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Prevalence of Hearing Loss in Adults with Diabetes Mellitus Using Brainstem Evoked Response Audiometry: A Cross-Sectional Study

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Abstract: ***This study investigates the prevalence and characteristics of hearing loss among adults with diabetes mellitus (DM) using Brainstem Evoked Response Audiometry (BERA). Diabetes, a chronic metabolic disorder, has been linked to a variety of complications, including sensorineural hearing loss (SNHL), attributed to microvascular damage, oxidative stress, and neuropathy. Among 206 diabetic patients analyzed, 70% exhibited varying degrees of hearing loss, with mild SNHL being the most prevalent. Poor glycemic control (HbA1c > 8%) and a diabetes duration exceeding 10 years significantly increased the likelihood and severity of hearing impairment. The study highlights the role of diabetes-related complications, such as neuropathy and nephropathy, in exacerbating auditory dysfunction. These findings underscore the importance of early screening, glycemic control, and comprehensive management strategies to mitigate the impact of diabetes on auditory health and improve patients' quality of life.***

Keywords: diabetes mellitus, sensorineural hearing loss, Brainstem Evoked Response Audiometry, glycemic control, diabetic complications

1. Introduction

Diabetes mellitus (DM) is a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. It can cause dysfunction of multiple target organs, including the eyes, kidneys, and heart, leading to diabetic retinopathy, diabetic nephropathy, and diabetic cardiomyopathy. [1] The inner ear is also one of the affected organs, with patients presenting with varying degrees of hearing loss. However, due to its insidious onset, patients may not be aware of diabetes-related complications until their deafness becomes severe. Unfortunately, there is currently no effective clinical treatment, which places a huge psychological burden on diabetic patients. [2]

Diabetes mellitus is classified into two primary types: Type 1, characterized by autoimmune destruction of insulin-producing beta cells, and Type 2, typically associated with insulin resistance and progressive beta-cell dysfunction. [3] Both types lead to long-term complications affecting the cardiovascular, renal, and nervous systems. Diabetic neuropathy, a well-documented consequence of poorly controlled diabetes, involves damage to peripheral nerves, leading to sensory and motor deficits. This neuropathic effect has raised questions about its potential impact on the auditory system. [4]

There are various complications associated with diabetes mellitus. The most common complication of diabetes is neuropathy. As a consequence of long-standing hyperglycemia in diabetes, a downstream metabolic cascade leads to peripheral nerve injury.
Decreased vascular supply with impaired auto regulation is likely to cause hypoxic damage in the nerve. Hence peripheral neuropathy has become the most common and intractable complication of diabetes. [5]

The correlation between diabetes mellitus and hearing loss has been known for more than 100 years. In 1857 Jordao was the first to report a case of incipient diabetic coma exhibiting impairment of vision, hearing, smell, and taste in a 41-year-old man. Hearing loss caused by DM can be referred to as diabetes-related hearing loss. This type of deafness is distinct from conductive deafness, which affects the external auditory canal or middle ear. [6] It is classified as sensorineural hearing loss (SNHL) and primarily affects the nerve fibers or auditory sensory cells of the inner ear. In the process of exploring DRHL, pure tone audiometry (PTA), otoacoustic emissions (OAE), and Auditory brainstem response (ABR) are often used to evaluate patients' auditory function. Many Studies have shown that both type 1 diabetes mellitus (T1DM) and type 2 diabetes mellitus (T2DM) patients have worse hearing than normal people. OAE, which reflects the condition of hair cells of the inner ear, is significantly lower in patients with DM. The latency of the ABR, which reflects the electrical activity of the auditory nerve and its brainstem connections, is also prolonged in patients with DM. [7]

Hearing loss is a multifactorial condition influenced by various environmental and genetic factors. Diabetes mellitus is a significant risk factor for hearing impairment. The pathophysiological mechanisms linking diabetes and hearing loss are complex and not yet fully understood but are thought to involve microvascular damage, oxidative stress, and inflammation. Chronic hyperglycemia in diabetes can lead to damage to the small blood vessels in the inner ear, compromising blood flow and nutrient supply to auditory structures. [8] Moreover, elevated blood sugar levels contribute to the production of reactive oxygen species, causing oxidative damage to delicate sensory cells in the cochlea. Additionally, diabetes-related inflammation may exacerbate cochlear injury, further impairing auditory function. The cumulative effect of these processes manifests as sensorineural hearing loss, particularly affecting high-frequency sounds. The relationship between diabetes mellitus and hearing impairment is crucial for early detection. [9] The relationship between DM and deafness differs by gender is currently unknown. Some studies believe that female diabetic patients have poorer hearing and a higher risk of hearing loss than males. The incidence of hearing loss was 29.64 per 1, 000 person-years in women with DM and 25.23 per 1, 000 person-years in men with DM. [10]

Brainstem Evoked Response Audiometry (BERA) is a simple noninvasive objective test to observe the auditory function. When the sound reaches the cochlea it is converted into an electrical impulse and passes from the cochlea to the auditory cortex via an auditory pathway. BERA test evaluates the structural and functional integrity of this pathway from spiral ganglia to the level of the lateral lemniscus. [11] The auditory impulse traverses through the different stations in the auditory pathway, the passage of impulse through this pathway generates an electrical activity which can be monitored by placing a surface electrode on the vertex of the scalp. The electrical activity recorded from the electrodes is plotted as waveforms in a graph and by analyzing this waveform morphology and latency, any abnormality of the auditory pathway can be detected. [12]

The normal BERA recording consists of five or more waves arising within 10 msec of the auditory stimulus. BERA study relies on the measurement of the latencies and amplitude of waves arising after giving a sound higher than the hearing threshold. Wave I represents the neuroelectrical response which starts from the distal end of the cochlear nerve, wave II from the proximal end, wave III from the cochlear nucleus, wave IV from the superior olivary complex, and lateral lemniscus and wave V from the lateral lemniscus and the inferior colliculus. [13]

2. Rationale of the study

Diabetes mellitus is a chronic metabolic condition characterized by elevated blood glucose levels, with a growing prevalence worldwide. Apart from its established effects on cardiovascular health, neuropathy, and renal function, emerging evidence suggests that diabetes may also have implications for auditory health. Specifically, studies have indicated a potential link between diabetes and hearing loss, yet the underlying mechanisms remain unclear. Given the complex physiology of diabetes and the intricate pathways involved in hearing, further investigation is required to understand this relationship in detail.

BERA provides a unique opportunity to explore auditory function at the level of the brainstem. This non-invasive technique measures electrical responses generated by the auditory nerve and brainstem pathways following auditory stimuli, allowing for precise assessment of auditory processing. By applying BERA to adults with diabetes, researchers can investigate whether diabetes-associated complications, such as microvascular damage or neuropathy, extend to the auditory system, potentially contributing to hearing loss.

Despite the growing interest in this area, there exists a significant gap in the literature. Most studies have focused on general audiometric assessments without exploring the specific neural pathways involved. Additionally, while research has identified correlations between diabetes and hearing loss, there is limited data on how these correlations manifest at the neural level or what specific aspects of diabetes contribute to this risk. Addressing these gaps can help establish a clearer understanding of the pathophysiology of hearing loss in diabetic individuals and guide clinical interventions to preserve auditory health in this population.

3. Aims and Objectives

Aim: To assess prevalence of hearing loss in adults with diabetes mellitus using brainstem evoked response audiometry

Primary Objectives:

- To assess the total burden of hearing loss in Diabetes Mellitus patients.
- Correlation between the degree of hearing loss and blood sugar levels in Diabetes Mellitus patients.
- Correlation between the duration of Diabetes Mellitus and the onset and degree of hearing loss.
- Correlation between the type of Diabetes Mellitus (Type I / Type II) and the onset and degree of hearing loss.
- Prevalence of Hearing Loss in Patients with Diabetes Mellitus
- Degree of Hearing Loss in Patients with Diabetes Mellitus
- Associated Ear Symptoms in Patients with Diabetes Mellitus
- Treatment Modalities for Hearing Loss in Patients with Diabetes Mellitus
- Other Factors Affecting the Onset of Hearing Loss in Patients with Diabetes Mellitus

4. Materials and Method

Study Design- This was an observational cross-sectional study.

Study Setting- This study was conducted at the Department of Otorhinolaryngology Vilasrao Deshmukh Government Medical College, Latur.

Study Population- Patients attending the Otorhinolaryngology OPD and undergoing treatment in our institute during the study duration.

Sample size- This study utilized a sample size of 206 patients.

Study Period- The study was conducted over a period of 22 months, from August 2022 to August 2024.

Selection Criteria of Study Subject

Inclusion Criteria

- All patients with Fasting blood sugar levels >/= 126 mg/dL.
- All patients with Post prandial blood sugar levels >/= 200 mg/dL.
- All patients with HbA1c >/= 6.5%.
- All diagnosed cases of Diabetes Mellitus with or without Hearing Loss.

Exclusion Criteria

- Patients with Fasting blood sugar levels < 126 mg/dL and not a previously diagnosed case of Diabetes Mellitus.
- Patients with Post prandial blood sugar levels < 200 mg/dL and not a previously diagnosed case of Diabetes Mellitus.
- Patients with HbA1c <6.5% and not a previously diagnosed case of Diabetes Mellitus.
- Patients below 18 years of age.
- Patients with congenital ear malformations.

5. Methodology

After obtaining the approval of the protocol review committee and the institutional ethics committee (IEC), a total of 206 patients were enrolled in the study. Patients who satisfied any of the inclusion criteria were considered for the study. Informed consent was obtained from each participant for their involvement in the study and for performing Brainstem Evoked Response Audiometry (BERA). The examination of participants included a general physical examination and an ENT examination. Specifically, the examination of the ear encompassed the preauricular area, pinna, postauricular area, external auditory canal, and tympanic membrane.

All patients underwent the BERA test according to the standard protocol. The BERA waves considered for the study included the threshold level, the latency of each wave, and the interpeak latency. Threshold values exceeding normal levels were deemed abnormal, indicating some form of hearing impairment. The mean absolute latencies of each wave were recorded as follows: Wave I at 1.75 msec, WaveII at 2.8 msec, Wave III at 3.9 msec, Wave IV at 5.1 msec, and Wave V at 5.7 msec. Additionally, the interpeak latency values were 2.1 msec for waves I-III and 4.0 msec for waves I-V. The obtained data from these measurements were used to assess the hearing threshold and identify any abnormalities in hearing function.

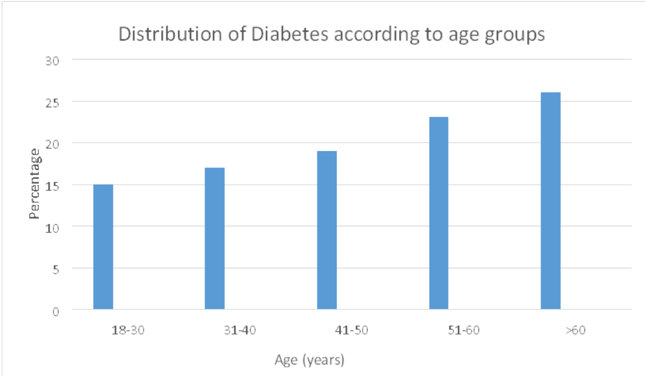
Statistical analysis:

Data was entered in Microsoft Excel Spreadsheet. Continuous variables were summarised as mean and standard deviation (SD). Categorical variables were summarised as frequency and percentage. The reported p values were based on analysis, in which p<0.5 was considered significant.

6. Results and Observation

Table 1: Distribution of Diabetes according to Age groups

Age groups (years)	No. of cases of Diabetes	%
18 – 30	30	15%
31 - 40	36	17%
41 - 50	39	19%
51- 60	48	23%
>60	53	26%
	206	100%

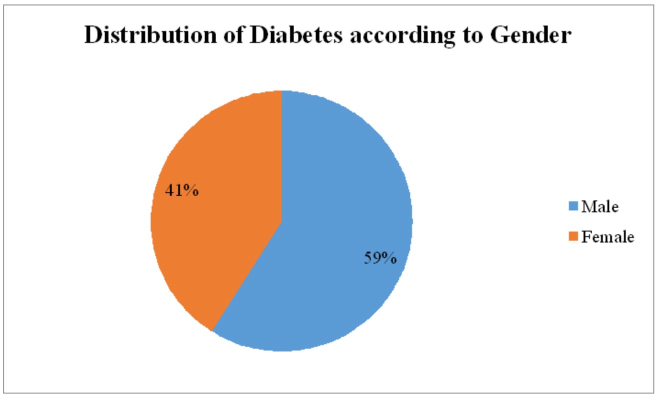


Graph 1: Distribution of Diabetes according to Age groups

The above table showed that, the majority of cases (26%) occur in individuals over 60 years old. The 51-60 age group accounts for 23% of cases, while the 41- 50 age group represents 19%. The 31-40 age group has the 17% cases, and 18-30 age group has 15% (fewest) cases. Overall, there are 206 cases, with the older age groups experiencing a higher incidence.

Table 2: Distribution of Diabetes according to Gender

Gender	No. of cases	%
Male	121	59%
Female	85	41%
Total	206	100%

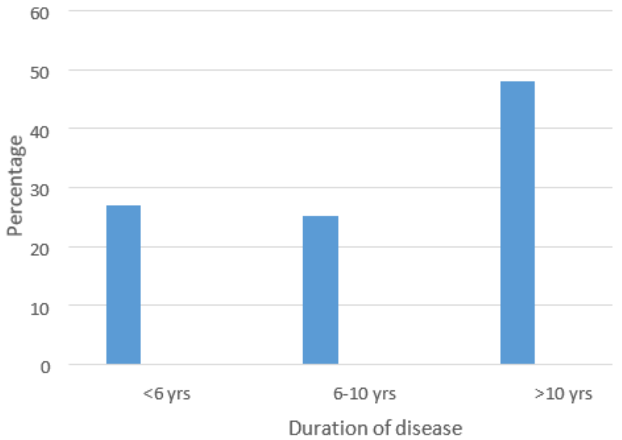


Graph 2: Distribution of Diabetes according to Gender

The above table showed that, males are more frequently affected, comprising 59% of the total cases, while females account for 41%. Out of the 206 total cases, 121 are male and 85 are female.

Table 3: Distribution of Diabetes according to Duration of disease

Duration of diabetes	No. of cases	%
< 6 years	56	27%
6 – 10 years	52	25%
>10 years	98	48%
Total	206	100%



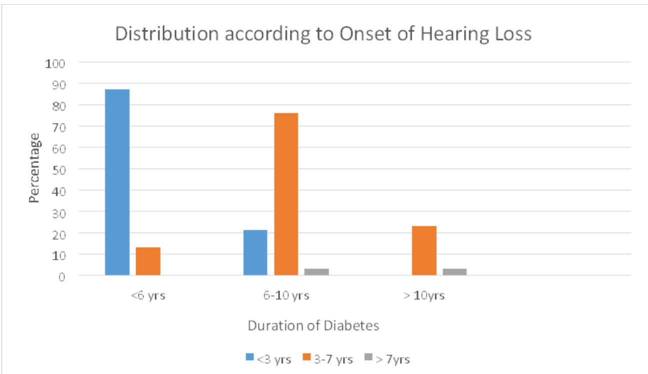
Graph 3: Distribution of according to duration of disease

The above table showed that, 56 cases (27%) have had diabetes for less than 6 years, and 52 cases (25%) fall into the 6 to 10 years category and 98 cases (48%) had diabetes for more than 10 years.

Table 4: Distribution according to Onset of Hearing Loss

Duration of Diabetes (years)	Onset of Hearing loss (years)		
	<3	3-7	>7
<6	34 (87%)	5 (13%)	0
6-10	6 (21%)	22 (76%)	1 (3%)
>10	0	18 (23%)	59 (77%)

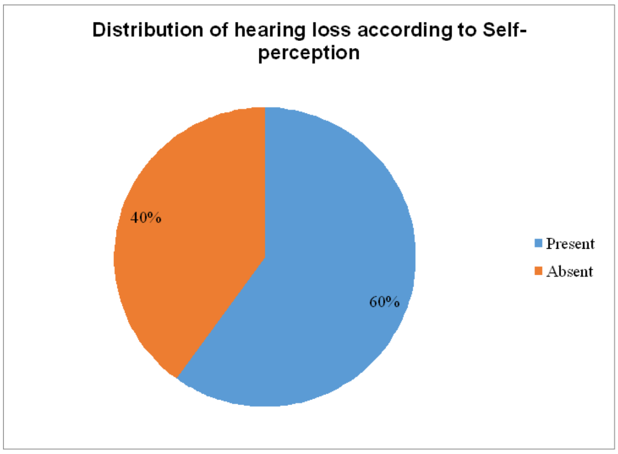
The above table showed that, in the category of <6 years duration of diabetes, 34 cases (87%) had hearing loss since <3 years, 5 (13%) had hearing loss since 3-7 years, whereas in the 6-10 years category, maximum i.e.22 cases (76%) had hearing loss since 3-7 years, 6 (21%) since <3 years and only1 (3%) since >7 years. In the >10 years category, maximum i.e 59 cases (77%) had hearing loss since >7 years and 18 (23%) since 3-7 years.



Graph 4: Distribution according to Onset of Hearing Loss

Table 5: Distribution of Hearing loss according to Self-perception

Self-perceived hearing loss	No. of cases	%
Present	124	60%
Absent	82	40%
Total	206	100%

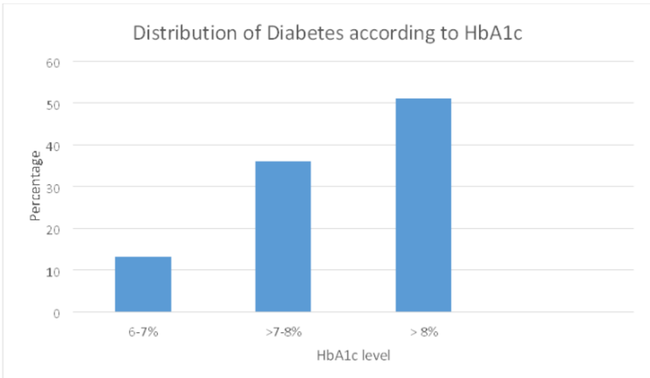


Graph 5: Distribution of Hearing loss according to Self-perception

The above table showed that, 124 out of 206 cases (60%) report self-perceived hearing loss, while 82 cases (40%) do not.

Table 6: Distribution of Diabetes according to HbA1c

HbA1c	No. of cases	%
6.5 -7 %	26	13%
>7-8%	75	36%
>8%	105	51%
Total	206	100%



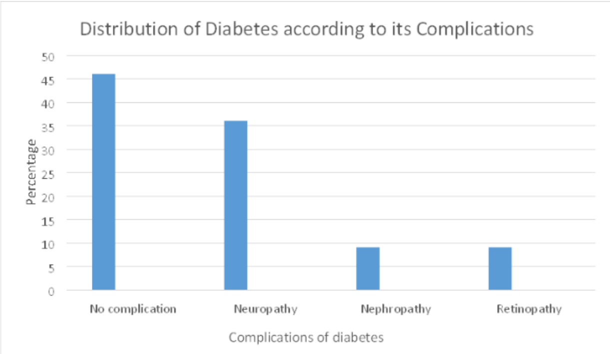
Graph 6: Distribution of Diabetes according to HbA1c.

The above table showed that, 105 cases (51%) have an HbA1c level greater than 8%, indicating poor glycemic control.

Additionally, 75 cases (36%) fall into the > 7-8% range, while 26 cases (13%) have levels between 6.5-7%.

Table 7: Distribution of diabetes according to its complications

Complications of DM	No. of cases	%
No complication	95	46%
Neuropathy	74	36%
Nephropathy	19	9%
Retinopathy	18	9%
Total	206	100%

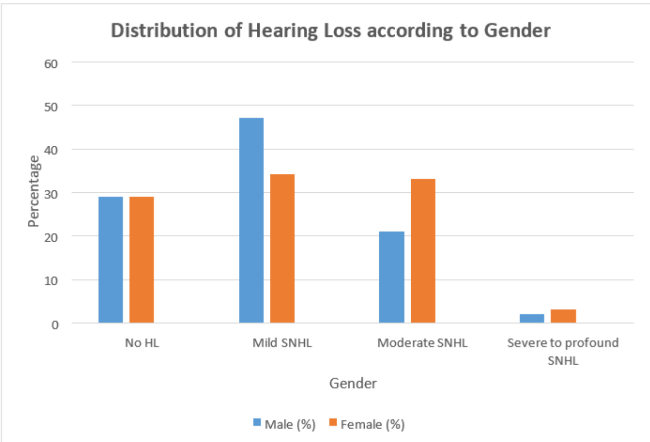


Graph 7: Distribution of diabetes according to its complications

The above table showed that, 95 (46%) have no complication related to diabetes, 74 (36%) have diabetes related neuropathy making it the most common complication. Nephropathy is reported in 19 cases (9%), while retinopathy affects 18 cases (9%). This distribution indicates that majority patients had no complication of diabetes, neuropathy is the predominant complication, followed by nephropathy and retinopathy, underscoring the need for comprehensive management strategies to address these varied complications of diabetes.

Table 8: Distribution of Hearing Loss according to Gender

Gender	No hearing loss	Mild SNHL	Moderate SNHL	Severe to profound SNHL	P-value
Male	36(29%)	57(47%)	26(21%)	2(2%)	0.15
Female	25(29%)	29(34%)	28(33%)	3(3%)	



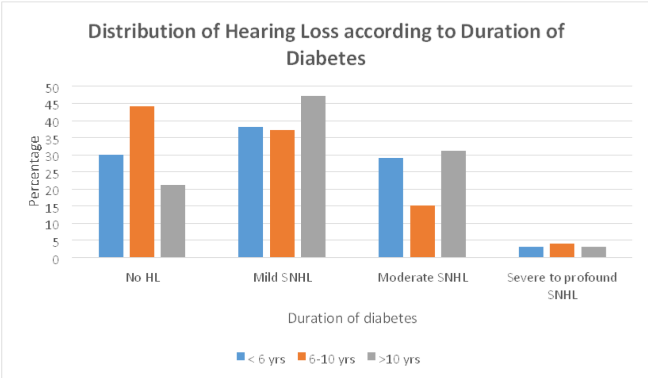
Graph 8: Distribution of Hearing Loss according to Gender

The above table showed that, for males, the majority have mild sensorineural hearing loss (47%), with fewer having moderate

(21%) or severe to profound SNHL (2%). Females show a similar trend, with 34% experiencing mild SNHL and fewer having moderate (33%) or severe to profound SNHL (3%). There was no significant gender-based differences in the severity of hearing loss.

Table 9: Distribution of Hearing Loss according to Duration of diabetes

Duration of diabetes	No hearing loss	Mild SNHL	Moderate SNHL	Severe to profound SNHL	P-value
< 6 years	17(30%)	21(38%)	16(29%)	2(3%)	<0.0003
6 – 10 years	23(44%)	19(37%)	8(15%)	2(4%)	
>10 years	21(21%)	46(47%)	30(31%)	1(1%)	

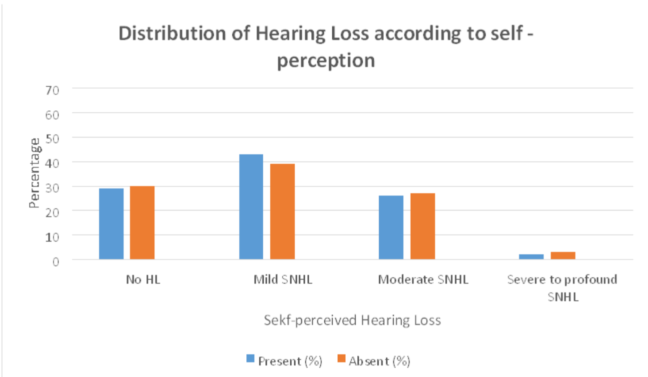


Graph 9: Distribution of Hearing Loss according to Duration of diabetes

The above table showed that, Patients with diabetes for less than 6 years mostly have mild SNHL (38%), or no hearing loss (30%). In the 6-10 years group, 37% have mild SNHL and 15% have moderate SNHL. For those with diabetes for more than 10 years, 47% experience mild SNHL and 31% have moderate SNHL.

Table 10: Distribution of Hearing Loss according to Self-perception

Self perceived hearing loss	No hearing loss	Mild SNHL	Moderate SNHL	Severe to profound SNHL		P-value
Present	36(29%)	54(43%)	32(26%)	2(2%)	124	0.76
Absent	25(30%)	32(39%)	22(27%)	3(4%)	82	

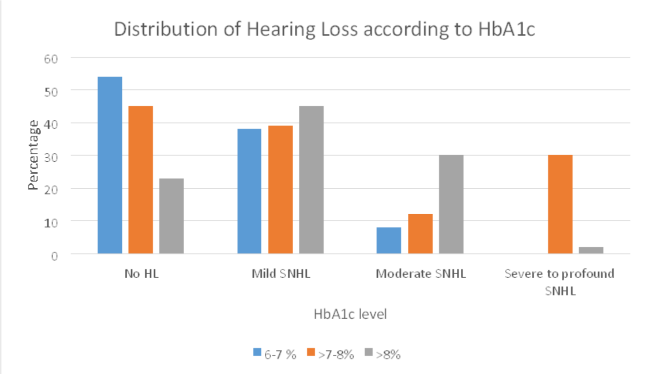


Graph 10: Distribution of Hearing Loss according to Self-perception

The above table showed that, in individuals with self - perceived hearing loss, 43% have mild SNHL, 26% have moderate SNHL, and 2% have severe to profound SNHL. Conversely, in individuals without self-perceived hearing loss, 30% have no hearing loss and 39% have mild SNHL, and 4% having severe to profound SNHL with P value of 0.76 indicating similar distributions across all categories.

Table 11: Distribution of Hearing Loss according to HbA1c

HbA1c	No hearing loss	Mild SNHL	Moderate SNHL	Severe to profound SNHL	P-value
6.5-7 %	14(54%)	10(38%)	2(8%)	0	<0.0019
>7-8%	34(45%)	29(39%)	9(12%)	3(4%)	
>8%	24(23%)	47(45%)	32(30%)	2(2%)	

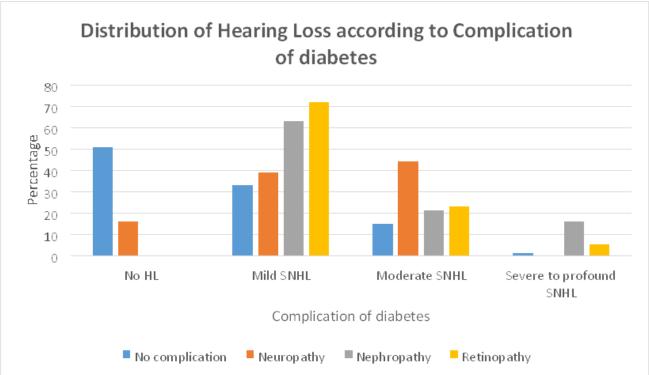


Graph 11: Distribution of Hearing Loss according to HbA1c

The above table showed that, HbA1c levels of 6.5-7% predominantly have no hearing loss (54%) or mild SNHL (38%), with a p value of <0.0019 indicating statistical significance. In the > 7-8% HbA1c group, 45% have no hearing loss and 39% have mild SNHL. For those with HbA1c levels above 8%, 45% experience mild SNHL, and 30% have moderate SNHL.

Table 12: Distribution of Hearing Loss according to Complication of Diabetes

Complications of DM	No hearing loss	Mild SNHL	Moderate SNHL	Severe to profound SNHL	P-value
No complication	48(51%)	31(33%)	15(15%)	1(1%)	<0.0006
Neuropathy	12(16%)	29(39%)	33(44%)	0	
Nephropathy	0	12(63%)	4(21%)	3(16%)	
Retinopathy	0	13(72%)	4(23%)	1(5%)	

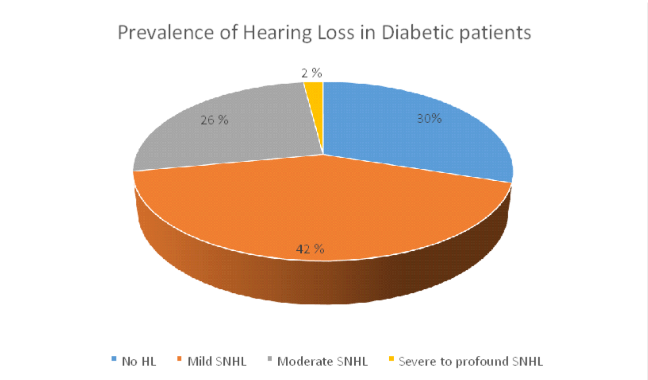


Graph 12: Distribution of Hearing Loss according to complication of Diabetes

The above table showed that, a significant association between diabetic nephropathy and retinopathy and hearing loss severity, 16% patients of nephropathy and 5% patients of retinopathy having severe to profound hearing loss. In nephropathy patients, 63% have mild SNHL, and in neuropathy patients, 44% have moderate SNHL.

Table 13: Prevalence of Hearing Loss in Diabetic patients

No Hearing Loss	Mild SNHL	Moderate SNHL	Severe to profound SNHL	**Total patients with Hearing Loss**
61	**86**	**54**	**5**	**145**
30%	42%	26%	2%	**70%**



Graph 13: Prevalence of Hearing Loss in Diabetic patients

The above table states that amongst the 206 cases of diabetes, 145 patients (70%) had hearing loss, out of which 86 (42%) have mild SNHL, 54 (26%) have moderate SNHL and a lesser proportion, 5 patients (2%) have severe to profound SNHL, suggesting a prevalence of 70%, whereas 61 patients (30%) had no hearing loss as per the findings of BERA.

7. Conclusion

The analysis of the prevalence of hearing loss in adults with diabetes mellitus reveals significant insights into the demographic and clinical characteristics of affected individuals. The data indicates that the highest incidence of hearing loss occurs in those over 30 years of age, comprising 48% of the cases, with a notable prevalence in males (59%) compared to females (41%).

The duration of diabetes also plays a critical role, as individuals with diabetes for over ten years represent 53% of cases, correlating with increased severity of hearing loss.

Self-perceived hearing loss is reported in 60% of the cases, indicating a significant awareness among patients regarding their auditory health. The relationship between glycemic control, as indicated by HbA1c levels, and hearing loss severity is evident, with poor glycemic control (HbA1c > 8%) linked to higher instances of mild to moderate sensorineural hearing loss.

Additionally, the presence of complications related to diabetes, particularly neuropathy, is associated with increased severity of hearing loss, importance the interconnectedness of diabetes-related health issues.

Overall, this study concluded the urgent need for targeted screening and management strategies for hearing loss in adults with diabetes, particularly in older populations with a prolonged duration of diabetes and poor glycemic control. Addressing these factors may improve the quality of life for individuals affected by both diabetes and hearing loss, emphasizing the importance of comprehensive healthcare approaches in managing chronic conditions.

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Abbreviations

Abbreviations	Full form
DM	Diabetes mellitus
SNHL	Sensorineural hearing loss
OAE	otoacoustic emissions
ABR	Auditory brainstem response
T1DM	Type 1 diabetes mellitus
T2DM	Type 2 diabetes mellitus
BERA	Brainstem Evoked Response Audiometry
IHCs	Inner hair cells

CSF	Cerebrospinal Fluid
VCN	Ventral Cochlear Nucleus
IC	Inferior Colliculus
PVCN	Posteroventral Cochlear Nucleus
VCN	Ventral Cochlear Nucleus
DCN	Dorsal Cochlear Nucleus
NO	Nitric Oxide