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Original Article

Relation Between Glycated Hemoglobin Level and Hearing Loss in Type 2 Diabetic Patients

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BACKGROUND: Glycemic control and the efficacy of therapy in diabetic patients with type 2 diabetes during the previous 2-3 months are usually evaluated by measuring the glycated hemoglobin (HbA1c). Our aim is to study the correlation between serum glycated hemoglobin level (HbA1c) and the hearing thresholds in diabetic patients.

METHODS: A case–control study was conducted in the Audio-Vestibular Medicine Unit, xxxx University on 82 subjects. The subjects were divided into 2 groups: the first group consisted of 42 diabetic patients and the second group consisted of 40 healthy subjects. All the participants underwent a pure tone audiogram and speech audiometric evaluation. All participants also underwent diabetes laboratory assessments, including fasting blood glucose serum level and serum HbA1c level. The average hearing threshold at frequencies from 250 Hz to 16 000 Hz in both groups was calculated and correlated to different variables.

RESULTS: Diabetic patients showed higher hearing thresholds than those of the control group, with an increasing tendency of elevation of the hearing threshold levels toward the higher frequencies in both groups. There was no statistically significant difference in the hearing thresholds between patients with diabetes < 5 years (20 subjects) and those with a duration of ≤ 5 years (22 subjects). Also, there was no statistically significant difference in the average hearing thresholds among type 2 diabetic patients based on fasting blood sugar level results, except at 16 000 Hz.

CONCLUSION: Poor glycemic control status [Hb A1c ≥ 7%] is significantly associated with elevated hearing thresholds.

KEYWORDS: Hearing loss, type 2 diabetes, glycated hemoglobin

INTRODUCTION

Diabetes mellitus (DM) is considered a major health issue by the WHO due to its rising prevalence around the world.[1] Type 2 DM (T2DM) is the essential form of DM, accounting for 90%-95% of all cases of DM.[2] Also known as non-insulin dependent diabetes or adult-onset diabetes, it is characterized by insulin resistance, which can gradually worsen to absolute resistance. However, in the past decade, decreased β-cell function has been recognized as a key problem in T2DM.[3]

Type 2 diabetes mellitus (T2DM) has been suggested to potentially contribute to the development of hearing loss through microvascular disease, acoustic neuropathy, and oxidative stress.[4]

Glycemic control and the efficacy of therapy during the previous 2-3 months are usually evaluated by measuring the glycated hemoglobin (Hb1Ac).[5]

Even though several studies have been conducted to demonstrate the link between diabetes and HL, the exact nature of that link is still unclear.[6]

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Therefore, the aim of this study is to determine the correlation between glycated hemoglobin serum levels (HbA1c) and the audiometric parameters in type 2 diabetic patients.

METHODS

Sample Size Calculation

The specific objective of this study is to compare hearing threshold between diabetic type 2 patients and norms and subgroups of diabetic good control and poor control. A minimum required sample size of 30 patients with DM and a control group achieves 80% power to detect the mean difference of hearing threshold between both groups based on a study that detected mean thresholds of 44.63 ± 8.27 and 39.75 ± 4.07 for diabetics and controls, respectively, at 8000 Hz.[7] A minimum required sample of 15 cases of diabetic poor control and 15 cases of good control was based on 38.9 ± 19.9 versus 16.7 ± 6.4 mean hearing thresholds at 8 kHz.[8] Sample size was calculated at a .05 significance level, at a 95% confidence level, and 80% power using R software.

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This case–control study was conducted in the Audio Vestibular Medicine Unit, Alexandria University. The study was approved by the Ethics Committee of the Faculty of Medicine at our institution (IRB number: 00012098). All patients provided written informed consent. The study involved dividing participants into 2 groups: the first group comprised 42 diabetic patients with type 2 diabetes, while the second group consisted of 40 healthy control subjects. Criteria for exclusion from the study included individuals with presbycusis, a family history of hearing loss, a history of ear infections, use of ototoxic drugs, exposure to acoustic trauma, malignancy, prior ear surgery, or neurological disorders.

All participants provided signed informed consent before undergoing a series of evaluations. These evaluations included a complete history-taking session, otoscopic examination, and pure tone and speech audiometry conducted in a soundproof room using a calibrated Interacoustics clinical audiometer (AD629 audiometry, Denmark). Audiometric thresholds were measured at frequencies of 250, 500, 1000, 2000, 4000, 8000, 12 500, 14 000, and 16 000 Hz. If there was no response at a particular frequency, the threshold was recorded as the maximum output value for that frequency. The high-frequency hearing threshold average was calculated by summing the hearing thresholds at 12.5k, 14k, and 16 kHz and dividing by 3 for each ear.

MAIN POINTS

- Diabetic patients had higher hearing thresholds than the control group.
- Poor glycemic control status [Hb A1c ≥ 7%] is significantly associated with hearing loss.
- There was no statistically significant difference in the hearing thresholds based on the duration of diabetes.

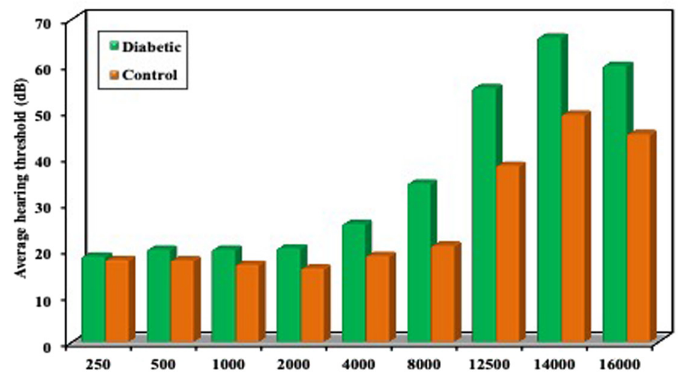

Figure 1. Comparison of the average hearing thresholds between the diabetic and control groups.

Participants were further categorized into 3 age groups (30-60 years old) for comparison of hearing thresholds between diabetic patients and control subjects. Tympanometry and auditory reflexes were assessed using an Interacoustic (AT235) tympanometer to evaluate middle ear status. Additionally, all participants underwent laboratory assessments for diabetes, including fasting blood glucose serum levels and serum HbA1c levels. Hearing thresholds for all tested frequencies in both groups were measured and compared with various variables.

RESULTS

Eighty-two subjects were enrolled in the study with 42 DM patients in the diabetic group (12 men and 30 women). Their ages ranged from 39 to 60 years, with the mean age being 50.67 ± 6.37 years and the mean duration of DM being 7.48 ± 6.01 years. The control group contained 40 healthy volunteers (17 men and 23 women), matched in age and sex with the diabetic group. Their ages ranged from 39 to 60 years, with the mean age being 49.73 ± 6.35 years. The mean FBS was 180.12 ± 66.57 mg/dL in the diabetic group and 87.30 ± 7.04 mg/dL in the control group. The mean HbA1c mean value was 7.92 ± 1.89 in the diabetic group and 5.06 ± 0.46 in the control group. Based on the serum HbA1c in the diabetic group, 19 patients had good glycemic control (serum HbA1c < 7%) and 23 patients had poor glycemic control (serum HbA1c ≥ 7%).

In the diabetic group, the results were as follows: Among the patients, 38 individuals (90.5%) had normal hearing across frequencies from 250 to 2000 Hz. However, there was a gradual increase in hearing thresholds starting from 4 kHz and extending to higher frequencies. The remaining 4 patients (9.5%) exhibited sensorineural hearing loss (SNHL), which began at lower and mid frequencies. This loss was classified as mild in 2 patients and moderate in 2 others, based on the WHO's mean pure tone average classification.

In the control group of 40 subjects, 2 individuals had normal hearing across all frequencies from 250 to 16 000 Hz. The remaining 38 subjects had normal hearing thresholds up to 8 kHz, with a gradual increase in thresholds at extended high frequencies (Table 1).

Diabetic patients had higher hearing thresholds than those of the control group, with increasing tendency of elevation of the hearing threshold levels toward the higher frequencies in both groups. Figure 1: Comparison of the average hearing thresholds between

Table 1. Comparison Between the 2 Studied Groups According to Hearing Status and Severity

	Diabetic (n = 42)	Control (n = 40)	χ^2	*P*
	N	N		
Hearing status[#]				
Normal (0-25 dB HL)	38 (90.5)%	40 (100.0)%	4.005	^{FE}P = .116
Abnormal (>25 dB HL)	4 (9.5)%	0 (0.0)%		
Severity				
Normal (0-25dB HL)	38 (90.5)%	40 (100.0)%	3.260	^{MC}P = .247
Mild (26-40dB HL)	2 (4.8)%	0 (0.0)%		
Moderate (41-60dB HL)	2 (4.8)%	0 (0.0)%		

the diabetic and control groups. Hearing thresholds were compared between both studied groups according to age group. Diabetic patients and control subjects were divided into 3 groups from 30 to 60 years old. Diabetic hearing thresholds were higher in all age groups (30-39), (40-49), and (50-60) years old than those of the control group, also with increasing tendency of elevation of the hearing threshold levels toward the higher frequencies in both groups.

In the age group from (30-39) years, the control group hearing threshold is entirely within the normal range, but the diabetic group is within the normal range until 8000 Hz and shows an elevation of the hearing threshold levels from 12 000 to 16 000 Hz. In the age groups from (40-49) and (50-60) years, the control group hearing threshold is within the normal range until 8000 Hz with elevation of the hearing threshold levels from 12 000 to 16 000 Hz. In contrast, the diabetic group shows the hearing threshold is within the normal range until 4000 Hz, with elevation of the hearing threshold levels from 8000 to 16 000 Hz. Figures 2 and 3.

There was no statistically significant difference in the hearing thresholds between patients with diabetes < 5 years (20 subjects) and those with a duration of ≤ 5 years (22 subjects). Also, there was no statistically significant difference in the average hearing thresholds among type 2 diabetic patients based on fasting blood sugar level results, except at 16 000 Hz (*P* = .006*) (Table 2).

Although speech audiometric assessment was within normal limits in both groups, diabetic patients had significantly lower word

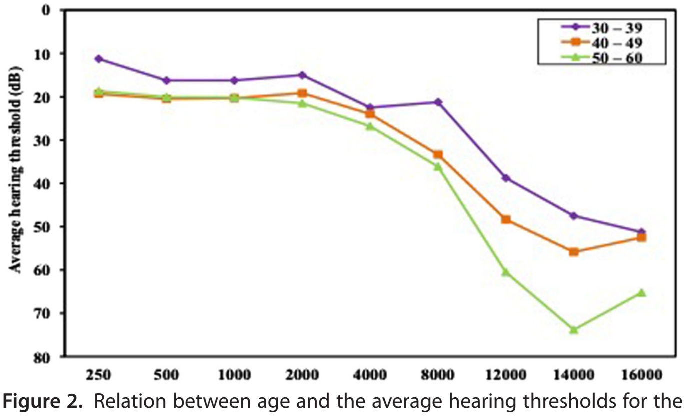

Figure 2. Relation between age and the average hearing thresholds for the diabetic group (n = 42)

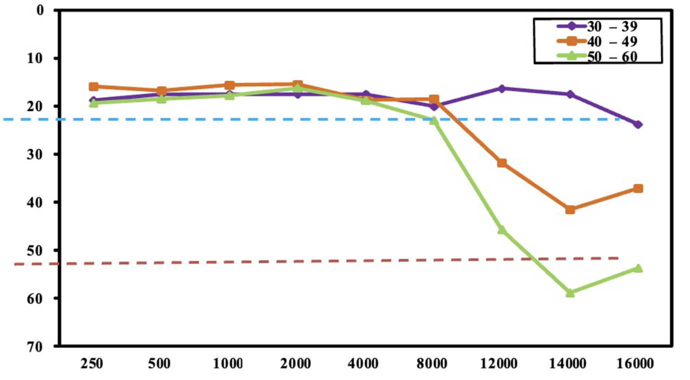

Figure 3. Relation between age and the average hearing thresholds for the control group (n = 40).

discrimination scores than those of the control group (*P* ≤ .001) Also, patients with poor glycemic control showed significantly lower WDS than those with good glycemic control (*P* ≤ .001). Table 3 shows that patients with poor glycemic control had significantly higher hearing thresholds at all tested frequencies compared to those with good glycemic control, with a significant difference present from frequencies 12 500 Hz to 16 000 Hz (Figure 4).

DISCUSSION

Hearing loss in diabetics at low, mid, and high frequencies has been documented in many studies. Hearing loss in DM can be bilateral and sensorineural and may be gradually progressive.[9]

The sensory receptors and supporting cells of the cochlea, stria vascularis, and spiral ligament were found to include insulin receptors,

Table 2. Relation Between Fasting Blood Sugar (FBS) and the Average Hearing Thresholds for the Diabetic Group.

Frequency (Hz) | Mean ± SD	Fasting Blood Sugar (FBS) 100-150 (n = 18)	151-200 (n = 7)	>200 (n = 17)	*H*	*P*
250					
	18.61 ± 4.94	16.79 ± 3.13	19.26 ± 8.47	0.720	.698
500					
	19.58 ± 3.35	17.14 ± 3.04	21.76 ± 9.22	2.126	.345
1000					
	19.17 ± 4.29	16.79 ± 4.50	22.35 ± 11.30	1.696	.428
2000					
	20.28 ± 6.80	16.07 ± 4.05	22.21 ± 12.59	2.143	.343
4000					
	24.86 ± 7.97	21.07 ± 8.15	28.24 ± 15.10	1.293	.524
8000					
	34.31 ± 11.63	26.43 ± 11.07	37.79 ± 17.68	2.377	.305
12 500					
	50.83 ± 20.24	44.29 ± 22.35	64.12 ± 16.51	5.182	.075
14 000					
	62.22 ± 24.19	52.86 ± 23.69	75.74 ± 11.35	5.249	.072
16 000					
	54.58 ± 18.28	52.86 ± 18.11	68.68 ± 6.91	10.100*	.006*

Table 3. Comparison Between the Diabetic (Good Control and Poor Control Groups) and Control Groups According to the Extended High-Frequency Hearing Threshold (Average 12 000 + 14 000 + 16 000)

(Average 12 000 + 14 000 + 16 000)	Control (n = 40)	Diabetic (n = 42)		*U*	*P*
Mean ± SD	44.27 ± 17.84	60.42 ± 18.33		405.0*	<.001*
		Good control (<7) (n = 19)	Poor control (≥7) (n = 23)		
		51.45 ± 21.40	67.83 ± 11.18	116.50*	.010*

*Statistically siginificant at p ≤ 0.05.

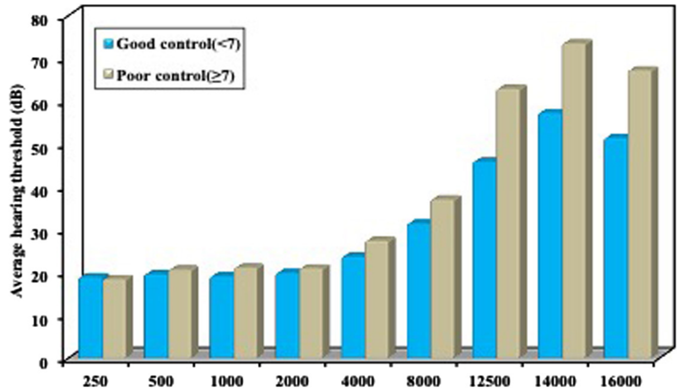

Figure 4. Comparison of the average hearing thresholds between the diabetic sub-groups.

glucose transporters, and insulin signaling components, revealing that hearing and balance are vulnerable to defective glucose utilization.[10]

The pathology of hearing loss in diabetics remains unclear. Many theories of the underlying mechanisms of the hearing loss in diabetes have been proposed. One of these accepted theories is that high blood glucose levels can damage the small blood vessels in the inner ear, which is known as microangiopathy. Also, nerves in the inner ear could be damaged by advanced glycation end products and reactive oxidative stress. Another theory is auditory nerve demyelination, damage of spiral ganglion cells, and atophic changes in the organ of Corti.[11]

Previous studies on both human temporal bone and experimental animals have observed thickening of the capillary basement membrane in the stria vascularis on the lateral wall of the cochlea. Other parts of the cochlea, such as the organ of Corti and spiral ganglion neurons, have also been found to be affected. The current study's results indicate that individuals with poor glycemic control exhibited higher hearing thresholds across all frequencies compared to those in the good glycemic control group, with a significant difference noted from 12 500 Hz to 16 000 Hz. These findings, illustrating the impact of sustained hyperglycemia on auditory acuity, could be attributed to diabetic microangiopathy and neuropathy of the inner ear.[12] This is in line with the findings of Abo-Elfetoh et al (2015), who reported that patients with poor glycemic control showed significantly higher mean hearing thresholds at both low and high frequencies when compared to those in the good glycemic group.[8]

In addition to our findings, Panchu (2008) noted that individuals with inadequate glycemic control exhibited notably greater hearing thresholds across all frequencies in comparison to the group with good glycemic control.[13]

Likewise, Al-Rubeaan and colleagues (2021) found that individuals with inadequately controlled diabetes, indicated by HbA1c levels of 8% or higher, exhibited higher occurrences of hearing impairment in comparison to those with HbA1c levels below 8% (62.9% vs. 48.3%). Furthermore, they observed a positive correlation between escalating HbA1c levels and the seriousness of sensorineural hearing loss.[14]

Additionally, Bethiun (2016) noted a substantial contrast in frequencies ranging from 250 to 8000 Hz between individuals with optimal glycemic control and those with suboptimal glycemic control, with the exception of a few specific frequencies.[15]

On the other hand, Salvinelli et al (2003) found in their research that the median hearing thresholds of type 2 diabetic patients with good glycemic control ranged from 10 to 30 dB HL. In contrast, for patients with poor glycemic control, the median hearing thresholds spanned from 10 dB HL to 20 dB HL, with the most prominent threshold observed at 4000 Hz. However, similar to the previous study, the deviations in thresholds across various frequencies did not reach statistical significance.[16]

Our assumption is that maintaining proper blood sugar levels can help prevent vascular damage and diabetes-related complications. As a result, we recommend that all diabetic patients undergo assessments of blood sugar levels alongside routine hearing evaluations to promptly identify potential hearing-related issues.

One limitation of the study is the small sample size, coupled with the absence of patient follow-up, either through audiological assessments or laboratory tests. Future studies on a larger scale are necessary to validate our findings, with comprehensive audiological assessments that encompass otoacoustic emissions and auditory brainstem responses.

CONCLUSION

The pure tone audiometric testing results indicated a sensorineural impact, particularly evident at the extended high frequencies, even among patients with normal conventional pure tone thresholds. There was a notable association between hearing loss and poor glycemic control status, as individuals in the type 2 diabetic category with inadequate glycemic control [HbA1c ≥7%] displayed elevated auditory thresholds compared to those in the good glycemic control group.

Data Availability Statement: Data sharing is not applicable to this article.

Ethics Committee Approval: This study was approved by the Ethics Committee of Alexandria University (Approval No: 00012098, Date: 16/2/2023).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – H.K.; Design – H.K.; Supervision – M.E.; Resources – N.G.; Materials – A.F.; Data Collection and/or Processing – A.F.; Analysis and/or Interpretation – A.F., M.E., N.G.; Literature Search – A.F.; Writing – M.E., A.F.; Critical Review – M.E., H.K.

Declaration of Interests: The authors have no conflicts of interest to declare.

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