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The Hidden Sound of Diabetes: Acoustic Reflexes in Normo-acoustic Individuals

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Abstract

Introduction: Diabetic neuropathy is a prevalent complication of diabetes, potentially involving acoustic reflexes. **Aim:** To assess the acoustic reflex arc in diabetic individuals and investigate the impact of diabetes on ipsilateral and contralateral acoustic reflex thresholds in patients with normal hearing, in comparison to non-diabetic counterparts. **Methods:** A case-control study involving 120 participants, categorised into 30 with uncontrolled diabetes, 30 with controlled diabetes, and 60 healthy individuals aged 18-45 years. All participants underwent otoscopy, pure tone audiometry, tympanometry, and assessment of acoustic reflex thresholds (both ipsilateral and contralateral). **Results:** At a frequency of 500 Hz, the acoustic reflexes exhibited no statistically significant differences among the tested groups. At frequencies of 1000 Hz and 2000 Hz, substantial differences were observed between the uncontrolled diabetic group and the control group, but not between the controlled diabetic group and the control group. **Conclusion:** The acoustic reflex threshold elevates in uncontrolled diabetic adult patients, particularly at high frequencies, suggesting central neuropathy.

Keywords: Diabetes, PTA, Acoustic Reflexes, Ipsilateral, Contralateral, Diabetic Neuropathy.

1. Introduction

Diabetes mellitus (DM) is a complex metabolic condition characterised by hyperglycemia. Abnormalities in insulin secretion or action result in hyperglycemia, which is the basis of metabolic diseases causing ongoing and diverse disruptions in carbohydrate, lipid, and protein metabolism [1, 2]. Vascular abnormalities and chronically increased blood glucose levels linked to diabetes mellitus impact the cranial nerves, resulting in malnutrition, membrane dysplasia, degeneration, and demyelination of nerve cells [3]. These alterations are thought to diminish conduction efficacy, a characteristic of diabetic peripheral neuropathy. Ischaemic and sclerotic changes in the ventral and dorsal cochlear nuclei, inferior colliculus, and medial geniculate body represent additional degenerative modifications in the auditory brainstem system [4]. Pure-tone audiometry, a technique for assessing an individual's hearing threshold by their reactions to pure tones of varying frequencies and intensities, underpins the identification and measurement of hearing loss [5]. The middle ear houses the stapedius muscle, which contracts in response to elevated sound levels. The engagement of this muscle is termed the acoustic reflex (AR) [6]. Cranial nerves VII and V link the efferent limb of the reflex to the stapedius and tensor tympani muscles, respectively, whilst nerve VIII connects the afferent limb to the cochlear nucleus. Nevertheless, the intricate and unidentified fundamental neural network exists between these extremities [7]. Acoustic reflex thresholds (ARTs) can be evaluated using various stimuli, such as clicks, pure tones, and wideband sounds [8, 9]. Testing of both ipsilateral and contralateral acoustic reflexes is crucial for a comprehensive understanding of auditory function and associated problems. These reflexes are crucial for assessing the integrity of auditory circuitry and may indicate various neurological diseases [10]. This study seeks to elucidate the effects of diabetes on auditory pathways and to investigate how acoustic reflexes assist in diagnosing diabetic auditory neuropathy.

2. Patients and Methods

This case-control study involves 120 individuals selected based on specific criteria via non-random consecutive sampling, categorised into three groups: 30 patients with well-controlled diabetes, 30 patients with uncontrolled diabetes as determined by HBA1C values, and 60 non-diabetic individuals.

The sample size was calculated based on sample size equation formula

$$\text{Sample Size} = \frac{[z2 * p(1-p)] / e2}{1 + [z2 * p(1-p)] / e2 * N}$$

- N = population size (Baghdad Population density is 7,921,134)
- z = z-score (2.58 at confidence interval of 99%)
- e = margin of error (0.05)
- p = standard of deviation (0.5)

Considering the population proportion of diabetes with neurological complications in Iraq at 2.2%, the calculated sample size was 58; hence, we utilised 60 people compared to a control group of 60.

Patients with diabetes, irrespective of type, who had a minimum duration of 5 years, were included in the study. All subjects were aged between 18 and 45 years, had a hearing threshold not exceeding 25 dB on pure tone audiometry and exhibiting a Type A tympanogram. Individuals with neurological or systemic disorders, cognitive impairments, those on ototoxic or CNS-interfering medications, and those with extended exposure to noise stress were excluded from the study. The audiometry was conducted blindly by the audiologist technicians for patients with diabetes or the control group. The testing was conducted in a controlled environment with background noise levels below [70] dB, as verified by a calibrated sound level meter. The floor, walls, and doors of the test chamber were soundproofed.

The selected location for the sample was a specialised tertiary centre for diabetes and endocrine illnesses, known as Al-Wafaa, located in Mosul, Iraq. The data collection process commenced following the acquisition of ethical approval, utilising a non-probability consecutive sampling method wherein all patients meeting the specified criteria completed a questionnaire designed by the researcher and evaluated by two supervisors.

All chosen patients underwent clinical evaluation, subsequently followed by audiological assessment. The audiological assessment comprised:

1. A pure tone audiometric test was conducted using the AD226 Interacoustics audiometer, which has been recently calibrated to comply with the requirements established by the American National requirements Institute (ANSI). The test was conducted across the frequency spectrum of 250 Hz to 8000 Hz.
2. Tympanometry and acoustic reflex assessments use the Titan tympanometer and Titan Suite software. The Titan Suite is a software platform designed to deliver enterprise-level solutions for laboratory informatics, scientific data management, and compliance.

The technique commences with the measurement of immittance utilising a 226 Hz probe, with each ear evaluated separately. This is succeeded by the execution of ipsilateral and contralateral auditory reflex tests employing pure tones as stimuli at the frequencies of 500 Hz, 1000 Hz, and 2000 Hz. The sound intensity automatically increased by 5 dB till the ART was achieved.

3. Results

The present study involved 120 participants divided into three groups: the uncontrolled diabetes mellitus group comprised 30 patients (HBA1C>7%), the controlled diabetes mellitus group included 30 patients (HBA1C<7%), and the control group consisted of 60 healthy individuals.

Table (1) indicates that the mean ages were 32.66±9.079 years, 33.76±9.412 years, and 32.78±7.629 years for the uncontrolled diabetes mellitus group, controlled diabetes mellitus group, and control group, respectively; the difference was statistically insignificant (p=0.847) according to the One-Way ANOVA test.

Table 1: Distribution of the Groups Studied According to Age.

	Uncontrolled DM Group (N=30)	Controlled DM Group (N=30)	Control Group (N=60)	p value
Age (years)	32.66±9.079	33.76±9.412	32.78±7.629	0.847*

Figure (1) illustrates the sex distribution, indicating that males were predominant in the uncontrolled diabetes mellitus (D.M) and control groups, comprising 53.3% and 56.7%, respectively, whereas the controlled D.M group had a male representation of 43.3%. The male-to-female ratio among the studied groups was not statistically significant (p=0.488) as determined by the Chi-square test.

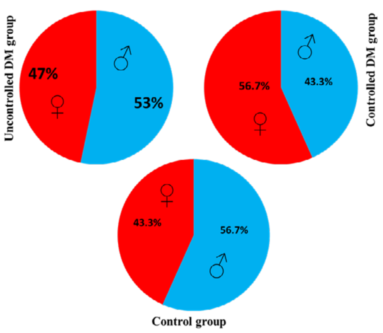

Figure 1: Distribution of the Studied Group based on Sex Differences.

In the uncontrolled diabetes mellitus group, type I diabetes was observed in 46.7% of cases, while type II diabetes was present in 53.3%. Conversely, in the controlled diabetes mellitus group, type I and type II diabetes comprised 53.3% and 46.7%, respectively, with no statistically significant difference identified using Chi-square analysis (Figure 2).

The results of Table (2) indicated that at frequencies of 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz, One-Way ANOVA revealed no statistically significant differences among the studied groups on either the right or left side. At 4000 Hz and 8000 Hz, the uncontrolled DM group had significantly higher mean values in both the right and left ears compared to the controlled DM group and the control group.

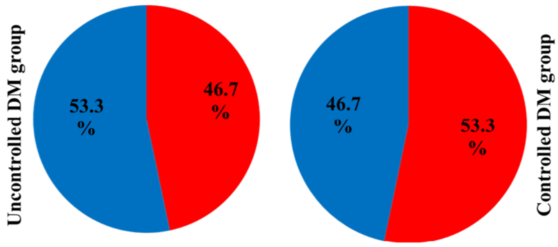

Figure 2: Distribution of the Studied Groups According to Type of Diabetes.

At a frequency of 500 Hz, the acoustic reflexes exhibited no statistically significant variations among the examined groups. At a frequency of 1000 Hz, significant differences were observed for IPSI and contralateral measurements, except for the right IPSI. These significant differences were subsequently evaluated using a post hoc test, revealing that the left IPSI, right contralateral, and left contralateral measurements were elevated in the uncontrolled diabetes mellitus group compared to the control group, but not in the controlled diabetes mellitus group, as illustrated in Table 3. The differences among the examined groups at a frequency of 2000 Hz were statistically significant. The post hoc test revealed that, compared to the control group, the uncontrolled DM group exhibited elevated levels in the right IPSI, left IPSI, right contra, and left contra, whereas the controlled DM group did not show such increases.

Table 2: Comparison of PTA Parameters.

Frequencies	Side	Uncontrolled DM Group (N=30)	Controlled DM Group (N=30)	Control Group (N=60)	P value
250	Right	10.83±5.583	10.16±5.331	9.08±5.912	0.198
	Left	11.50±4.939	11.83±4.251	10.00±4.871	0.156
500	Right	13.33±5.622	13.33±5.306	11.50±5.150	0.172
	Left	13.33±5.306	13.33±5.466	11.16±5.072	0.081
1000	Right	14.50±5.469	15.00±6.017	13.16±9.275	0.658
	Left	14.83±5.942	16.00±5.930	14.36±6.911	0.453
2000	Right	15.33±6.288	15.50±5.469	13.25±5.661	0.125
	Left	16.16±5.031	16.00±6.214	14.25±5.027	0.175
4000	Right	17.16±5.521A	15.28±3.266B	13.75±6.678C	0.022
	Left	18.00±5.508A	16.33±5.403B	14.66±4.721C	0.019
8000	Right	19.33±5.978A	18.83±5.20B	17.08±5.621C	0.041
	Left	20.66±5.371A	17.11±5.075B	15.32±5.236C	0.002

Data expressed as mean±SD, Different letter indicates significant differences as compared to other groups at p value less than 0.05 using one way ANOVA test followed by Posthoc test to indicates the different group

Table 3: Comparison of Acoustic Reflexes Parameters.

Frequencies	Side	Uncontrolled DM Group (N=30)	Controlled DM Group (N=30)	Control Group (N=60)	P-value
500	Right IPSI	86.33±4.535	85.66±5.040	86.08±4.423	0.851
	Left IPSI	85.33±4.138	85.00±4.152	84.25±2.885	0.351
	Right contra	91.50±3.971	91.16±5.031	91.00±4.584	0.887
	Left contra	90.00±4.354	90.40±4.910	89.75±3.730	0.787
1000	Right IPSI	87.66±5.529	86.16±4.857	85.75±5.111	0.250
	Left IPSI	87.50±3.655A	86.83±4.449AB	84.83±4.599B	0.013
	Right contra	92.33±4.866A	91.00±5.477AB	89.50±4.756B	0.037
	Left contra	92.33±3.407A	91.83±5.166A	88.83±5.237B	0.002
2000	Right IPSI	88.66±5.074A	87.83±5.675AB	85.83±5.612B	0.050
	Left IPSI	88.00±4.842A	88.00±4.660A	84.41±5.049B	0.001
	Right contra	93.50±4.576A	92.00±5.017AB	89.83±5.597B	0.006
	Left contra	92.83±4.086A	92.83±4.086A	89.41±5.375B	0.001

*One-Way ANOVA; Different letters mean significant Post-hoc test while similar letters mean insignificant Post-hoc test

4. Discussion

This study examined audiological evaluation techniques to measure the impact of diabetes on auditory circuits. No substantial variations were seen in the PTA thresholds at the assessed frequencies among the three groups. The uncontrolled DM group demonstrates a little inclination towards elevated thresholds, indicating a decline in normal auditory function when compared to the control group with analogous inclusion criteria. The distinction is more pronounced at elevated frequencies, specifically 4000Hz and 8000Hz (Table 2).

These findings may be ascribed to early-stage or moderate hearing impairment linked to diabetes, potentially exerting a negligible effect on low-frequency hearing. The basal part of the cochlea, which processes high-frequency sounds, may demonstrate greater vulnerability to microvascular alterations linked to diabetes compared to low-frequency sections [11].

hearing dysfunction is more pronounced in the uncontrolled diabetes cohort, indicating that inadequate metabolic regulation exacerbates hearing impairment. The controlled diabetic group exhibited superior hearing compared to the uncontrolled group, suggesting that manageable factors, such as glycaemic regulation, may have a 'auditory protective' effect on hearing function. The present study's PTA results align with those of Kiran *et al.* [12], who indicated that across all frequency bands from 250 Hz to 8000 Hz, the control group exhibited the lowest hearing thresholds, the controlled diabetes group displayed intermediate thresholds, and the uncontrolled diabetic group recorded the highest thresholds. Similarly, Fernandes *et al.* [13] shown that patients with type 1 diabetes exhibited elevated PTA thresholds, even within the normal hearing range, in comparison to healthy subjects. They attributed their findings to a hyperosmolarity syndrome caused by hyperglycemia, leading to salt accumulation in the inner ear.

Conversely, Mahallik *et al.* [14] observed no significant differences in PTA thresholds between diabetic and control groups across any frequency, whereas Bhattarai *et al.* [15] and Akinpelu *et al.* [16] documented markedly elevated PTA thresholds—particularly at high frequencies (6000 Hz and 8000 Hz), indicating potential early sensorineural hearing loss. Moreover, the study by Khakurel *et al.* [17] shown that, at all frequencies except 250 Hz, the hearing thresholds of the diabetic group were elevated compared to the control group for both the right and left ears, with the differences being statistically significant. Comparable findings were noted in additional investigations [18-20].

The auditory response threshold in diabetes patients has been investigated due to potential modifications in the auditory pathway. Table (3) indicates that certain frequencies exhibited no significant variation. The left ipsilateral reflex threshold in the uncontrolled diabetes group (87.50 ± 3.655) at 1000 Hz was substantially elevated compared to the control group (84.83 ± 4.599), with a p-value of 0.013. In the uncontrolled diabetic cohorts, contralateral reflex thresholds at 1000 Hz were markedly elevated compared to the healthy cohorts, especially in the left ear, which had the most significant disparities (p-value = 0.002). A notable disparity was seen at 2000 Hz, with the left ipsilateral reflex threshold elevated in the uncontrolled diabetic group compared to the controls (p value = 0.001).

The auditory response threshold (ART) at 1000 and 2000 Hz was heightened in the uncontrolled diabetes group, likely due to alterations in the cochlear nucleus (CN) and superior olivary complex (SOC), which hinder higher frequency processing in the brain, resulting in increased ART. This may suggest an initial impairment in the auditory brainstem, which in diabetes can markedly interfere with the auditory pathways due to microvascular and neuropathic alterations, especially at elevated frequencies [21]. Long-term poorly managed diabetes results in chronic hyperglycemia, leading to neuropathy that can impact both the central nervous system (CNS, responsible for signal interpretation) and the peripheral nervous system (peripheral nerves transmitting and receiving signals from the body) [22].

Neuropathy causing disruptions in nerve conduction may also impede the passage of auditory information from the ears to the brain. This disease may damage the auditory brainstem, an essential structure for sound processing and interpretation [3, 23]. They may have sufficient peripheral hearing but experience difficulties in perceiving and processing sounds, particularly at elevated frequencies [3].

Praneetha *et al.* [24] employed a t-test to assess the ipsilateral and contralateral mean ART and ARA across patients and controls at 500, 1000, 2000 Hz, and BBN, revealing no significant changes in mean ART between the groups on either side. Conversely, Fernandes *et al.* [13] noted a reduction in contralateral acoustic threshold in a combined cohort of diabetic patients relative to control subjects. The findings were characterised as a side effect of hyperglycemia, which diminishes intracellular hyperosmolarity and auditory sensitivity, thereby impairing acoustic responses. This may also stem from the microangiopathic effects of diabetes in the inner or middle ears. Diabetic individuals exhibited longer latencies and reduced amplitudes in auditory responses compared to the healthy control group. Mittal *et al.* [25] performed a systematic review and established a correlation between auditory impairments (altered auditory reflex thresholds (ARTs)) in Type 1 Diabetes Mellitus (T1DM) and contributory factors such as duration, age, and HbA1C levels. Conversely, Virtaniemi *et al.* [26] determined that the statistical analysis of the acoustic reflex threshold disparity between the two groups was insignificant. This was attributed to alterations in the rigidity of the middle ear system rather than to central neuropathy. This was ascribed to modifications in the rigidity of the middle ear system, rather than central neuropathy.

Current research continues to focus on assessing the efficacy of acoustic reflexes in evaluating the neural pathways of the auditory system. Nevertheless, these findings should not be solely relied upon to ascertain central neuropathy; it is advisable to complement them with additional audiological assessments, including auditory brainstem response and speech audiometry.

This study has drawbacks, including a non-random sample approach that restricts the generalisability of the findings due to selection bias. Furthermore, the study's external validity may be constrained by its concentration on a single specialised tertiary centre (Al-Wafaa in Mosul). Patients attending a speciality centre may get enhanced healthcare access or exhibit demographic differences compared to the general community. To enhance the study's validity, inclusion and exclusion criteria are established to mitigate confounders that may influence the findings, excluding hyperglycaemic conditions. Acoustic reflex testing alone cannot definitively detect central neuropathy. It is advisable to incorporate multimodal assessment, such as speech audiometry, in conjunction with ART.

5. Conclusion

ART measures indicated that the uncontrolled diabetic cohort displayed the greatest auditory reflex thresholds, whereas the control group exhibited the lowest. The findings indicate that inadequately managed diabetes may disrupt the auditory reflex circuit, especially at mid and high frequencies, signifying early neuronal involvement.

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