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Original Article

Correlation between hearing loss and glycemic control in patients seen at an otorhinolaryngology unit

Correlação entre perda auditiva e controle glicêmico em pacientes diabéticos atendidos em um serviço de otorrinolaringologia

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ABSTRACT: *Introduction:* Hearing loss is the fourth leading cause of disability in the world, with more than a billion people with some degree of loss, resulting in high annual costs. The auditive deficit can be a consequence of infections, genetic and environmental factors and comorbidities such as hypertension and diabetes mellitus (DM). Although the role of DM in hearing loss is still uncertain, studies suggest that diabetic microangiopathy and neuropathy are involved. *Objective:* Evaluate the audiometric profile of patients with DM treated at an outpatient clinic in Curitiba-PR. *Methods:* Cross-sectional observational study evaluating 41 diabetic patients between April 2020 and March 2021 regarding hearing complaints, presence of comorbidities and degree and type of hearing loss. *Results:* The mean age was 66.3 years, being 63.4% female and the mean value of glycated hemoglobin (HbA1c) was 7.67%. 82.9% of patients had tinnitus and 68.3% had hearing loss. 36.6% had hypertension, while 80.5% had dyslipidemia. As for the diabetes control, 65.9% had a HbA1c ≥ 7%. *Conclusions:* DM may be associated with hearing loss; however, it is not possible to verify a clear correlation between cause and effect. Thus, further studies with more extensive and detailed data are necessary.

Keywords: Diabetes mellitus; Audiometry; Hearing loss.

RESUMO: *Introdução:* Perdas auditivas correspondem à quarta maior causa de incapacitação no mundo, com mais de um bilhão de pessoas com algum grau de perda, acarretando elevados gastos anuais. O déficit auditivo pode ser consequência de infecções, fatores genéticos, ambientais e comorbidades como hipertensão e diabetes mellitus (DM). Apesar de ainda o papel da DM na perda auditiva ser incerto, estudos sugerem que a microangiopatia e neuropatia diabéticas estejam envolvidas. *Objetivo:* Avaliar o perfil audiométrico de pacientes com DM atendidos em um ambulatório em Curitiba-PR. *Métodos:* Estudo observacional transversal com avaliação de 41 pacientes diabéticos entre abril de 2020 e março de 2021 quanto a queixa auditiva, presença de comorbidades e grau e tipo de perda auditiva. *Resultados:* A média de idade foi de 66,3 anos, sendo 63,4% do sexo feminino e o valor médio da hemoglobina glicada (HbA1c) foi de 7,67%. 82,9% dos pacientes apresentaram tinnitus e 68,3% apresentaram hipoacusia. 36,6% apresentaram hipertensão, enquanto 80,5% tinham dislipidemia. Quanto ao controle de glicemia, 65,9% tinham HbA1c ≥ 7%. *Conclusões:* A DM pode estar associada com perda auditiva, não sendo, contudo, possível constatar uma clara correlação de causa e efeito. Assim, novos estudos, mais aprofundados e com um N maior, são necessários.

Descritores: Diabetes mellitus; Audiometria; Perda auditiva.

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INTRODUCTION

Hearing is an essential form of sensitivity for inter-human relationships, in order that hearing loss is the 4th leading cause of disability in the world, has a direct impact on education, employability and communication[1,2]. In childhood, this deficiency prevents the development of speech and language, which can cause a reduction in educational performance. Adults with hearing loss often experience from social isolation and abuse to the development of psychiatric disorders[3]. According to the World Health Organization (WHO), about 1.5 billion people live with some degree of hearing loss, with an even more substantial increase each year. It is also estimated an annual expenditure of 980 billion dollars with the disease, including educational support and loss of productivity[1,4].

Hearing loss can be analyzed through audiometric tests and, thus, divided into sensorineural, conductive or mixed, according to the pattern of lowering of auditory thresholds, being classified in degrees ranging from mild to profound[2,5]. Some of these tests include pure tone audiometry, logoaudiometry, immitanciometry/ tympanometry, brainstem auditory evoked potentials (BAEP), otoacoustic emissions (OAE) and vestibular evoked myogenic potential (VEMP)[5,6]. Regarding its etiology, hearing loss has several causes, including infections, genetic factors, environmental factors, chronic diseases and the metabolic syndrome, including its components, mainly hypertension, dyslipidemia and diabetes[1,7,8].

Diabetes Mellitus (DM) stands out among the components of metabolic syndrome, a disorder of glycemic metabolism of different etiology characterized by persistent hyperglycemia, with a high prevalence in the world population, reaching rates of 10.5%[9]. In addition to glycemic dysfunction, diabetes is associated with several complications, including peripheral neuropathies, retinopathies, angiopathies and chronic kidney disease[10,11]. The control of DM can be evaluated through several tests, with glycated hemoglobin (HbA1c) being one of the most used methods, which provides us with information on the average glycemic index in the last 3 to 4 months and is closely linked with the microvascular complications of the disease[11 ,12].

Currently, there is still no consensus on the role of DM in hearing loss[1,7,10]. Several studies have identified associations between the disease and hearing loss through audiological, clinical (such as tinnitus, dizziness/vertigo and hypoacusis) and pathological aspects, raising the hypothesis that diabetic microangiopathy and/or diabetic neuropathy may be the mechanisms involved in hearing loss of these patients[7,10,13]. Despite these findings, it is still a very controversial issue, mainly due to its overlap with presbycusis and other risk factors[7].

Given the above, it is understood that it is important to clarify the audiometric profile of this population and its possible association with glycemic levels, so that this relationship can be understood more clearly and so that these patients have a more effective follow-up. Thus, the objective of this study is to evaluate the audiometric profile of patients with Diabetes Mellitus treated at an outpatient clinic of a university hospital in Curitiba/PR.

METHOD

This was a cross-sectional observational study based on the analysis of medical records collected by the Philips TASY system at the Otorhinolaryngology and Facial-Cervico Surgery Ambulatory of a University Hospital located in Curitiba-PR, from April 2020 to March 2021. Data collection began after obtaining the Term of Commitment to Use Data (TCUD) and approval of the study by the Research Ethics Committee of the Pontifical Catholic University of Paraná (CAAE: 47226821.0.0000.0020). As it was just an analysis of medical records, the Free and Informed Consent Term (FICT) was waived.

All patients with type 1 or 2 diabetes who underwent audiometric assessment through Audiometry, Immittance and Logoaudiometry in the period were eligible to participate in the study. Exclusion criteria were age younger than 18 years, patients whose medical records were incomplete, history of temporal bone trauma, history of noise exposure, history of middle ear disease, use of ototoxic drugs, central nervous system tumors and congenital hearing loss. Initially, a sample of 108 patients eligible for the study was obtained, which, after applying the exclusion criteria, included 41 individuals.

The variables of interest collected were age, sex, hearing complaints (hypoacusis, tinnitus and aural fullness), dyslipidemia, systemic arterial hypertension (SAH), HbA1c, degree of hearing loss, type of hearing loss, tympanometric curve, presence of acoustic reflex and other complaints. Data tabulation was performed using Microsoft Excel software.

Hearing loss was classified as a categorical variable based on the WHO 2008 classification[14] and on the hearing threshold values obtained from audiometry. For the analysis of glycemic control by HbA1c as a categorical variable, a classification in 3 levels was used, with good control, moderate control or poor control when HbA1c was <7%, between 7 and 9% or > 9%, respectively[12]. The immitanciometry curves were classified into A, As, Ad, B and C[15]. Patients with middle ear abnormalities were those who presented type B curves in tympanometry and/ or presented abnormal middle ear acoustic muscle reflex[16].

The results of age and absolute value of HbA1c were described by mean, standard deviation, minimum and maximum value. Categorical variables were described by frequency and percentage. The association of dichotomous variables was performed using Fisher's exact test and the

association of categorical variables, in which at least one of them has 3 or more categories, was verified using the Chi-square test. One-way analysis of variance (ANOVA) was used to compare age between the 3 groups established by ranges of HbA1c values. Age was compared between the two groups established by ranges of HbA1c values by Student's t test for independent samples. Values of $p<0.05$ indicated statistical significance. Data were analyzed using the computer program IBM SPSS Statistics v.20.0. Armonk, NY: IBM Corp.

RESULTS

Forty-one individuals were included in this study, 15 males and 26 females. The mean age obtained was 66.3 years, ranging from 46 to 83 years. The mean value of HbA1c was 7.67%, with a SD of 1.82, ranging from 5.1% to 13.6%. The prevalence of dyslipidemia was 80.5% and of SAH 36.6%. As for HbA1c levels, 65.9% had values ≥ 7%. Table 1 shows the prevalence of hearing complaints presented by the individuals.

Table 1 – Presentation of hearing complaints

Variable	Classification	Result	
		N	%
Tinnitus	Absent	7	17,1%
	Present	34	82,9%
Hypoacusis	Absent	13	31,7%
	Present	28	68,3%
Degree of hearing loss LE	No loss	8	19,5%
	Mild	12	29,3%
	Moderate	6	14,6%
	Severe	3	7,3%
	Profound	1	2,4%
	From 2kHz	1	2,4%
	Not classified*	10	24,4%
Degree of hearing loss RE	No loss	10	24,4%
	Mild	8	19,5%
	Moderate	8	19,5%
	Severe	3	7,3%
	Profound	1	2,4%
	From 2kHz	2	4,9%
	Not classified*	9	21,9%
Higher degree of hearing loss, considering both ears	No loss	9	21,9%
	Mild	9	21,9%
	Moderate	9	21,9%
	Severe	4	9,7%
	Profound	1	2,4%
	From 2kHz	3	7,3%
	Not classified*	6	14,6%

continua

Table 1 – Presentation of hearing complaints *continuação*

Variable	Classification	Result	
		N	%
Type of hearing loss LE	Absent	9	21,9%
	Sensorineural	27	65,8%
	Conductive	0	0,0%
	Mixed loss	2	4,9%
	Not classified*	3	7,3%
Type of hearing loss RE	Absent	9	21,9%
	Sensorineural	27	65,8%
	Conductive	0	0,0%
	Mixed loss	3	7,3%
	Not classified*	2	4,9%
Type of hearing loss considering both ears	Absent	7	17,0%
	Sensorineural	30	73,2%
	Conductive	0	0,0%
	Mixed loss	3	7,3%
	Not classified*	1	2,4%
Change in tympanometric curve of at least one ear	No	31	75,6%
	Yes	10	24,4%
Presence of acoustic reflex in at least one ear	No	11	26,8%
	Yes	30	73,2%

Legend: N (number of patients); LE (left ear); RE (right ear); HbA1c (glycated hemoglobin); kHz (kilohertz); * (refers to the number of patients who were not classified due to the absence of such graduation).

Regarding the comparison of the variables age, sex, and presence of comorbidities (SAH and dyslipidemia) in diabetic patients, there was no difference between groups with HbA1c < 7, between 7 and 9 or > 9.

As for the comparison between hearing complaints, degree and type of hearing loss, tympanometric curve and presence of acoustic reflex in the three groups of HbA1c, the data did not meet the prerequisites for performing the Chi-square test in the following variables: presence of tinnitus, hypoacusis, other complaints (dizziness, pruritus or aural fullness), degree of bilateral hearing loss, type of bilateral hearing loss and type of tympanometric curve alone in the left ear (LE) or in the right ear (RD). It was possible to perform the Chi-square test for alteration in the tympanometric curve of at least one ear, for the presence of acoustic reflex in the RE or LE and for the presence of acoustic reflex in at least one ear, as shown in Table 2.

Regarding the presence of alteration in the conformation of the tympanometric curve on at least one side or the presence of acoustic reflex, there was no statistical difference between the three levels of HbA1c and these variables evaluated. Also, the same type of comparison described above was performed, however, only with HbA1C values < 7 or ≥ 7[11]. In this sense, it was possible to perform the Chi-square test for the presence of tinnitus, hearing loss, type of hearing loss in the RE, alteration in the tympanometric curve of at least one ear and the presence of acoustic reflex in the RE and LE, as described in the Table 2.

Table 2 - Comparison of auditory alterations (tinnitus, hypoacusis, degree and type of hearing loss, tympanometric curve result and presence of reflex) among patients with HbA1c value <7 and ≥7

Variable	Classification	HbA1c level				P-value
		<7		≥7		
		N	%	N	%	
Tinnitus		(N valid = 14)		(N valid = 27)		0,207
	None	0	0,0%	7	25,9%	
	Present	14	100%	20	74,1%	
Hypoacusis		(N valid = 14)		(N valid = 27)		0,701
	None	4	28,6%	9	33,3%	
	Present	10	71,4%	18	66,7%	
Type of hearing loss LE		(N valid = 12)		(N valid = 26)		#
	None	2	16,7%	7	26,9%	
	Sensorineural	10	83,3%	17	65,4%	
	Conductive	0	0,0%	0	0,0%	
	Mixed	0	0,0%	2	7,7%	
	Unclassified*: N = 3					
Type of hearing loss RE		(N valid = 13)		(N valid = 26)		1
	None	3	23,1%	6	23,1%	
	Sensorineural	9	69,2%	18	69,2%	
	Conductive	0	0,0%	0	0,0%	
	Mixed	1	7,7%	2	7,7%	
	Unclassified*: N = 2					
Type of hearing loss considering both ears		(N valid = 14)		(N valid = 26)		0,437
	None	1	7,1%	6	23,1%	
	Sensorineural	12	85,7%	18	69,2%	
	Conductive	0	0,0%	0	0,0%	
	Mixed	1	7,1%	2	7,7%	
	Unclassified*: N = 1					
Alteration in tympanometric curve of at least one ear		(N valid = 14)		(N valid = 27)		1
	No	11	78,6%	20	74,1%	
	Yes	3	21,4%	7	25,9%	
Presence of acoustic reflex in at least one ear		(N valid = 14)		(N valid = 27)		0,719
	No	3	21,4%	8	29,6%	
	Yes	11	78,6%	19	70,4%	

Legend: N (number of patients); RE (right ear); LE (left ear); kHz (kilohertz); # (the data do not meet the prerequisites for the Chi-square test); * (refers to the number of patients who were not classified due to the absence of such graduation).

DISCUSSION

Diabetes consists of a set of changes that involve mitochondrial dysfunction, oxidative stress, and deposition of glucose products in tissues, leading to metabolic disorders. Currently, numerous theories seek to explain the pathophysiology of the mechanism responsible for the audiological damage caused by diabetes, however none clearly elucidates the relationship between diabetes and hearing loss[17,18].

The first theory addresses microangiopathy as the main cause of hearing loss, as in diabetic retinopathy and nephropathy, since the cochlea is richly irrigated by small vessels[17]. The *stria vascularis* is located on its lateral wall,

a complex and highly vascularized structure that acts as a barrier between the blood and the labyrinth, maintaining the electrochemical balance of the *organ of Corti*, in addition to producing endolymph[19]. Diabetic patients have an endothelial dysfunction of this microvasculature, with an increase in the basement membrane, degeneration of pericytes and hyperplasia of endothelial cells, with alteration of capillary permeability. These changes will hinder the circulation and transport of nutrients, which may be associated with hearing loss, however, this change in circulation with an impact on hearing can also be found in elderly patients and in hypertensive patients[18]. With aging, metabolically healthy patients present a slight loss of high-frequency hearing that may eventually progress to all frequencies, which is known as presbycusis[20]. However, Samocha-Bonet et al.[18] suggest that hearing loss caused by type 2 diabetes usually affects older patients, in addition to being a risk factor for other morbidities that can also affect the ear, leading to a greater risk for hearing loss in this age and consequent worse prognosis.

Another theory is related to diabetic neuropathy, so that hyperglycemia promotes glycosylation of myelin in the peripheral nervous system, causing demyelination of the 8th cranial nerve, affecting more peripheral than central auditory function[10,17]. In addition, there are reports of spiral ganglion atrophy and decrease in ganglion cells in the cochlear nuclei, superior olivary nucleus, inferior colliculus and medial geniculate body[10]. Other studies hypothesize that glucose concentration in endolymph is influenced by serum glucose levels, thus hyperglycemia can cause chronic cochlear damage or decrease in endolymph homeostasis.

Studies show that patients with DM have a higher prevalence of audiological symptoms and hearing loss. In addition, hearing problems usually affect both ears, which was observed in our sample, since most patients with tinnitus and hearing loss had the complaint in both ears. As in our study, Idugboe et al.[21] and Hlayisi et al.[22] also found no association between hearing problems and glycemic control. However, Pillay et al.[23] reveal that patients with worse glycemic control have more hearing complaints. Furthermore, our result demonstrates a higher prevalence of sensorineural hearing loss (p=0.437), both when comparing only one ear and when evaluating both ears, which is in line with the findings of other studies[21,22].

According to the US National Institute of Health, tinnitus is a very common symptom, affecting around 15% of Americans[24]. Considering the elderly population, this symptom can be noticed in up to 40% of people[25]. In our study, tinnitus was detected in at least one ear in 74.1% of patients with HbA1c $\geq$ 7 (p 0.075). Although our population is considered elderly (mean age 66.3 years) and this symptom is more prevalent in patients in this age group, studies have shown that the prevalence of tinnitus is higher and that this symptom develops at an earlier age in patients with DM[26,27].

Several studies try to define an association between DM and hearing loss; however, few studies have described the association of DM and SAH with the presence of tinnitus. In this sense, Gibrin et al.[28] demonstrated that the concomitant presence of DM and SAH is an independent risk factor for the occurrence of tinnitus (p=0.04 in the left ear). In the same study, for patients who only have DM, the presence was not considered significant (p=0.09 in the right ear), while our study found p=0.075 for the presence of tinnitus in at least one ear. Although the isolated presence of DM is not considered an isolated risk factor for tinnitus, it is known that the increase in blood viscosity resulting from the reduced flow and availability of oxygen, which occurs in SAH, is a possible explanation for the occurrence of this symptom[29–31]. Also, studies describe that DM is one of the risk factors for SAH, so that diabetic individuals are twice as likely to develop hypertension. Thus, it is understood that the recognition of the association between these two comorbidities is directly related to the development and prevention of tinnitus[28,32–34].

The limitations of this study are the lack of a control group, which did not allow a more accurate comparison. This study analyzed a small number of patients and found no correlation between diabetes control, as measured by glycated hemoglobin, and hearing loss. Other demographic data were not evaluated in the present study, not providing a more detailed analysis.

CONCLUSIONS

Current knowledge allows us to infer that DM may be associated with hearing loss, although it is not possible to state that there is a clear correlation of cause and effect. Also, it is known that diabetic patients have a higher risk of developing hypertension, which can also corroborate the development of hearing deficit. Thus, it is necessary to carry out more studies to assess more deeply the relationship between DM and hearing loss. So far, it is feasible to carry out the correct investigations and guidelines regarding auditory symptoms in patients with diabetes.

Authors' contribution: *Daniel Muzyka Oyarzabal Nunes*: Literature review, data collection and interpretation, manuscript writing and translation. *Enzo Oku Martinazzo*: Literature review, data collection and interpretation and manuscript writing. *Felipe Cintra Staub*: Literature review and data collection and interpretation. *Felipe Montesano Fazionato*: Literature review, data collection and interpretation, manuscript writing and translation. *Francisco Lorenzo Frazon Carbonar*: Literature review and data collection and interpretation. Vitor Augustin: Literature review and data collection and interpretation. Laura Martins Giraldi: Conception and design of the research and critical review of the manuscript. *Marco Cesar Jorge dos Santos*: Conception and design of the research and critical review of the manuscript.

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