The relation between Diabetes, its neurological and optical complications with hearing loss

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Abstract

Diabetes mellitus (DM) is a chronic metabolic disorder that affects approximately 422 million people worldwide. DM is typically related to a number of complications, including hearing loss, neurological problems, and eye problems.Hearing loss is twice as common in people with DM as in people without DM. The type of hearing loss that is most common in people with DM is sensorineural hearing loss, which is caused by damage to the inner ear. Neurological complications of DM can include diabetic neuropathy, which is damage to the nerves. Diabetic neuropathy can affect the nerves that control hearing, vision, and other functions.

Eye problems that can occur in people with DM include diabetic retinopathy, which is damage to the retina. Diabetic retinopathy can lead to blindness. The exact cause of hearing loss, neurological problems, and eye problems in people with DM is not fully understood. However, it is thought that these complications are caused by high blood sugar levels, which can damage blood vessels and nerves.

Aim

This research will investigate the relationship between DM and hearing loss, neurological problems, and eye problems. The study will also examine the risk factors for these complications and the potential treatments.The findings of this research will help to improve the understanding of the complications of DM and to develop better prevention and treatment strategies.

Introduction

Diabetes Mellitus (DM) is a metabolic disorder that rises from poorly controlled sugar, causing glucose levels to elevate in blood and urine.

This happens when insulin levels are Insufficient or completely non-existing, where the beta cells in the pancreas are destructed due to an autoimmune disorder, resulting in what is known as Type 1 Diabetes Mellitus (T1DM),

While the other cause for (DM) is when the balance between insulin levels and its sensitivity gets impaired when insulin resistance is developed, inducing Type 2 Diabetes Mellitus (T2DM) (1).

The prevalence of type 2 diabetes mellitus (T2DM) has been gradually increasing over the past two decades, affecting approximately 21 million people, and the number of T2DM patients is much higher than the number of those affected by type 1 diabetes mellitus (T1DM) (2-4).

Due to the biochemical and molecular changes that hyperglycemia brings about in microvascular cells, DM can result in microangiopathy. These changes can have effects on multiple systems in the body, including the visual pathway and the auditory system.

People with diabetes are more likely to develop a number of ophthalmic conditions, such as proliferative diabetic retinopathy(PDR), macular edema (5,6), and cataract (7), according to population-based studies. DM can lead to visual impairment, which is regarded as a leading cause of blindness in the United States. Diabetics are 25 times more likely to experience blindness than non-diabetics (8).

Furthermore, the correlation between DM and its affection for the hearing system is receiving greater attention recently on a worldwide level, since hearing impairments are likely to occur in more than 43% of diabetic patients (9).

The first case report of a diabetic patient and hearing loss was published in 1857 by Jordao, Edgar published the first report of high-frequency hearing loss in a diabetic patient in 1915 (10).

It is also noted that DM can trigger tinnitus and the feeling off balance which is related to the inner ear, Which could lead to hearing disabilities and psychological depression.

Making DM varies in its mortality and morbidity, and how it affects the lifestyle of its patients. Considering that DM prevalence is expected to elevate from 6.4% to 7.7% by 2030 (11),and considering The Middle East and North Africa region had the highest global prevalence of diabetes by 2019 (12.2%)(12),Our study aimed to evaluate the prevalence of HL in diabetic patients in Syria.

Methods

2.1. Study design :

This cross-sectional study enrolled Syrian nationals diagnosed with Diabetes to evaluate the DM complications, beginning in July 2022 and ending in November of the same year.

Each of the participants provided their written informed consent by signing a document that described the nature and goals of the study.

This study was ethically approved by the ethical committee of Damascus Hospital and the IRB of the Syrian Private University.

2.2. Participants :

Patients who attended the diabetic clinic in Damascus Hospital who were already diagnosed with DM were approached to participate in the study. Subjects from both genders, aged 18-70 years, after consenting to be included in the study, were interviewed by endocrinology residents, where the demographic data were collected including details such as gender, age, profession, marital status,

and income. Followed by the diabetic record, with information on which type of DM, duration, family history, committing to a diet, and treatment with types of medications and dosages. Both medical and surgical histories were also recorded.

Weight was recorded while wearing indoor clothes, and height was taken without shoes. Using the noted measurements, Body Mass Index was calculated and classified using the WHO classification. Patients were considered hypertensive if they were prescribed anti-hypertensive drugs. As for smoking, subjects were classified as smokers and non-smokers, and none of the patients who enrolled in the study had consumed alcohol during the previous year.

Systolic and diastolic blood pressure were measured using a standard mercury sphygmomanometer in a sitting position.

We used the latest blood test for each patient, to collect laboratories such; Fasting blood sugar, glycated hemoglobin (HbA1c), and creatinine levels.

Patients with history of middle ear disease, noise exposure, under the age of 18 and over 69 were excluded. In addition to subjects who were perseriped with Ototoxic medications, patients with lab tests older than 3 days, and patients with no ocular disease, and with diabetic foot were also excluded.

2.3. Auditory and visual testing:

All subjects were referred to the Ear, Nose, throat, and neck (ENT) clinic. Both the middle and inner ear were examined by otolaryngology residents using an otoscope. As part of the survey, air-conduction pure tone hearing thresholds were collected in a double-walled soundproof booth using the Amplaid A321 twin-channel audiometer, at frequencies of 250, 500, 1000, 2000, 4000, and 8000 Hz. The testing equipment was all expertly adjusted. Therefore, only those who had normal ear functions were enrolled in the study.

The correlation between bone and air hearing thresholds was utilized to diagnose the kind of hearing loss. Conductive hearing loss is defined by normal bone conduction and an abnormal air conduction threshold, whereas sensorineural hearing loss is defined by abnormal air and bone conduction hearing thresholds (hearing thresholds above 25 dBHL). A wider air/bone gap than 10 dBHL and aberrant air and bone conduction hearing thresholds, on the other hand, are traits associated with mixed hearing loss.

The hearing thresholds for low frequencies (250 and 500 Hz), medium frequencies (1000 and 2000 Hz), and high frequencies (4,000 and 8,000 Hz) were used to categorize hearing impairment.

Mild hearing loss was defined as between 25 and 40 dB. While moderate and severe hearing loss, respectively, were defined as 40–70 and 70–90 dB. Those who received results higher than 90 dB were taken to have profound hearing loss.

2.4. Ocular testing

Each patient was sent to the ophthalmology clinic in Damascus Hospital. Trained ophthalmologists have conducted a dilated eye examination.

The presence of nuclear, cortical, or posterior subcapsular opacity in at least one eye was referred to as a cataract [13]. The International Society of Geographical and Epidemiological Ophthalmology (ISGEO) criteria were used to diagnose glaucoma [13]. Watkins et al criteria (2003) were used to categorize diabetic retinopathy. if macular edema, hard exudates, or hemorrhages were detected, background retinopathy would be suspected. If cotton wool patches, numerous big blot hemorrhages of the retina or iris, an angle, venous beading, loops, and reduplication, arterial sheathing, or an atrophic-appearing retina were present, proliferative diabetic retinopathy would be the cause. if glaucoma, rubeosis iritis, vitreous hemorrhage, retinal detachment, or advanced diabetic eye disease were present [14].

2.5. Statical analysis

IBM SPSS software, version 26 was used to analyze data, a chi square test was used to assess the difference between categorical data,which we categorized the continuous data of hearing loss by calculated the mean of each ear and founding the overall mean for all participants into two groups: non-hearing loss and hearing loss. Within the hearing loss group, we further categorized the data into three degrees: mild, moderate, and severe We assigned each participant to one of these categories based on their hearing status and degree Overall, our findings suggest that categorizing hearing loss into these three degrees can provide a useful framework for understanding the prevalence and severity of hearing loss in diabetes and its visual and its neurological and visual complications the independent sample T-test Mann Whitney U was calculated for the age, also we used the regression linear between the hearing frequency and creatinine levels, HbA1 and fasting glucose, and A P value of 0.05 or less was regarded as statically significant.

Results

Of the initial 967 patients, only 86 met all the eligibility criteria and underwent all the necessary examinations. The remaining patients were excluded for various reasons, including personal reasons for not undergoing the PTA test (n=19), diabetic foot (n= 36), pregnancy (n=23), outdated lab tests (n=137), recent middle ear infection (n=16), and use of aspirin (n=13) or aminoglycoside antibiotics (n=12).

Table 1. Hearing impairment by Characteristics of the study population

			No hearing Impairment	Hearing Impairment	Total(n=87)	P value
Demographic Characteristic	Age		48.2(13.1)	56.2(9.99)		0.047
	Gender (%)	Male	4 (13.8)	26 (44.8)	30(34.5)	0.004
		Female	25 (86.2)	32 (55.2)	57(65.5)	
	Financial Status (%)	Low income	9 (31)	28 (48.3)	37(42.5)	0,065
		Fair income	20 (69)	26 (44.8)	46(52.9)	
		High income	0.0	4 (6.9)	4(4.6)	
	Profession (%)	Retired	0.0	(13.8)	8(9.2)	0.047
		Housewife	22 (75.9)	28 (48.3)	50(57.5)	
		worker	7 (24.1)	21 (36.2)	28(32.2)	
		Student	0.0	1 (1.7)	1(1.1)	
	Education	Lower than high school	4(13.8)	34(58.6)	38(43.7)	<.001***
		Highschooler	14(48.3)	11(19)	25(28.7)	
		More than high school	11(37.9)	13(22.4)	24(27.6)	

	Smoking (%)	yes	8(27.6)	22(37.9)	30(34.5)	0.627
		No	20 (69)	34 (58.6)	54(62.1)	
		Former	1(3.4)	2(3.4)	3(3.4)	
	Hypertensio n(%)	yes	13 (44.8)	45 (77.6)	58(66.7)	0.002
		no	16 (55.2)	13 (22.4)	29(33.3)	
	Physical Activity (%)	yes	4 (13.8)	6 (10.3)	10(11.5)	0.635
		No	25 (86.2)	52 (89.7)	77(88.5)	
	Applying diet (%)	No	(44.8)	(72.4)	55(63.2)	0,042
		Partial Diet	(41.4)	(20.7)	24(27.6)	
		Complete diet	(13.8)	(6.9)	8(9.2)	
	BMI ranges (%)	Normal	11(37.9)	10(17.2)	21(24.1)	0.1
		High	9(31)	26(44.8)	35(40.2)	
		Obese	9(31)	22(37.9)	31(35.6)	

Data are n (%) for age its mean (standard deviation)

The table 1 shows that The average age of participants with hearing impairment was higher than that of those without hearing impairment. The former had a mean age of 56.2 years, while the latter had a mean age of 48.2 years. The difference was statistically significant, with a p-value of 0.047.
The prevalence of hearing impairment is significantly influenced by gender. While women made up the majority of those with some sort of hearing impairment (55.2%), men were more likely to have impaired hearing (86.6% of men had some degree of hearing loss compared to 41.5 percent of women).
Patients with impaired hearing were found to have lower levels of education and belong to a lower socioeconomic status. Interestingly, all retired patients had some degree of hearing loss.
Hypertension showed a strong association with hearing impairment, as 77.6% of those with hearing loss also suffered from hypertension, with a p-value of 0.002. However, smoking, BMI, and physical

activity did not show any significant statistical relationship with hearing loss. While those who have committed to a healthy diet appeared to be more reluctant to develop hearing impairment.

Table 2 : relation between hearing impairment and neuropathy

Neuropathy		No hearing Impairment	Hearing Impairment	Total	P value
Tingling sensation (%)	yes	20 (69)	51 (87.9)	71(81.6)	0.031
	No	9(31)	7(12.1)	16(18.4)	
Vasculopathy (%)	yes	14(48.3)	33(56.9)	47(54)	0,447
	No	15(51.7)	25(43.1)	40(46)	
Vertigo (%)	Yes	29(50)	12(41.4)	41(47.1)	0.448
	No	29(50)	17(58.6)	46(53.9)	
Fatigue (%)	Yes	15(51.7)	43(74.1)	58(66.7)	0.037
	No	14(48.3)	15(25.9)	29(33.3)	
Polyuria (%)	Yes	20(69)	49(84.5)	69(79.3)	0.092
	No	9(31)	9(15.5)	18(30.7)	

Table 2 :showed that there is a statistically significant difference in the prevalence of tingling sensation and fatigue between those with and without hearing impairment (p=0.031 and p=0.037, respectively) which there is 74.1% of participant showing fatigue with hearing impairment and 87.9% of participants showing tingling sensation with hearing impairment. However, there is no statistically significant difference in the prevalence of vasculopathy, vertigo, and polyuria between those with and without hearing impairment (p=0.447, p=0.448, and p=0.092, respectively).

Tabel 3. hearing status by Ophthalmic diseases

Using chi-square test

Ophthalmic diseases		Hearing status					P value
		Normal	Mild	Moderate	Sever	Total	
Cataract (%)	yes	3 (10.3)	6 (17.1)	13 (59.1)	0.0	23(26.4)	*<.001***
	No	26 (89.7)	29 (82.9)	9 (40.9)	100	64(73.6)	
Diabetic retinopathy (%)	yes	6 (20.7)	10 (28.6)	15(68.2)	0.0	32(36.8)	0.002**
	No	23 (79.3)	25 (71.4)	7 (31.8)	100	55(63.2)	
Glaucoma (%)	yes	4 (13.8)	8 (22.9)	8(36.4)	0.0	21(24.1)	0.083
	No	25 (86.2)	27 (77.1)	14 (63.6)	100	66(75.9)	
Eye floaters (%)	Yes	17(58.6)	19(54.3)	13(59.1)	1(100)	50(57.5)	0.819
	No	12(41.4)	16(45.7)	9(40.9)	0	37(42.5)	
Eye pain (%)	Yes	2(6.9)	8(22.9)	10(45.5)	1(100)	21(24.1)	0.004
	No	27(93.1)	27(77.1)	12(54.5)	0	66(75.9)	
Eye redness (%)	Yes	3(10.3)	10(28.6)	6(27.3)	1(100)	20(23)	0.078
	No	26(89.7)	25(71.4)	16(72.7)	0	67(77)	
Nyctalopia (%)	yes	8(27.6)	6(17.1)	10(45.5)	1(100)	25(28.7)	0.049
	No	21(72.4)	29(82.9)	12(54.5)	0	62(71.3)	
Hyperopia and Myopia (%)	Hyperopia	13(44.8)	24(68.6)	12(54.5)	0	49(56.3)	0.062
	Myopia	7(24.1)	7(20)	8(36.4)	0	22(25.3)	
	Normal visual ability	9(31)	4(11.4)	2(9.1)	1(100)	16(18.4)	

The prevalence of various eye conditions in the population is presented in table 3, there appears to be a significant association between the presence of cataracts and the severity of hearing impairment. A greater part of individuals with cataracts exhibited moderate (59.1%) to severe (100%) hearing impairment, while a lesser proportion exhibited either mild (17.1%) or negligible (10.3%) hearing impairment. On the other hand, a higher percentage of individuals without cataracts showed normal hearing (89.7%) or mild hearing impairment (82.9%), with a lower proportion presenting with moderate (40.9%) while none had severe impairment. A significant relation was also found between having a diabetic retinopathy and hearing loss degree, a high percentage of individuals affected by diabetic retinopathy revealed some degree of hearing impairment, with a significant prevalence of moderate (68.2%) and severe (100%) hearing impairment cases, while a lower percentage corresponds to mild (28.6%) or none (20.7%) hearing impairment cases. Conversely, a higher proportion of individuals without diabetic retinopathy showcase an absence of significant hearing deficit, with approximately 79.3% exhibiting normal hearing while only a minority presents moderate (31.8%) and none was found to have severe hearing loss. The prevalence of eye pain was significantly higher in individuals with mild, moderate, or severe hearing loss compared to those with normal hearing ability (P = 0.004). Similarly, the prevalence of nyctalopia was significantly higher in individuals with mild or moderate hearing loss compared to those with normal hearing (P = 0.049), however there were no significant differences in the prevalence of eye floaters, eye redness, and hyperopia/myopia between individuals with different degrees of hearing loss and those with normal hearing.

Table 4: Affection of family history of diabetes and hearing loss, on hearing status

		Hearing status					*P value*
		Normal	Mild	Moderate	Sever	Total	
Family History of Diabetes	No	30.4	43.5	26.1	0	23(26.4)	*0.023*
	1st	36.2	37.9	25.9	0	58(66.7)	
	2nd	16.7	50.0	16.7	16.7	6(6.9)	
Family History Of hearing loss	No	23(79.3)	25(71.4)	18(81.8)	0	66(75.9)	*0.239*
	1st	3 (10.3)	5(14.3)	3(13.6)	1(100)	12(13.8)	
	2nd	3 (10.3)	5(14.3)	1(4.5)	0	9(10.3)	

Table 4 presents a significant relationship between a family history of diabetes and the degree of hearing loss (P=0.023). However, family history was found to have no discernible impact on hearing acuity as determined by a P value of 0.239.

Table 5: relation between lab tests and dBs means at each frequency.

		frequencies					
		250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Creatinine levels	P value	<.001***	0.001**	<.001***	<.001***	0.002**	0.019**
Fasting glucose	P value	0.184	0.163	0.277	0.044*	0.103	0.154
HbA1c	P value	0.006**	0.004**	0.005**	<.001***	0.003**	<.001***

Table 5: Regarding laboratory tests, some were found to affect hearing acuity. Poorly controlled HbA1c blood levels significantly impacted the mean sound intensity score at each frequency, with the most significant effect observed at frequencies of 2000 and 8000 Hz (P=0.001 for each frequency), and a significant impact also noted at other tested frequencies. High Creatinine levels were significantly associated with higher sound intensity scores at higher frequencies. The effect of fasting glucose levels, meanwhile, was found to be relatively limited, with significant effects detected only in regard to 2000 Hz scores (P=0.044).

Table 6: relation between the duration of diabetes duration and the auditory symptoms.

Auditory symptoms		Duration				Total	P value
		1-5 years	5-10 years	10-15 years	> 15 years	Total	
hearing loss impairment (%)	yes	11 (68,8)	19 (63,3)	16 (55,2)	12 (100)	58	0.048
	no	5 (31,3)	11 (36,7)	13(44,8)	0	29	
Hyperacusis (%)	yes	7 (43,8)	15 (50)	17(58)	12 (100)	51(58,6)	0.013
	no	9 (56,3)	15 (50)	12 (41,4)	0	36(41,4)	
Tinnitus (%)	yes	12 (75)	19 (63,3)	17 (58,6)	9 (75)	57(65,5)	0.617
	no	4 (25)	11 (36,7)	12 (41,4)	3 (25)	30(34,5)	
Vertigo (%)	yes	4 (25)	15 (50)	15 (50)	7 (58,3)	41 (47,1)	0.251
	no	12 (75)	15 (50)	14 (48,3)	5 (41,7)	46(52,9)	
auditory neuropathy, understanding (%)	yes	8 (50)	20 (66,7)	14 (48,3)	10 (83,3)	52 (59,8)	0.133
	no	8 (50)	10 (33,3)	15 (51,7)	2 (16,7)	35 (40,2)	

Table 6: showed a strong correlation between the duration of diabetes and hyperacusis, with a significant P value of 0.013. The prevalence of hyperacusis among all participants was found to be 58.6%. Further analysis revealed that the prevalence of hyperacusis increased with an increase in the

duration of diabetes. Specifically, 43.8% of those with diabetes for 1-5 years had hyperacusis, 50% of those with diabetes for 5-10 years had hyperacusis, and 58% of those with diabetes for 10-15 years had hyperacusis. Interestingly, all participants with diabetes for more than 15 years had hyperacusis.

A significant correlation was found between the duration of diabetes and hearing loss, with a P value of 0.043. Among the patients in the study, those with diabetes for more than 15 years had the highest prevalence of hearing loss, with all patients in this group experiencing some level of hearing loss. This group was also more likely to experience hearing loss at higher frequencies, particularly 4000 and 8000 Hz as shown in figure (D) when compared with patients of lower durations However, the study did not find a significant relationship between the duration of diabetes and other auditory symptoms such as vertigo, tinnitus, and auditory neuropathy."

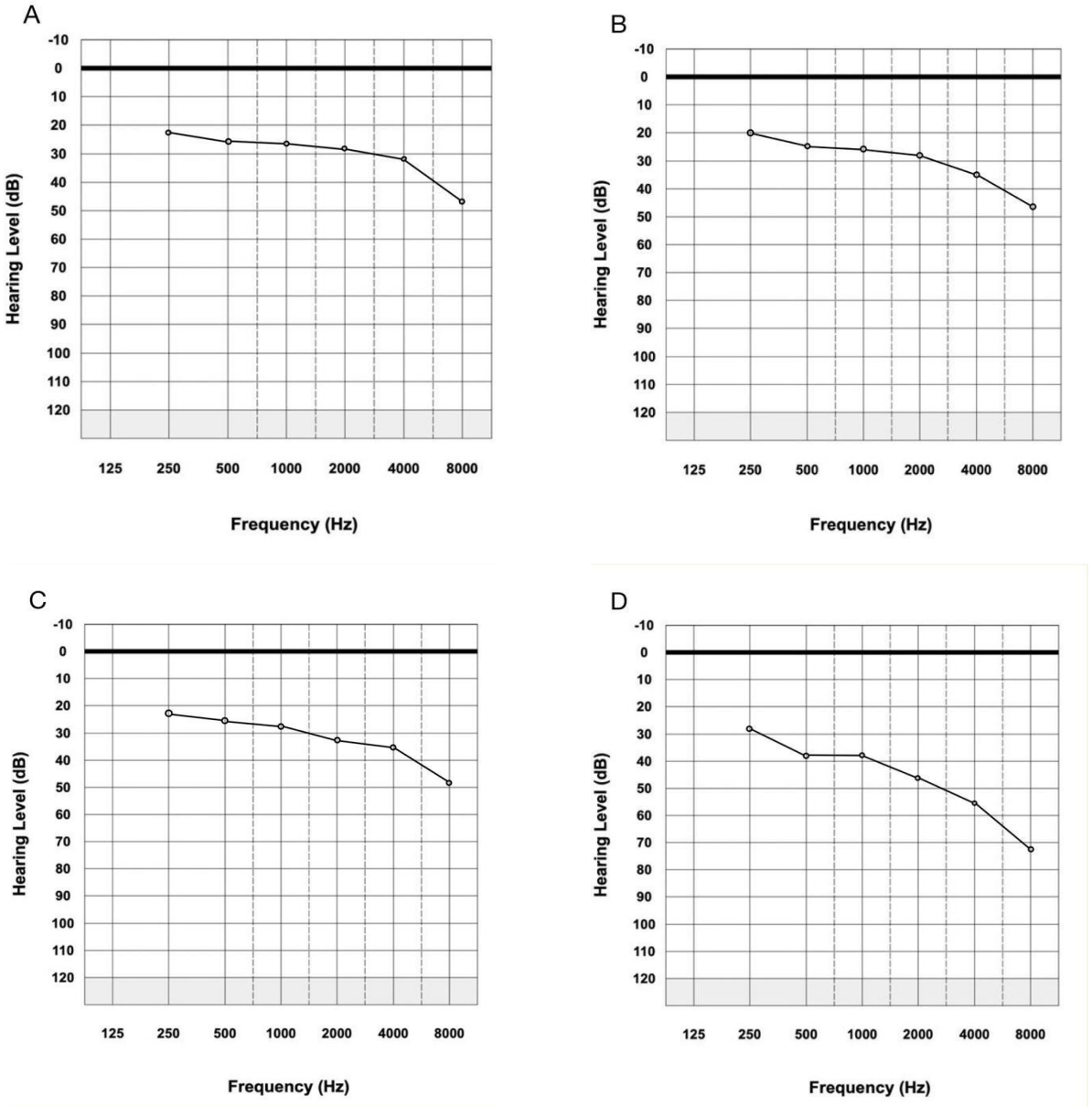

Figure (A), average thresholds on PTA for patients with diabetes duration between 1-5 years.
Figure (B), average thresholds on PTA for patients with diabetes duration between 5-10 years.
Figure (C), average thresholds on PTA for patients with diabetes duration between 10-15 years.
Figure (D), average thresholds on PTA for patients with diabetes duration of more than 15 years

Discussion

According to the latest statistics from the International Diabetes Federation (IDF) in 2022, the prevalence of diabetes in Syria was significantly higher than average, with a rate of 13.6% (15). Our city-based research aimed to explore the relationship between Diabetes Mellitus and its neurological complications, including ophthalmic and auditory issues, to understand their impact on the quality of life.

Demographically, 66.7% of enrolled diabetic patients have experienced some degree of hearing loss, and 81% of them are between the ages of 45 and 69 years old, with a fairly high mean age of 55.3 years. Although most of the subjects who had impaired hearing were females, the prevalence of hearing loss among male diabetic patients was higher. This can be hypothesized to be due to their greater exposure to occupational and environmental noise.

People with low levels of education and elevated blood pressure were more likely to suffer from hearing impairment. The duration of diabetes was a significant risk factor for hearing impairment. Of those with 5-10 years, 10-15 years, and ≥15 years of diabetes, 63.3%, 55.2%, and 100%, respectively, experienced hearing impairment. Thresholds were fairly lower in patients with longer duration, especially at higher frequencies of 4000 and 8000Hz.

Other auditory symptoms were present in many subjects, such as tinnitus, hyperacusis, vertigo, and auditory neuropathy, but the only one that was found to have a significant

relationship with the duration of diabetes was hyperacusis. This result is partly in line with the findings of an Iranian epidemiological study that discussed the topic (16).

Poorly controlled levels of Hba1c were also noted, with a mean of 8.06, which is considered significantly elevated. This was mostly accompanied by hypertension, and it can be concluded that high glucose levels can cause hearing loss by damaging the endothelial cells lining the blood vessels. As a result, atherosclerotic plaques form, which eventually lowers the blood flow to the nerves (17).

In our study, we found that the higher the Creatinine levels were, the lower the scored threshold on the PTA test. This relationship was apparent at all frequencies, but it was most significant at 0.25, 1, and 2 KHz. This result is partly in line with the findings of a Korean study (18), where they recruited 9,798 subjects. In that study, the affected frequencies in males were 3.6 KHz, while females were more affected at 1, 3, 4, and 6 KHz. The difference can be explained because of the large difference in sample size, and they used Albumin-to-creatinine ratio tests (ACR), while our study only used creatinine tests.

Having a family history of hearing loss did not appear to significantly impact an individual's hearing status, regardless of whether the relative was a first-degree or second-degree relation. Conversely, individuals with a family history of diabetes were more likely to experience hearing impairment. The results showed that 36.2% of those with first-degree relatives had normal hearing, while only 16.7% of participants with second-degree relatives who had diabetes had normal hearing, indicating that they were more susceptible to deafness. This is supported by a study that examined the role of family history in diabetes and deafness and how it affected later generations (19).

Diabetic retinopathy is a common complication of diabetes that affects the microscopic blood vessels in the retina and can lead to blindness. Inflammatory cytokines and oxidative stress are major contributors to vascular dysfunction in the retina in diabetes. Considering high blood sugar levels can also have an impact on the structure and function of the retina, as well as damage the small blood vessels in the cochlea, which can lead to impaired hearing. In the study we found a significant relation between hearing loss and diabetic retinopathy, even though this can be backed by multiple studies [20,21], it is still a challenging process to differentiate whether hearing loss is due to aging-related physiology or due to diabetes. [21]

High levels of glucose in the blood cause changes to the lens's structure, leading to the development of cataracts. Additionally, oxidative stress and inflammation, which are driven by, among other things, high glucose levels, can contribute to cataract formation. In the study we found that diabetic patient with hearing loss had a higher risk to develop cataract [22]

Conclusion

In the present study we found that while hearing loss can co-occur with various ocular diseases, multivariate models demonstrated that it was significantly associated only with increased rates of cataract and diabetic retinopathy. These findings highlight the importance of regular ocular assessments for patients with hearing impairment, and auditory screening for those with impaired vision. Clinicians should be vigilant in monitoring both ocular and auditory health in patients with these conditions, as well as consider potential comorbidities when developing treatment plans. Early detection and management of ocular and auditory conditions can significantly improve patients' quality of life and reduce the risk of comorbidities.

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