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Original Article
Artigo Original

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Contralateral Occlusion Test (COT): the effect of external ear canal occlusion with aging

Teste de Oclusão Contralateral (TOC): o efeito da oclusão do canal auditivo externo com a idade

Keywords

Hearing Loss Conductive
Audiometry
Ear Canal
Hearing Tests
Bedside Testing
Auditory Threshold

ABSTRACT

Purpose: This study aimed to evaluate the effects of complete external ear canal occlusion on hearing thresholds with aging. The goal was to decide which tuning fork is more appropriate to use for the contralateral occlusion test (COT), in individuals of different ages. **Methods:** Forty-two normal hearing subjects between 21 and 67 years were divided into three age groups (20-30 years, 40-50 years, and 60-70 years). Participants underwent sound field audiometry tests with warble tones, with and without ear canal occlusion. Each ear was tested with the standard frequencies (250, 500, 1000, and 2000 Hz). The contralateral ear was suppressed by masking. **Results:** Hearing thresholds showed an increase as the frequency increased from 20.85 dB (250 Hz, 20-30 years group) to 48 dB (2000 Hz, 60-70 years group). The threshold differences between occlusion and no occlusion conditions were statistically significant and increased ranging from 11.1 dB (250 Hz, 20-30 years group) to 32 dB (2000 Hz, 20-30 years group). We found statistically significant differences for the three age groups and for all evaluations except to 500 Hz difference and average difference. The mean hearing loss produced by occlusion at 500 Hz was approximately 19 dB. We found no statistically significant differences between right and left ears and gender for all measurements. **Conclusion:** We conclude that the use of the 512 Hz tuning fork is the most suitable for COT, and its use may allow clinicians to distinguish mild from moderate unilateral conductive hearing loss.

Descritores

Perda Auditiva Condutiva
Audiometria
Meato Acústico Externo
Testes Auditivos
Testes Imediatos
Limiar Auditivo

RESUMO

Objetivo: O objetivo deste estudo foi avaliar o efeito da oclusão completa do canal auditivo externo nos limiares auditivos, em indivíduos de idades distintas, para apurar qual o diapasão mais adequado na realização do teste de oclusão contralateral (TOC). **Método:** 42 indivíduos normo-ouvintes (21-67 anos) foram divididos em três grupos etários (20-30, 40-50 e 60-70 anos). Os participantes foram avaliados com testes de audiometria tonal liminar em campo livre, com e sem oclusão completa do canal auditivo externo. Cada ouvido foi testado para as frequências 250, 500, 1000 e 2000 Hz. No ouvido contralateral, foi realizado mascaramento, para evitar a ocorrência de audição contralateral. **Resultados:** Verificou-se aumento dos limiares auditivos, diretamente proporcional ao aumento da frequência (desde 20.85 até 48 dB). A diferença nos limiares auditivos entre a condição de oclusão e de não oclusão foi estatisticamente significativa em todas as frequências e aumentou de forma diretamente proporcional com a frequência (desde 11.1 até 32 dB). Foram também encontradas diferenças estatisticamente significativas para os três grupos etários, em todos os parâmetros, exceto na diferença a 500 Hz e na diferença total média. A perda auditiva média resultante da oclusão aos 500 Hz foi de 19 dB. Não se encontraram diferenças estatisticamente significativas entre o ouvido direito e o esquerdo, e entre o gênero. **Conclusão:** A utilização do diapasão de 512 Hz é a mais adequada para o TOC. A sua utilização pode permitir aos clínicos, em ambiente de consulta e de forma rápida, a distinção entre perda condutiva de grau leve a moderada.

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INTRODUCTION

Many of the early diagnostic tests are initially performed at bedside[1,2]. This practice may decrease turnaround time, reduce costs, and improve decision making[3-5]. Tuning fork testing allows a quick and qualitative assessment of hearing[6-8]. However, none of these tests really permits a quantitative hearing assessment.

In a previous study, the authors of this paper described the contralateral occlusion test (COT)[9]. We designed a bedside test that permit quantitative evaluation of hearing loss in the presence of unilateral conductive hearing loss. After the confirmation of unilateral conductive hearing loss with Weber and Rinne tests[10-15], the COT is carried out with total occlusion of the external auditory meatus (EAM) of the contralateral ear (the unaffected ear). This will produce a hearing loss in the unaffected ear that can be higher, lower, or similar to that in the affected ear. In this scenario, the sound of a vibrating tuning fork placed in the middle of the forehead will lateralize to the ear with the greater hearing loss.

Once the hearing loss produced by EAM occlusion in each frequency is established, we can decide which tuning fork is more suitable to use in the COT[9]. Moreover, we can evaluate the reproducibility of that effect for several ages and several frequencies.

This study aimed to evaluate the effects of complete occlusion of the EAM on hearing thresholds with aging in order to decide which tuning fork is more appropriate for COT in individuals of different ages.

METHODS

Participants

This study was approved by the Health Ethics Committee (CES) of the West Lisbon Hospital Centre (CHLO), Lisbon, Portugal, on November 19, 2014, and by the Ethics Research Committee of the NOVA Medical School (nr. 49/2014/CEFCM). The study was conducted according to the Declaration of Helsinki. All participants voluntarily signed the informed consent.

The study involved patients from the Department of Otolaryngology, Egas Moniz Hospital, Lisbon, who underwent audiological assessments in the Department of Audiology. This analytical, cross-sectional study enrolled participants by convenience sampling. The inclusion criteria were as follows: 1) ages within one of the three groups (20-30, 40-50, or 60-70 years); 2) absence of a pathological, otological history; 3) normal otoscopy; 4) normal pure-tone audiometry[16]; 5) type A tympanogram[17]; 6) oral communication ability; and 7) a signed informed consent (following clarification of the study procedures). The exclusion criteria were: 1) history of external or middle ear pathology or symptomatology; 2) neurological and/or psychiatric disorders that could interfere with language; and 3) serious visual changes. The study sample comprised 42 individuals (84 ears), divided into three groups: 20-30 years (21 patients, 42 ears), 40-50 years (11 patients, 22 ears), and 60-70 years (10 patients, 20 ears). None of the participants had hearing aids or formal training in pure tone audiometry.

Procedures

All patients underwent a comprehensive medical and audiological evaluation. All tests were conducted in a soundproof test room according to ISO 8253 and 389 standards. The following equipment were used: the Orbiter clinical audiometer (Madsen Electronics A/C; Herley, Copenhagen, Denmark), the 922 TDH39 earphones (Telephonics; Farmingdale, NY, USA), the ME70 noise-excluding headset (Madsen Electronics A/C; Herley, Copenhagen, Denmark), and the B-71 bone conductor (Radioear Corporation; New Eagle, PA, USA). An audiological study, including admittance and tonal audiograms, was performed, and patients then underwent an office-based reassessment. If all of the inclusion criteria were fulfilled, a sound field audiometry testing was given with warble tones. Each ear was first tested as non-occluded followed by occluded, using the standard frequencies of 250, 500, 1000, and 2000 Hz in order to determine each frequency's thresholds. The contralateral ear was suppressed by masking at 50 dB with the headset. For the purpose of this study, occlusion was operationally defined as complete blockage of the external auditory meatus. Implicit in this definition are the psychoacoustic and physical perceptions resulting from such conditions. The occlusion was performed by application of tragal pressure by the examiner's finger until complete occlusion of the EAM had occurred (through digital sense and asking the subject).

Accordingly, we followed these sequential steps:

1. Right ear (RE) uncovered and masked left ear (LE) with determination of the hearing thresholds at 250, 500, 1000, and 2000 Hz in the RE;
2. RE with an EAM occlusion produced by digital pressure on the tragus and masked LE with determination of the thresholds at 250, 500, 1000, and 2000 Hz in the RE;
3. In the LE, we proceeded in an identical manner to the RE by repeating steps 1 and 2.

The results for each frequency before and after occlusion were recorded in a table. The examiner was right-handed.

Statistical analysis

All calculations were performed with the Statistical Package for the Social Sciences 21.0® for Windows (IBM SPSS Statistics; Armonk, NY, USA). For the 20 to 30 years group and for the total sample we tested the conditions for statistical tests application (normality and homoscedasticity) in order to choose parametric or nonparametric tests, as appropriate. In order to evaluate the effect of EAM occlusion on hearing thresholds, we used nonparametric tests (40-50 and 60-70 years groups consisting of $n<30$ in each group). We tested for statistically significant differences between non-occluded and occluded conditions, ages, LE and RE, and gender. We computed 95% confidence intervals and considered $p < 0.05$ as statistically significant.

RESULTS

In individuals in the 20-30 years group, age ranged from 21 to 30 years (mean age, 25.6±3.03 years; median age, 26 years). In the 40-50 years group, age ranged from 41 to 50 years (mean age, 45.2±3.7 years; median age, 46 years), and in the 60-70 years group, age ranged from 60 to 67 years (mean age, 63±2.4 years; median age, 62.5 years).

Normality testing of data

In the 20-30 years group, we analyzed the normal data distribution in each dimension in order to select either the parametric or the nonparametric tests. Table 1 shows the results obtained using the Kolmogorov-Smirnov test. All variables except the 1000 Hz difference followed a normal distribution ($p < 0.05$), and parametric tests were selected accordingly. In the others age groups with $n < 30$, we did not test normality, and used nonparametric tests. In the total sample, only the 250 Hz with occlusion, 250 Hz difference, and average dimensions followed the normal distribution.

Differences between right and left ears

To compare the RE and LE in the 20-30 years group, we used the Student's *t*-test. In the 40-50 and 60-70 years groups, we used the Mann-Whitney test. No statistically significant differences were found between the RE and LE (Table 2).

Differences between occlusion and no occlusion conditions

In order to evaluate potential differences in hearing thresholds under different conditions, we compared the results under occluded condition with those in the non-occluded condition. We used the Wilcoxon test in the two upper age groups ($n < 30$), and the paired sample t-test for the 20-30 years group (Table 3).

Table 1. Results of normal distribution of data in the several study conditions (difference, with and without EAM occlusion)

	z	p	z	p
	20-30 years group		Total	
250 Hz without occlusion	1.289	0.072	1.917***	.001
250 Hz with occlusion	0.798	0.548	1.010	.259
250 Hz difference	1.025	0.244	1.243	.091
500 Hz without occlusion	1.328	0.059	2.023***	.001
500 Hz with occlusion	1.204	0.110	1.650**	.009
500 Hz difference	1.146	0.144	1.512*	.021
1000 Hz without occlusion	1.354	0.051	2.007***	.001
1000 Hz with occlusion	1.029	0.241	1.522*	.019
1000 Hz difference	1.847	0.002	2.030***	.001
2000 Hz without occlusion	1.164	0.133	1.837**	.002
2000 Hz with occlusion	1.222	0.101	1.852**	.002
2000 Hz difference	1.290	0.072	1.809**	.003
Average without occlusion	0.881	0.419	1.321	.061
Average with occlusion	0.715	0.686	0.689	.735
Average difference	0.738	0.647	0.748	.630

*p≤0.05; **p≤0.01; ***p≤0.001

Caption: EAM = External Auditory Meatus; z = Kolmogorov-Smirnov z-value; p = p-value. Kolmogorov-Smirnov test

Table 2. Hearing thresholds (dB) with occlusion in right and left ears

Frequency	Age (years)	Right ear (dB)		Left ear (dB)		z (or t)	p
		M (dB)	SD (dB)	M (dB)	SD (dB)		
250 Hz	20-30	23.00	6.77	16.00	6.41	3.359***	.002
	40-50	17.27	8.48	17.27	8.17	0.000*	1.000
	60-70	18.00	5.87	15.00	11.06	–0.731*	.465
500 Hz	20-30	26.00	6.20	24.50	7.59	0.684**	.498
	40-50	18.18	7.17	19.09	7.69	–0.438*	.662
	60-70	19.50	4.97	18.00	7.53	–0.506*	.613
1000 Hz	20-30	35.50	6.05	29.75	6.17	2.976***	.05
	40-50	19.09	5.84	22.73	6.84	–1.079*	.281
	60-70	22.50	7.17	24.50	6.85	–0.750*	.453
2000 Hz	20-30	42.25	4.99	36.00	5.28	3.846****	<0.001
	40-50	26.82	6.43	25.00	5.00	–0.797*	.425
	60-70	28.50	6.69	28.50	10.55	–0.039*	.969

*p > .05; **p≤0.05; ***p≤0.01; ****p≤0.001

Caption: M = mean; SD = standard deviation; z = z-value for Mann-Whitney test; t = Student's t-test value; p = p-value. Student's *t*-test, and the Mann-Whitney test

We found statistically significant differences between occlusion and no occlusion conditions for all measurements. Considering non-occluded and occluded conditions respectively, the average values varied for the 20-30 years group from 7.65 dB to 29.87 dB (difference of 22.5 dB), for the 40-50 years group from 9.84 dB to 30.26 dB (difference of 20.44 dB), and for the 60-70 years group from 17.09 dB to 38.90 dB (difference of 21.84 dB). The results showed higher values with occlusion at all frequencies.

Differences between ages

In order to test if there were differences between age groups, and because not all dimensions followed a normal distribution, a non-parametric test was chosen (Kruskal-Wallis test). We found statistically significant differences for the three age groups and for all evaluations, except for 500 Hz difference and average difference (Table 4). For the 500 Hz difference the results ranged from 18.33 dB (40-50 years group) to 19.51 dB (40-50 years group), with an average rounded to 19 dB. In order to compare between pairs for statistically significant differences, we used the Mann-Whitney test. Comparing the 20-30 years group with the 40-50 years group we found higher values for the 20-30 years group only at 1000 Hz difference and 2000 Hz difference, and for the 40-50 years group for the remaining items (250 Hz without occlusion, 250 Hz with occlusion, 250 Hz difference, 500 Hz with occlusion, 2000 Hz with occlusion and average without occlusion). Comparing the 20-30 years group with the

Table 3. Hearing thresholds without occlusion and occlusion conditions at different frequencies and in the different age groups

Frequency	Age (years)	Without occlusion		With occlusion		z (or t)	p
		M (dB)	SD (dB)	M (dB)	SD (dB)		
250 Hz	20-30	9.27	5.31	20.85	8.58	–9.251***	<0.001
	40-50	12.73	4.00	30.00	9.26	–4.124*	<0.001
	60-70	19.25	6.94	35.75	9.22	–3.936*	<0.001
500 Hz	20-30	7.56	5.02	27.07	6.42	–18.18***	<0.001
	40-50	9.77	3.61	28.41	7.62	–4.130*	<0.001
	60-70	16.00	6.20	34.75	8.19	–3.946*	<0.001
1000 Hz	20-30	6.59	4.93	32.44	6.72	–39.71***	<0.001
	40-50	7.95	4.27	28.86	5.55	–4.132*	<0.001
	60-70	13.50	8.29	37.00	8.01	–3.958*	<0.001
2000 Hz	20-30	7.07	5.70	39.02	5.94	–41.04***	<0.001
	40-50	8.18	6.08	34.09	6.10	–4.157*	<0.001
	60-70	19.50	9.31	48.00	10.44	–3.940*	<0.001
Average	20-30	7.65	3.81	29.87	5.09	–35.95***	<0.001
	40-50	9.84	2.77	30.26	5.25	4.017*	<0.001
	60-70	17.09	6.33	38.90	6.94	3.924*	<.001

*p≤.05; ***p≤ .001 in 20-30 years group
Caption: M = mean; SD = standard deviation; z = z-value for Wilcoxon test; t = paired sample t-test value; p = p-value. Wilcoxon test, and the paired sample t-test

Table 4. Hearing thresholds in the various age groups, for the different frequencies and conditions (without occlusion of the EAM, occlusion of the EAM, and difference)

	20-30 years		40-50 years		60-70 years		χ^2	p
	M (dB)	SD (dB)	M (dB)	SD (dB)	M (dB)	SD (dB)		
250 Hz without occlusion	9.27	5.31	12.86	4.05	19.25	6.94	27.009***	<.001
250 Hz with occlusion	20.85	8.58	29.52	9.21	34.75	9.22	26.655***	<.001
250 Hz difference	11.59	8.02	16.67	7.80	16.50	8.75	6.700*	.035
500 Hz without occlusion	7.56	5.02	10.00	3.54	16.00	6.20	26.529***	<.001
500 Hz with occlusion	27.07	6.42	28.33	7.80	34.75	8.19	10.805**	.005
500 Hz difference	19.51	6.87	18.33	7.30	18.75	6.26	.240	.887
1000 Hz without occlusion	6.59	4.93	8.10	4.32	13.50	8.29	12.810**	.002
1000 Hz with occlusion	32.44	6.72	29.05	5.62	37.00	8.01	11.908**	.003
1000 Hz difference	25.85	4.17	20.95	6.64	23.50	6.90	8.653*	.013
2000 Hz without occlusion	7.07	5.70	8.33	6.19	19.50	9.31	23.637***	<.001
2000 Hz with occlusion	39.02	5.94	34.05	6.25	48.00	10.44	23.417***	<.001
2000 Hz difference	31.95	4.99	25.71	5.76	28.50	8.60	14.338***	.001
Average without occlusion	7.65	3.81	9.84	2.77	17.09	6.33	33.199***	<.001
Average with occlusion	29.87	5.09	30.26	5.25	38.90	6.94	22.538***	<.001
Average difference	22.25	3.96	20.44	5.28	21.84	5.00	1.496	.473

*p≤.05; **p≤.01; ***p ≤.001
Caption: M = mean; SD = standard deviation; EAM = external auditory meatus; χ = chi-square value for Kruskal-Wallis test; p = p-value. Kruskal-Wallis test

60-70 years group we found higher values in the 20-30 years group only at 2000 Hz difference, and we found higher values in the 40-50 years group for 250 Hz without occlusion, 250 Hz with occlusion, 250 Hz difference, 500 Hz without occlusion, 500 Hz with occlusion, 1000 Hz without occlusion, 1000 Hz with occlusion, 2000 Hz without occlusion, 2000 Hz with occlusion, average without occlusion and average with occlusion. Finally, comparing the 40-50 years group with the 60-70 years group we found higher values only for the 60-70 years in 250 Hz without occlusion, 250 Hz with occlusion, 500 Hz without occlusion, 500 Hz with occlusion, 1000 Hz without occlusion, 1000 Hz with occlusion, 2000 Hz without occlusion, 2000 Hz with occlusion, average without occlusion e average with occlusion. Based on Table 4, in each age group and as the frequency increased, the hearing threshold difference between occlusion and without occlusion conditions also increased (Figure 1). However, the correlation is statistically significant for the 40-50 ($r = .99$; $p = .002$) and 60-70 ($r = .99$; $p = .014$) years groups but not for the 20-30 years group ($r = .94$; $p = .059$).

Differences between gender

To assess for gender differences in the 20-30 years group, we used the t-test for two independent samples. There were no statistically significant gender differences except at 500 Hz with occlusion ($t [38] = 2.202$ and $p = 0.034$). For the 40-50 and 60-70 years groups, we used the Mann-Whitney test. Equally, for the 40-50 years group, statistically significant gender differences were observed only at 500 Hz difference, with $z= –2.096$ and $p= 0.036$. The results showed higher values in males only for these two evaluations. In the 60-70 years group, no statistically significant differences were found between genders (Table 5).

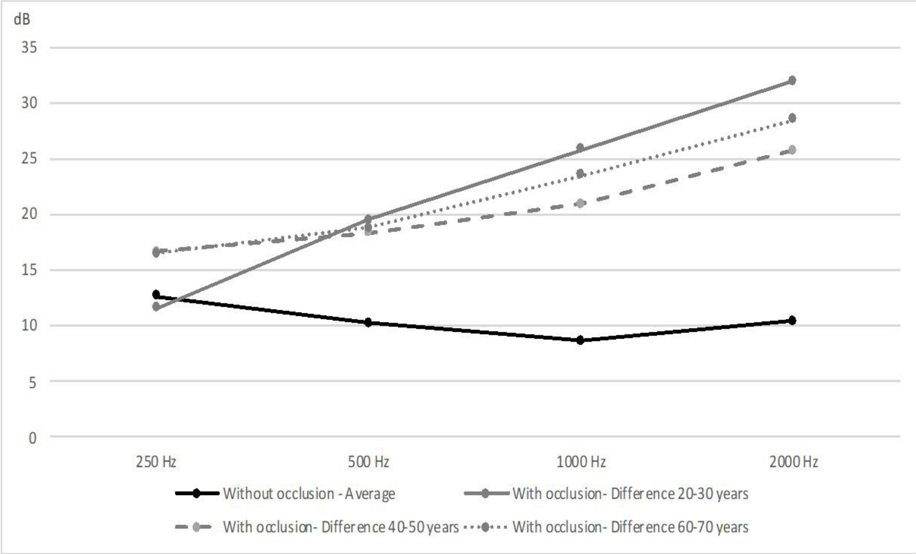

Figure 1. Occlusion/no occlusion difference (dB) and hearing average without occlusion (dB), for each frequency (250 Hz, 500 Hz, 1000 Hz and 2000 Hz) in different age groups

Table 5. Differences between gender in hearing thresholds (dB) with occlusion difference

Frequency	Age (years)	Male		Female		z (or t)	p
		M (dB)	SD (dB)	M (dB)	SD (dB)		
250 Hz	20-30	19.72	7.37	19.32	7.61	.169	.886
	40-50	18.75	8.82	15.50	7.25	-873	.383
	60-70	17.50	9.50	15.50	8.32	-.539	.590
500 Hz	20-30	27.78	5.75	23.18	7.33	2.202*	.034
	40-50	21.67	6.16	15.00	7.07	-2.096*	.036
	60-70	19.00	7.38	18.50	5.30	-.545	.586
1000 Hz	20-30	33.33	5.94	32.05	7.35	.600	.552
	40-50	21.67	6.85	20.00	6.24	-.508	.612
	60-70	24.50	5.99	22.50	7.91	-.671	.502
2000 Hz	20-30	39.17	5.75	39.09	6.29	.039	.969
	40-50	27.08	5.42	24.50	5.99	-1.079	.281
	60-70	30.00	9.13	27.00	8.23	-.271	.787

Caption: M = mean; SD = standard deviation; z = z-value for Mann-Whitney test; t = Student's t-test value; p = p-value. t-test for two independent samples, and Mann-Whitney test. *p≤.05

DISCUSSION

Bedside testing may be used as a screening procedure for testing hearing in the office or in an emergency[11,12,18]. While formal audiometry is preferable, it may not always be possible for reasons of expense or accessibility. Tuning forks allow for the distinction between conductive and sensorineural hearing loss[6-8]. However, in some real clinical situations, we need a rapid or at least a strong indication of hearing loss severity. This information permits immediate clinical management that will improve patient safety and clinical outcomes.

COT may help to quantify the hearing loss. Total EAM occlusion of a normal ear can produce a hearing loss[19,20] that can be higher, lower, or similar to the contralateral ear with conductive hearing loss. If the sound of the tuning fork lateralizes to the affected ear (non-occluded ear), it suggests that the ear has a moderate or severe hearing loss; if the sound of the tuning fork lateralizes to the normal ear (occluded ear), it suggests that the ear has a mild hearing loss.

A prior study demonstrated the reproducibility of hearing loss induced by the EAM occlusion (between examiners) and the correlation of degree of hearing loss with frequencies[9]. In this study the objective was to understand if the occlusion effect was reproducible with aging. At each frequency, hearing thresholds increased in the two conditions (occlusion and without occlusion) with aging; probably in relation to the normal process of hearing loss with aging. Complete EAM occlusion produced higher values for hearing thresholds in all frequencies, which increased with increasing frequencies. Differences between occluded and non-occluded conditions also increased with increasing frequencies and aging, ranging from 11.6 dB (250 Hz, 20-30 years group) to 32 dB (2000 Hz, 20-30 years group). These difference increases were homogeneous and similar with aging. However, at 500 Hz only, there were no statistically significant differences corresponding to age. The mean hearing loss produced by EAM occlusion at 500 Hz was approximately 19 dB (Table 4). There were no statistically significant differences between ears or according to gender at all frequencies tested.

In this study, our aim was to evaluate the hearing loss produced by EAM occlusion in different frequencies and find one frequency where a similar hearing loss was produced at all ages. Our study suggests that there will be a similar loss (19 dB) for all age groups at 500Hz. The 512Hz will be the ideal option to extrapolate to the tuning fork bedside test. Thus, when performing COT with 512 Hz, we will know that occlusion of the "contralateral ear" (healthy ear) produces a 19 dB loss. Using a loudness comparison technique, we can compare the "contralateral ear" with the conductive hearing loss ear.

This study has limitations. It was performed only with normal hearing individuals. We intent to evaluate the effects of the EAM occlusion in a normal ear and extrapolate the results to the "contralateral ear" of the COT. We did not study whether the occlusion effect is cumulative with the presence of pre-existing hearing loss. Only the effects of total occlusion were studied. The examiner was right-handed, but there were no statistically significant differences between the RE and LE. The start order was not randomly performed, on the right or left side, because that was tested on a prior study[9].

There are only two studies in the literature on the effects of external ear canal occlusion on hearing thresholds[19,20]. In both cases, the occlusion was performed with the use of inorganic materials. The use of an organic method (digital pressure) is different from previously described methods (gel and earplug) for EAM occlusion. External ear canal occlusion is a common situation in daily life and includes situations such as excessive cerumen (5% to 10% in children or adults), exostosis, and hearing aid use (14.2% of Americans aged ≥50)[21-25].

Tuning fork tests can be performed with different frequencies. For routine clinical practice, tuning forks of 256 or 512 Hz are ideal. Forks with lower frequencies produce a sense of bone vibration while those of higher frequencies have a shorter decay time. The results of our study suggest the use of a 512 Hz tuning fork for COT.

CONCLUSION

EAM occlusion produces a hearing loss that was reproducible with aging. The hearing loss increased with increasing frequencies. Only at the frequency of 500 Hz did the results overlap among all age groups. It is possible to assume that the use of the 512 Hz tuning fork is the most suitable for COT, and its use may allow clinicians to distinguish mild from moderate unilateral conductive hearing loss.

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Author contributions

LRR participated in the idealization of the study, data collection, analysis and interpretation, and article writing; LC and FC participated in data collection, analysis and interpretation of data; PE participated in the condition of guiding, idealization of the study and analysis.