RESUMO

Objetivo: Analisar as emissões otoacústicas evocadas produto de distorção (EOAPD) de indivíduos adultos entre 18 e 50 anos, com audição normal, e associar os resultados com os achados à timpanometria. **Métodos:** Foram selecionados 27 prontuários de adultos com audição dentro dos padrões de normalidade, sem queixa auditiva, com curva timpanométrica do tipo A, Ad ou Ar, presença de reflexos acústicos, sem queixa de zumbido e de exposição frequente a níveis de pressão sonora elevados, com repouso auditivo mínimo de 14 horas no momento do exame e que realizaram o exame de emissões otoacústicas evocadas produto de distorção. Os resultados do exame de emissões otoacústicas foram analisados considerando os resultados das curvas timpanométricas apresentadas por estes indivíduos. Para análise dos dados foram aplicados testes não paramétricos e o nível de significância foi de 5%. **Resultados:** foram analisados os resultados das emissões otoacústicas de 54 orelhas. Observou-se maior ocorrência da curva do tipo A em indivíduos sem queixas auditivas. Independente do lado, a maioria das orelhas que apresentou resposta presente ao exame de EOAPD, apresentou, também, curva timpanométrica normal. Observou-se correlação positiva entre a amplitude das EOAPD e o volume da orelha média para as frequências de 6000 Hz e uma tendência à significância em 4000 Hz **Conclusão:** Foi possível concluir que há maior ocorrência de emissões otoacústicas presentes em indivíduos com audição normal e curva timpanométrica do tipo A e que a amplitude das EOAPD em 6000 Hz mostra-se menor nos indivíduos com audição normal e curva timpanométrica do tipo Ar ou Ad.

Palavras-chave: Amplitude; Audição; Testes auditivos; Reflexo acústico; Testes de impedância acústica; Emissões otoacústicas espontâneas

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INTRODUCTION

In 1978, otoacoustic emissions (OAE) were defined as sounds generated in the normal cochlea, released from the inner ear to the outer ear, which can be recorded by a probe inserted in the external auditory meatus (EAM), coupled to a microcomputer[1].

Otoacoustic emission testing evaluates the functioning of the outer hair cells (OHC) and is subdivided into two groups: spontaneous emissions, whose recording does not require the presence of sound stimuli, and evoked otoacoustic emissions (EOAEs), which are generated with the presence of sound stimuli and are classified into two types: intransient evoked otoacoustic emissions (TOAEs) and distortion-product evoked otoacoustic emissions (DPOAEs)[2-5].

TOAEs can be evoked by clicks that cover a wide range of frequencies, scanning the cochlea; they are found in individuals with normal cochlear function[3,4]. DPOAEs are evoked by two pure tones of similar frequencies, applied simultaneously (f1 and f2). Since the cochlea is unable to linearly amplify two different stimuli at that same time, intermodulation occurs, generating a distortion-product response. The intermodulation response normally used in clinical practice is 2f1-f2[4].

OAEs are released from the inner ear, through the entire middle ear structure, cross the tympanic membrane (TM) and are recorded in the EAM. Abnormal results of OAE tests may be related not only to malfunction of the OHC, but also to any problem that compromises the transmission of energy generated by the cells in the path through the middle and/or outer ear. Thus, changes in the mobility of the tympanic-ossicular system, caused by low or high admittance, may affect or conceal the results of TOAEs/DPOAEs[3-6].

Importantly, when detecting the presence of OAE responses, both from TEOAEs and DPOAEs, the tests show integrity of both OHC and conduction, that is, the middle ear is also intact[7]. For this reason, immittance testing needs to be performed before OAEs to rule out any dysfunction of the middle ear. Immittance testing is objective, easy and quick to apply. It is used for analyzing the mobility of the tympanic-ossicular system and searching for stapedial acoustic reflexes, allowing a more thorough evaluation of the middle ear[6,8].

Acoustic immittance measurements can be used to define the type of tympanometric curve. There are three types of tympanograms[9]: type A tympanogram, which indicates normal middle ear, usually found in individuals with normal hearing or sensorineural hearing loss; type B tympanogram, in which fluid is present inside the middle ear; and type C tympanogram, whose peak pressure is shifted toward the negative pressure region, which suggests Eustachian tube dysfunction. Within group A, there are two other types: type As/Ar tympanogram, which reflects rigidity of the tympanic-ossicular system, and type Ad tympanogram, found in individuals with great mobility of the tympanic-ossicular system[10]. Thus, there may be distortions in the recording of OAEs, because of the low or high admittance of the system.

In clinical practice, it has been found that some individuals, even with normal hearing and without hearing complaints, present abnormal tympanometric curves (type Ad or Air), which can, eventually, compromise the recording of otoacoustic emissions[1-3].

Thus, as hearing is an important sense for individuals to live in society, an accurate diagnosis of the auditory pathway is essential to carefully define the treatment required. Based on the considerations presented above, the aim of this study was to analyze the distortion-product evoked otoacoustic emissions of normal-hearing adults and to associate the results with the findings of the tympanometric measurements.

METHOD

This is an observational, descriptive, analytical, retrospective study, carried out in a private clinic in the countryside of the state of São Paulo. This research only began after the project had been analyzed and approved by the Research Ethics Committee of the Universidade do Oeste Paulista (Unoeste), under protocol number CAAE 63539416.4.000.5515.

This research was exempted by the Research Ethics Committee from an Informed Consent Form (ICF) because it is a retrospective study which used old medical records.

For this research, analyses were made of the medical records of adult individuals, aged between 18 and 50 years old. Information collected included medical history, and results of meatoscopy, pure tone audiometry, speech audiometry, immittance testing and distortion-product evoked otoacoustic emissions. Medical records were selected of adults with the following conditions: normal hearing[11], without hearing complaints, with A, Ad or Ar type tympanometric curve[9], presence of acoustic reflexes[12], without complaints of tinnitus and of frequent exposure to high sound pressure levels, with a minimum hearing rest of 14 hours at the time of the test, and who had undergone distortion-product evoked otoacoustic emission testing.

Pure-tone audiometry and speech audiometry tests were performed in a soundproof booth, using an Interacoustic AD 229b audiometer. Immittance testing was performed with an Interacoustic AZ7 impedance meter. Distortion-product evoked otoacoustic emissions were measured using a Starkey DP 2000 DPOAE Measurement System, with its respective software properly installed in a notebook. The established parameters followed the standard recommended by the manufacturer and also proposed by Gorga et al.[13], namely: two pure tones f1 L1 = 65 dBSPL / f2 L2 = 55 dBSPL, yielding the value of the product 2f1-f2. The frequencies of 2000, 3000, 4000 and 6000 Hz were investigated. Duration of the evocative stimulus was 4 seconds for 6000 and 4000 Hz, 6 seconds for 3000 Hz and 8 seconds for 2000 Hz. Another parameter in use was probe stability greater than or equal to 90%. A DPOAE was considered to be present when 2f1-f2 was at least 6 dBSPL above the first standard deviation of the noise at the evaluated frequency, minimum amplitude was -10 dB and the background noise level was equal to or less than -5dBSPL[14,15].

A spreadsheet was prepared for data collection, containing equivalent volume of the middle ear (mL), maximum compliance peak (daPa) and the result of DPOAEs for the frequencies of 2000, 3000, 4000 and 6000 Hz.

After the end of data collection, all the results underwent descriptive and inferential statistical analysis with non-parametric tests. The level of statistical significance was set at 5%(< 0.05). The Wilcoxon test was used to compare the results for equivalent volume of the middle ear, maximum compliance peak and signal-to-noise ratio (S/N ratio) of otoacoustic emissions per ear. The two-proportion z-test was used to characterize the distribution of percentages for the type of tympanometry found for each ear, and the Chi square test was used to measure the

relationship between tympanometry and the results of otoacoustic emissions. Finally, the Mann-Whitney test was used to compare the normal and abnormal groups, as regards the results for tympanometry and the results for otoacoustic emissions.

RESULTS

A total of 262 medical records were analyzed, but only 27 of them (54 ears) were included in the research, because of the inclusion criteria established previously. The average age of the sample was 38.3 years, 18 (66.7%) of whom were females and 9 (33.3%) were males.

There was no significant difference in the results between the ears for the values described for tympanometry and DPOAEs (Tables 1 and 2). There was a greater occurrence of the type A curve in individuals without hearing complaints, for both ears (Table 3).

For the analysis of the findings, only the type A tympanometric curve was considered to have normal tympanometry results[9]. Table 4 shows a significant association between the results for DPOAEs (normal and abnormal) and the results for tympanometry (Table 4). Regardless of side, 86% of the ears which showed a present response to the DPOAE test also had a normal tympanometric curve.

Finally, the amplitude values of DPOAEs were compared, per frequency, considering the results of tympanometry (normal or abnormal). The Mann-Whitney test showed a significant difference for the frequency of 6000 Hz (p = 0.048) and a tendency towards significance for the frequency of 4000 Hz (p = 0.054) (Table 5).

Table 1. Descriptive values and comparison between the ears of the tympanometry results (N = 54 ears)

Tympanometry	Ear	Mean	Median	Standard Deviation	N	CI	p-value
Volume (mL)	RE	0.80	0.6	0.64	27	0.24	0.97
	LE	0.86	0.6	0.80	27	0.30	
Pressure (daPa)	RE	-1.85	0	9.62	27	3.63	0.31
	LE	0.00	0	0.00	27	- x -	

Statistical test: Wilcoxon test. Significance level: p <0.05
Subtitle: RE = right ear; LE = left ear; N = sample size; CI = confidence interval; mL = milliliters; daPa = decapascal

Table 2. Descriptive values and comparison between the ears of the results (S/N ratio in dBSPL) of distortion-product evoked otoacoustic emission testing (N = 54 ears)

S/N Ratio of Emissions (dBSPL)	Ear	Mean	Median	Standard Deviation	N	CI	p-value
2000 Hz	RE	9.52	9.60	8.32	27	3.14	0.53
	LE	10.39	10.10	8.33	27	3.14	
3000 Hz	RE	12.77	15.50	9.12	27	3.44	0.40
	LE	11.87	12.90	7.49	27	2.82	
4000 Hz	RE	13.21	14.20	10.70	27	4.04	0.44
	LE	12.03	13.80	9.60	27	3.62	
6000 Hz	RE	8.02	8.80	10.71	27	4.04	0.78
	LE	7.83	7.10	7.73	27	2.92	

Statistical test: Wilcoxon test. Significance level: p <0.05
Subtitle: RE = right ear; LE = left ear; N = sample size; CI = confidence interval; S/N ratio = signal-to-noise ratio; dBSPL = decibels sound pressure level; Hz = Hertz

Table 3. Distribution of tympanometric curves per ear (N = 54 ears)

Type (RE)	N	%	p-value	Type (LE)	N	%	p-value
Type A	14	51.9	Ref.	Type A	14	51.9	Ref.
Type Ad	6	22.2	0.02	Type Ad	5	18.5	0.01
Type Ar	7	25.9	0.05	Type Ar	8	29.6	0.09

Statistical test: Two-proportion z-test. Significance level: p <0.05
Subtitle: RE = right ear; LE = left ear; N = sample size; % = percentage; Ref = Reference

Table 4. Association of the results for distortion-product evoked otoacoustic emissions and tympanometry, per ear (N = 54 ears)

DPOAEs		Tympanometry						p-value
		Abnormal		Normal		Total		
		N	%	N	%	N	%	
RE	Abnormal	7	54	2	14	9	33%	0.029
	Normal	6	46	12	86	18	67%	
LE	Abnormal	9	69	2	14	11	41%	0.004
	Normal	4	31	12	86	16	59%	

Statistical test: Chi-square test. Significance level: p <0.05
Subtitle: RE = right ear; LE = left ear; N = sample size; % = percentage; DPOAEs = distortion-product evoked otoacoustic emissions

Table 5. Descriptive values and comparison of the amplitude of distortion product evoked otoacoustic emissions (dBSPL), considering the tympanometry results (N = 54 ears)

Tympanometry		S/N Ratio DPOAEs (dBSPL)					
		Mean	Median	SD	N	CI	p-value
2000 Hz	Abnormal	7.93	7.45	9.95	26	3.83	0.174
	Normal	11.83	11.70	5.88	28	2.18	
3000 Hz	Abnormal	10.58	11.55	9.93	26	3.82	0.264
	Normal	13.94	15.55	6.12	28	2.27	
4000 Hz	Abnormal	9.72	11.50	11.02	26	4.24	0.054
	Normal	15.31	16.20	8.46	28	3.13	
6000 Hz	Abnormal	6.05	4.30	10.25	26	3.94	0.048
	Normal	9.66	9.90	8.02	28	2.97	

Statistical test: Mann-Whitney test. Significance level: p <0.05

Subtitle: N = sample size; DPOAEs = distortion-product evoked otoacoustic emissions; Hz = Hertz; dBSPL = decibels sound pressure level; S/N ratio = signal-to-noise ratio; SD = standard deviation; CI = confidence interval

DISCUSSION

The purpose of this study was to find an association between the results of the tympanometric curves (A, Ar and Ad) with the results for DPOAEs in order to check whether abnormalities in the admittance of the tympanic-ossicular system may interfere with the emission findings, even in cases of normal hearing.

The tympanometric findings showed a higher occurrence of type A curves in subjects without hearing complaints (RE = 51.9% LE = 51.9%). However, in this population, there were also abnormal tympanometric curves, with a higher incidence in the type Ar curve (RE = 25.9% LE = 29.6%). The complaints reported by the individuals with abnormal curves ranged from dysphonia to allergies, such as rhinitis and sinusitis, ruling out possible otologic complaints.

Tables 1 and 2 show that there was no difference in the results, both for tympanometry and for DPOAEs, when comparing the ears. This finding confirms data from the literature, which have already pointed out that there is no difference between the ears, in the analysis of emissions otoacoustic in normal-hearing adults[16].

There was a predominance of present DPOAEs with normal tympanometric curves (86%), in the same way as absent DPOAEs, with abnormal tympanometric curves (RE = 54% LE = 69%), regardless of ear. Some previous studies have reported that individuals with normal audiograms may present variability in the results of DPOAEs, because of the conditions of the middle ear, which is responsible for the conduction of sound and directly interferes in the recording of otoacoustic emissions; namely, it may hide or even decrease the amplitude of response[6,8,17]. The transmission of sound from the outer ear to the inner ear can be affected by the pathologies of the tympanic membrane, thus impairing the recording of OAEs[1]. In a previous study, researchers concluded that there may be distortions in the recording of otoacoustic emissions at low frequencies, because energy transmission is less effective when energy passes through the middle ear. However, the cochlea can also produce less distortion at low frequencies when compared to high frequencies[13]. Another study investigated the influence of tympanometric curves on the amplitude of low frequencies in DPOAEs[18]. However, these distortions could not be found in the present study because it evaluated frequencies that ranged from 2000 to 6000 Hz, as a result of the high incidence of distortions at low frequencies, for reasons other than the middle ear alone[19]. There was a statistically significant difference (p = 0.048) regarding the S/N ratio (signal-to-noise ratio) of the DPOAEs, at the frequency of 6000 Hz, in which the median in the ears with abnormal curves was lower than that of the ears with the type A curve. A similar behavior was found for the frequency of 4000 Hz, but with a tendency to statistical difference (p = 0.054). One limitation of this study is sample size. If the sample had been larger, the difference might have been significant.

After the observation of clinical practice and the analysis of the results of tympanometry and otoacoustic emission testing in individuals with a dysfunctional middle ear - either because of rigidity or flaccidity of the tympanic-ossicular system - it can be inferred that there was a possible interference in the energy transmitted through the external auditory canal to the outer hair cells, and/or by the energy that is generated by the OHC and which is propagated throughout the EAM, thus interfering in the recording of the response by the probe of the OAE equipment.

The tests carried out in this study are complementary to one another, which highlights the importance of using different methods of auditory function assessment - whether behavioral, electroacoustic, or electrophysiological - for a more accurate and safer diagnosis, avoiding false positives and delayed diagnosis, regardless of the patient's age.

CONCLUSION

In conclusion, there is a higher occurrence of otoacoustic emissions in individuals with normal hearing and type A tympanometric curve, and the amplitude of DPOAEs at 6000 Hz is smaller in individuals with normal hearing and type Ar or Ad tympanometric curve.

REFERENCES

1. Kemp DT. Otoacoustic emissions, their origin in cochlear function, and use. Br Med Bull. 2002;63(1):223-41. http://dx.doi.org/10.1093/bmb/63.1.223. PMid:12324396.

2. Vasconcelos RM, Serra LSM, Aragão VMF. Emissões otoacústicas evocadas transientes e por produto de distorção em escolares. Rev Bras Otorrinolaringol. 2008;74(4):503-7. http://dx.doi.org/10.1590/S0034-72992008000400004.

3. Guedes MC, Passos SN, Gomez MVSG, Bento RF. Estudo da reprodutibilidade das emissões otoacústicas em indivíduos normais. Rev Bras Otorrinolaringol. 2002;68(1):34-8. http://dx.doi.org/10.1590/S0034-72992002000100006.

4. Azevedo MF. Emissões otoacústicas. In: Figueiredo MS, editor. Emissões otoacústicas e BERA. São José dos Campos: Pulso; 2003. p. 35-83.

5. Couto CM, Carvallo RMM. O efeito das orelhas externa e média nas emissões otoacústicas. Rev Bras Otorrinolaringol. 2009;75(1):15-23. http://dx.doi.org/10.1590/S0034-72992009000100003.

6. Coube CZV, Costa AO Fo. Princípios básicos das emissões otoacústicas. In: Frota S, editor. Fundamentos em fonoaudiologia: audiologia. 2a ed. Rio de Janeiro: Guanabara Koogan; 2003. p. 96.

7. Munhoz MS, Silva MLG, Frazza MM, Caovilla HH, Ganança MM, Carvalho P. Otoemissões acústicas. In: Munhoz MS, Caovilla HH, Silva MLG, Ganança MM, editores. Audiologia clínica. São Paulo: Atheneu; 2000.

8. Camboim ED, Correia AMN, Vasconcelos D, Torres R, Scharlach RC, Azevedo MF. Análise comparativa das emissões otoacústicas com a timpanometria em lactentes de 0 a 6 meses. Rev CEFAC. 2012;14(3):403-12. http://dx.doi.org/10.1590/S1516-18462011005000090.

9. Jerger J. Clinical experience with impedance auidometry. Arch Otolaryngol. 1970;92(4):311-24. http://dx.doi.org/10.1001/archotol.1970.04310040005002. PMid:5455571.

10. Russo ICP, Valente CHV, Lopes LQ, Brunetto-Borginanni LMB. Medidas de imitância acústica. In: Momensohn-Santos TM, Russo ICP. Prática da audiologia clínica. 8a ed. São Paulo: Cortez; 2011. p. 183-216.

11. Lloyd LL, Kaplan H. Audiometric interpretation: a manual of basic audiometry. Baltimore: University Park Press; 1978. p. 16-17.

12. Gelfand SA. The contralateral acoustic reflex threshold. In: Silman S, editor. The acoustic reflex: basic principles and clinical aplications. Orlando: Academic Press; 1984. p. 137-86. http://dx.doi.org/10.1016/B978-0-12-643450-7.50010-X.

13. Gorga MP, Neely ST, Ohlrich B, Hoover B, Redner J, Peters J. From laboratory to clinic: a large scale study of distortion product otoacoustic emissions in ears with normal hearing and ears with hearing loss. Ear Hear. 1997;18(6):440-55. http://dx.doi.org/10.1097/00003446-199712000-00003. PMid:9416447.

14. Mello JM, Della-Rosa VA, Carvallo RMM. Emissões otoacústicas evocadas por produto de distorção em frequências ultra-altas em pais de indivíduos com deficiência auditiva autossômica recessiva. CoDAS. 2014 Fev;26(1):3-9. http://dx.doi.org/10.1590/s2317-17822014000100002. PMid:24714853.

15. Marone MR. Emissões otoacústicas produto de distorção em recém-nascidos medicados com ototóxicos [tese]. São Paulo: Faculdade de Medicina, Universidade de São Paulo; 2006. http://dx.doi.org/10.11606/T.5.2006.tde-16082006-120318.

16. Paula CU, Carvallo RMM. Latency of DPOAE in milliseconds and waves. Rev Bras Otorrinolaringol. 2005 Dez;71(6):784-9. PMid:16878249.

17. Campos UDP. Função da orelha media e das curvas de crescimento nas respostas das emissões otoacústicas [tese]. São Paulo: Faculdade de Medicina, Universidade de São Paulo; 2011.

18. Margolis RH, Trine MB. Influence of middle-ear disease on otoacoustic emissions. In: Robinette MS, Glattke TJ, editores. Otoacoustic emissions clinical applications. New York: Thieme; 1997. p. 130-50.

19. Bassetto MCA, Chiari BM, Azevedo MF. Emissões otoacústicas evocadas transientes (EOAT): amplitude da resposta em recém-nascidos a termo e pré-termo. Rev Bras Otorrinolaringol. 2003;69(1):84-92. http://dx.doi.org/10.1590/S0034-72992003000100014.