Prevalence of Hearing Loss in Type 2 Diabetes Mellitus and Its Association with Severity of Diabetic Neuropathy

Abin M Abraham  
Christian Medical College and Hospital Ludhiana

Ashish Vargheese  
Christian Medical College and Hospital Ludhiana

Jubbin Jagan Jacob  (jubbin.jacob@gmail.com)  
Christian Medical College and Hospital Ludhiana  https://orcid.org/0000-0003-1755-5523

Research Article

Keywords: Type 2 Diabetes Mellitus, Diabetes, Hearing loss, hearing impairment, neuropathy, diabetic neuropathy

Posted Date: January 14th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1253537/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Purpose

This study assessed the prevalence of hearing loss (HL) in patients with Type 2 Diabetes (T2DM) and its relationship with the presence and severity of diabetic neuropathy.

Methods

Patients between the ages of 30 to 60 years (both ages inclusive) with T2DM were recruited and divided into three groups. Group 1 included patients without neuropathy. Group 2 had patients with mild neuropathy. Group 3 had patients with moderate and severe neuropathy. After informed consent hearing threshold was assessed using pure tone audiometry (PTA).

Results

Of the 200 patients recruited, the prevalence of hearing loss was overall 81%. The prevalence was 66.7% in group 1, 80.9% in group 2 and 87.6% in group 3 (p=0.009). Among patients with moderate to severe neuropathy (group 3) 33.3% had clinically significant hearing loss (p=0.015). Age, gender, presence of neuropathy and severity of neuropathy were associated with increased risk of developing hearing loss. Severity of hearing loss worsened with increase in severity of neuropathy.

Conclusions

Age, gender and severity of neuropathy were associated with increased risk of developing hearing loss. Screening for hearing loss in patients with moderate to severe diabetic neuropathy using self-report questionnaires can help in timely diagnosis and treatment.

1. Introduction

Type 2 diabetes mellitus (T2DM) is one of the major health problems with global estimates of more than 463 million affected individuals (1). The increasing prevalence of T2DM is likely to result in an increased number of individuals with diabetes related complications. T2DM has been associated with hearing loss in several population-based studies (2,3). Hearing loss (HL) is an impairment that severely affects quality of life and has significant economic and emotional impact. It leads to social withdrawal, psychological alienation, anxiety, depression, cognitive decline and dementia among those who suffer from it. T2DM and hearing loss have been proven to be independent risk factors for the development of dementia. The risk of developing dementia is three fold in a patient with moderate hearing loss and five fold in a patient with severe hearing loss when compared to a person with normal hearing (4,5).
Proposed pathophysiological mechanisms involved in the development of hearing impairment in T2DM includes microangiopathy, neuropathy and mitochondrial damage (6). Angiopathy occurs in diabetes as a result of glycoprotein accumulation in the tunica intima and endothelial damage. Hyperglycemia induced overproduction of free radicals and superoxide leads to oxidative stress which plays a major role in endothelial dysfunction and diabetes related complications (7). There is reduction in dendritic branching, degradation of vasa vasorum of blood vessels supplying the vestibulo-cochlear nerve, reduction in the number of cochlear cells and cochlear microangiopathy. The stria vascularis has an abundant vascular supply and this makes it particularly vulnerable to diabetic Angiopathy (9–11). There is substantial delay in auditory brainstem latencies of patients with T2DM which is suggestive of impaired neurological transmission in patients with diabetes (12,13).

Strong evidence supports that timely diagnosis and use of hearing aids can significantly improve the quality of life, improve communication, reduce depression and the rate of cognitive decline in patients with hearing loss (14,15). Despite the prevalence and burden of hearing loss in the society, it is underdiagnosed and undertreated. This makes it important to identify the patients with T2DM who are at high risk for developing hearing loss so that effective screening can be done for diagnosis and prompt initiation of treatment can then follow.

There are few published studies which assess the risk factors leading to hearing loss among patients with diabetes. However there has been no study comparing the association of hearing loss with the presence of distal peripheral sensory-motor neuropathy (DSPN) and its severity. In this study the prevalence of HL in patients with T2DM and its association with the presence of distal peripheral sensory-motor neuropathy and its severity was studied. Identifying the potential risk factors and the association of neuropathy with hearing loss can help in targeting the population that are at high risk of developing hearing loss. This can help us in planning optimal strategies for screening and prompt treatment of patients with hearing loss among patients with T2DM.

2. Materials And Methods

2.1 Setting

This was a cross sectional comparative study conducted among patients with T2DM attending the endocrinology outpatient clinics of a tertiary referral teaching hospital in North India. The study was conducted between 1st November 2016 to April 2018.

2.2 Subjects

Consecutive patients between the ages of 30 to 60 years (both ages inclusive) who were diagnosed to have type 2 diabetes mellitus for at least 6 months were enrolled after an informed consent. Patients with history of intake of ototoxic drugs, previous history of ear surgeries, recent infections in the ear, patients with clinical history suggestive of Meniere's disease (history of vertigo or tinnitus in spells), patients with past history of neurological diseases (stroke, multiple sclerosis, dementia or central nervous system conditions) were excluded.
infections), patients with past history of closed or open head injuries, patients with chronic over exposure of loud noises (90dB for 8 hours a day, 5 days a week), patients unable to comprehend PTA assessment and patients not willing to consent or not capable to consent were excluded. Demographic details were obtained from the subject's clinical notes followed by a clinical assessment of DSPN and assessment of hearing using pure tone audiometry.

2.3 Ethical approval and registration of study protocol

The Institutional Ethics Committee of Christian Medical College and Hospital approved the study protocol prior to any study related activities and the protocol was registered with the Baba Farid University of Health Sciences prospectively as part of part of Doctor of Medicine (MD) thesis in general medicine for the first author and the principal investigator of the study under supervision of the other two authors (https://www.bfuhs.ac.in/examination/PlanOfThesis/27-8-18/CMC-2016.pdf). Patients were recruited in the study after they provided an informed consent in a language comfortable to them (English, Hindi or Punjabi).

2.4 Sample Size

The prevalence of neuropathy in patients with diabetes was noted to be 50% (16). The sample size was calculated to be n=200 by using the formula \( n = \frac{Z_{\alpha/2}^2 \cdot P \cdot (1-P)}{d^2} \), where \( Z_{\alpha/2} \) is the critical value of the normal distribution at \( \alpha/2 \) (For our study the confidence level of 95%, \( \alpha \) is 0.05 and the critical value is 1.96), \( p = 50\% \) is the proportion and \( d = 7\% \) is margin of error.

2.5 Assessment of peripheral neuropathy

Distal peripheral sensory-motor neuropathy (DSPN) among the participants of the study was assessed using the clinical Michigan Diabetic Neuropathy Score (MDNS). The MDNS Score is calculated based on a neurological examination and it is a validated tool for assessment of the severity of neuropathy in patients with DSPN (17). Based on MDNS score, recruited patients were divided into 3 groups. Group 1 included patients with no neuropathy (MDNS score \( \leq 6 \)). Group 2 included patients with mild neuropathy (MDNS score 7 to 13). Group 3 included patients with both moderate (MDNS score 13 to 30) and severe neuropathy (MDNS score \( \geq 30 \)).

2.6 Assessment of hearing loss

Pure tone audiometry (PTA) was performed using Maico-MA 32 diagnostic audiometer in a soundproof compartment. Air conduction and bone conduction audiometric thresholds at 250, 500, 1000, 2000, 4000 and 8000Hz were obtained using 5dB steps. Hearing sensitivity for each ear was measured separately and the severity of hearing loss was assessed according to Goodman's classification. Patients were classified into those with mild, moderate, moderately severe, severe or profound hearing loss accordingly (18,19). Severity of hearing loss in the worse ear was considered for statistical analysis. In our study, hearing loss was defined as pure tone average >15 decibel hearing level in the worse ear. Clinically
significant hearing loss (CSHL) was defined as pure tone average > 25 decibel hearing level (dBHL) in the worse ear. Pure tone average was defined as the average of 500 Hz, 1000 Hz and 2000 Hz.

2.7 Statistical Analysis

Data was collected using a structured proforma. Data entry was done in Microsoft Excel spreadsheets. Mean, frequency and standard deviation was calculated. Chi-square test was used to compare categorical variables between the groups. Independent t-test was used to compare the continuous data between two groups and One-way ANOVA was used to compare the continuous variables between more than two groups. ANOVA for repeated measure was used to find the change in PTA averages at different frequencies. Linear regression was used to find the significant predictors by taking PTA average as outcome for both right and left ear. Bivariate logistic regression was used to find the significant predictors by taking Hearing loss in any one ear as outcome. A p-value < 0.05 was considered as statistically significant. Data analysis was done using Statistical Package for Social Sciences (SPSS Ver. 21.0).

3. Results

Total of 200 patients with T2DM, were enrolled in the study and the overall prevalence of hearing loss was 81%. Among them, 152 patients had neuropathy and 48 patients did not have neuropathy. Prevalence of hearing loss was 66.7% among patients without neuropathy, 80.9% among patients with mild neuropathy and 87.6% in patients with moderate to severe neuropathy (p value= 0.004). Flow of patients in the study is summarized in Figure 1.

3.1 Baseline profile of patients

The demographic, clinical and biochemical profile of the patients is summarized in Table 1. Patients with neuropathy, males and older patients (p=0.003) had higher risk of developing hearing loss.

3.2 Prevalence of hearing loss and its association with neuropathy

Figure 2A shows the prevalence of hearing loss and clinically significant hearing loss among patients with and without neuropathy. The correlation was statistically significant for hearing loss and clinically significant hearing loss (p=0.004 and 0.016). Figure 2B shows the association of hearing loss and clinically significant hearing loss with severity of the neuropathy (MDNS Grade). The prevalence of hearing loss and clinically significant hearing loss increased with the increase in severity of neuropathy (MDNS Grade) and the correlation was statistically significant (p-value 0.009 and 0.015 respectively).

3.3 Hearing loss in speech frequencies (pure tone average)

The clinical pure tone average (average of 500, 1000 and 2000 Hz) was found to be higher in patients with neuropathy and the pure tone average increased with an increase in severity of neuropathy (p=0.005). The severity of hearing loss in speech frequencies (pure tone average) had significant correlation with HbA1c (p=0.048 in right ear and p=0.012 in left ear). On univariate linear regression with
PTA Average as dependent variable age, severity of neuropathy (MDNS score and MDNS Class) and FBS was found to have significant positive correlation. eGFR had a negative correlation with PTA average.

### 3.4 Association of MDNS score/ MDNS class with hearing threshold in various frequencies

**Figure 3** shows the association of severity of neuropathy with hearing threshold values at various frequencies in the right and left ear. In patients with neuropathy, the hearing loss was found to be worse in the higher frequencies like 2000 Hz, 4000 Hz and 8000 Hz. With worsening grades of neuropathy, hearing loss in the higher frequencies also worsened. The correlation was statistically significant in the higher frequencies like 2000 Hz, 4000 Hz and 8000 Hz. P values were <0.001, 0.024 and 0.020 in the left ear. In the right ear p values were 0.005, 0.007 and 0.028 for these frequencies.

On comparing the MDNS score with the PTA hearing threshold, similar results were seen. The correlation was statistically significant for 2000, 4000 and 8000 Hz (p=0.001, 0.001, and 0.006 in the right ear and p= <0.001, 0.004 and 0.022 in the left ear).

### 3.5 Univariate and multivariate regression analysis with hearing loss in any one ear as outcome

On univariate analysis, age, gender, severity of neuropathy (MDNS score and MDNS grade) and presence of neuropathy was found to have significant correlation (Table 3). Prevalence of hearing loss was higher in older patients (p=0.004) and patients with neuropathy (p=0.006). The risk of developing hearing loss increased with worsening severity of neuropathy (p=0.007). Women had some protection against developing hearing loss (p=0.033). On multivariate analysis with AHL in any one ear as outcome, age (p=0.018), gender and MDNS score (p=0.005) were found to have significant correlation.

### 4. Discussion

Among the patients enrolled in our study with T2DM, the overall prevalence of any degree of hearing loss was 81% and the prevalence of clinically significant hearing loss was 28.5%. Patients with neuropathy were more likely to have hearing loss and the severity of hearing loss increased with increase in severity of the neuropathy. The prevalence of clinically significant hearing loss was 20.8% patients without neuropathy (Group 1), 25.5% in patients with mild neuropathy (Group 2) and 33.3% in patients with moderate to severe neuropathy (Group 3). The clinical pure tone average which represents the average hearing threshold in speech frequencies increased with increase severity of neuropathy. This was suggestive of worsening of hearing impairment with increase in severity of neuropathy. It was noted that the hearing impairment was more in the higher frequencies like 2000 Hz, 4000 Hz and 8000 Hz among patients with T2DM and the correlation of hearing loss with neuropathy was more in the higher frequencies. Age, gender, presence of neuropathy and severity of neuropathy was associated with significantly increased risk of developing hearing loss.

In our study, the clinical pure tone average (average hearing threshold in 500, 1000 and 2000 Hz) showed significant correlation with the severity of neuropathy, age and HbA1c. As speech sounds are more
densely represented in the mid frequencies, the average of 500, 1000 and 2000 Hz signifies the involvement of speech frequencies. Clinical pure tone average had significant association with MDNS score and MDNS grade. This was suggestive of worsening of hearing impairment in speech frequencies with increase in severity of neuropathy. The pure tone average was higher in older patients and patients with higher HbA1c. Similar results were seen in study by Austin et al, Sugimoto et al where higher HbA1c and uncontrolled blood sugars correlated with hearing loss in patients with T2DM (8,20). Most patients with T2DM tend to develop hearing loss in the higher frequencies however those with poorly controlled sugars had significant hearing loss in the speech frequencies also. In a cross sectional study conducted by Sugimoto et al diabetic neuropathy, creatinine clearance, and retinopathy were found to have some association with hearing loss (20). Pathophysiological changes seen in the auditory nerve and inner ear which are similar to the changes seen in the peripheral nerves of patients with diabetic neuropathy might explain the association of hearing loss with neuropathy.

It was noted in our study that the hearing loss was more prominent in the higher frequencies (2000, 4000 and 8000 Hz) for patients with T2DM. The correlation between hearing threshold and neuropathy was more in the higher frequencies. This suggests that patients with diabetic neuropathy are more likely to have hearing impairment in the higher frequencies. The hearing loss in higher frequencies was more than the hearing loss seen in speech frequencies. Similar results were seen in study by Sugimoto et al in which neuropathy correlated significantly with hearing loss in the higher frequencies among patients with T2DM (20). Studies done on diabetes and its association with hearing loss and systematic review by Akinpelu concluded that the severity of hearing loss was more in the higher frequencies among patients with T2DM (21–23). Patients with hearing loss in the higher frequencies have difficulty in hearing when there is background noise or when they are in a group which can lead to social withdrawal and avoidance of social interactions. People with high-frequency hearing loss tend to have difficulty in hearing certain consonants, like s, h and f which are uttered at a higher frequency than vowel sounds. This can result in speech sounding muffled, especially when talking on the phone, watching TV or trying to have a conversation in background noise.

Among patients enrolled in our study with moderate to severe neuropathy, the prevalence of clinically significant hearing loss was 33.3% while studies have reported that the prevalence of hearing loss in a population of middle aged adults is 14 to 20 % (24). Even though the prevalence of clinically significant hearing loss was higher in our study group, none of them were evaluated for hearing loss prior to our study or underwent any treatment for hearing loss.

Few studies showed some benefit of screening for hearing loss among adults however, there is no consensus regarding the high-risk groups who require screening for hearing loss. In our study it was seen that the prevalence of clinically significant hearing loss was significantly higher in patients with moderate to severe neuropathy compared to the prevalence of hearing loss reported among middle aged adults. Studies have shown that a 10 dB increase in PTA values were associated with 52% increased odds of social isolation and significant cognitive decline (25,26). Subclinical hearing loss has also been independently associated with cognitive impairment and depressive symptoms. Due to gradual onset of
hearing loss many elderly individuals are unaware of their hearing impairment and increasing age is associated with the under-estimation of severity of hearing loss (4). With increasing age and cognitive decline, it becomes progressively difficult to use hearing aids. Delay in diagnosis can lead to unwillingness to start treatment, poor compliance, improper maintenance of the hearing aids and poor treatment outcomes (27). Diagnosis and initiation of treatment at the right time is important for acceptance of treatment, adequate compliance and optimal treatment outcome. Screening for hearing loss in patients with diabetic neuropathy who are at a higher risk of developing hearing loss can help in the timely diagnosis and treatment of these patients.

American Speech-Language-Hearing Association recommends screening of all adults and World Health Organization's guidelines on integrated care for older people recommends screening of elderly. As suggested by Nieman et al although definitive recommendations have yet to be developed, appropriate clinical practice would be to screen any person with perceived hearing loss and persons with risk factors for developing hearing loss (28). Studies have suggested that stimulation of the auditory system may reduce the age related degeneration and using hearing aids might be beneficial in modifying the ageing process in the auditory system (29). Hence screening of patients with moderate-severe diabetic neuropathy who are at high risk for developing hearing loss should be considered to prevent the further worsening of quality of life related to hearing impairment.

Single question screening, Hearing Handicap Inventory for the Elderly- Screening version (HHIE-S), clinical tests like whispered voice test, finger rub tests, and hand-held audiometer has been used for screening for Hearing loss in various studies. In single question screening, the patient is asked a single screening question like “Do you have difficulty with your hearing?”. It has a sensitivity of 80% and specificity of 74%. HHIE-S is a well-studied self-report questionnaire with 10 questions. It has a sensitivity of 68% and specificity of 78% (30). These are simple tools that can be used by a physician or in a primary care centre for screening. Poor quality of life due to hearing impairment can be a potential preventable burden and the only cost of the screening questionnaire consists of the time required of the patient and clinician.

In a group of patients with severe neuropathy, the prevalence of clinically significant hearing loss might be higher than the prevalence reported in our study. Further studies including more patients with severe neuropathy can help in understanding the risk of hearing loss in patients with severe neuropathy. Further studies using self-reported questionnaire can help in evaluating the efficacy of the questionnaires in screening these patients. Treatment and treatment outcome of the patients diagnosed to have hearing loss were not evaluated in our study. Further randomized controlled trials studying the treatment outcomes in patients with diabetic neuropathy who are diagnosed to have hearing loss can help in better screening and treatment recommendations.

**Conclusion**

In this study age, nephropathy, presence of diabetic neuropathy and severity of diabetic neuropathy were associated with hearing loss. Severity of hearing loss worsened with worsening severity of neuropathy.
Patients with moderate to severe diabetic neuropathy are at increased risk of hearing loss and might benefit from screening for hearing loss. Timely diagnosis and treatment can lead to significant improvement in the quality of life of these patients and can prevent cognitive decline, depression and social withdrawal. Simple and cost-effective measures like self-reported screening questionnaires can help in the early diagnosis and treatment initiation.

**Declarations**

**Previous Presentation:** The paper was presented at the Annual Meeting of the Indian Academy of Clinical Medicine and published as an abstract @ Abraham A, Verghese A, Jacob J. Four out of five patients with type 2 diabetes mellitus have hearing loss. Endocrine Abstracts. 2019; 63: GP123

**Acknowledgements:** We would like to acknowledge the help provided by Surya Suresh in performing the Pure Tone audiometry for patients.

**Conflict of Interest:** None for all three authors

**Availability of Data:** Data can be made available on reasonable request to the corresponding author

**Author Contributions:** The first author (AMA) prepared the protocol under primary supervision of JJJ and AV. AMA collected and analysed all data under supervision of the JJJ and AV. All three authors contributed to writing the manuscript

**Funding:** This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Hearing assessments were conducted through departmental intramural funds.

**Disclosures:** None for all three authors

**References**

1. Saeedi P, Petersohn I, Salpea P, Malanda B, Karuranga S, Unwin N, et al. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9th edition. Diabetes Res Clin Pract. 2019 Nov;157:107843.

2. Kim M-B, Zhang Y, Chang Y, Ryu S, Choi Y, Kwon M-J, et al. Diabetes mellitus and the incidence of hearing loss: a cohort study. Int J Epidemiol. 2017 Apr 1;46(2):717–26.

3. Helzner EP, Contrera KJ. Type 2 Diabetes and Hearing Impairment. Curr Diab Rep. 2016 Jan;16(1):3.

4. Thomson RS, Auduong P, Miller AT, Gurgel RK. Hearing loss as a risk factor for dementia: A systematic review. Laryngoscope Investigative Otolaryngology. 2017;2(2):69–79.

5. Lin FR, Metter EJ, O'Brien RJ, Resnick SM, Zonderman AB, Ferrucci L. Hearing Loss and Incident Dementia. Archives of Neurology. 2011 Feb 1;68(2):214–20.
6. Fukushima H, Cureoglu S, Schachern PA, Paparella MM, Harada T, Oktay MF. Effects of type 2 diabetes mellitus on cochlear structure in humans. Arch Otolaryngol Head Neck Surg. 2006 Sep;132(9):934–8.
7. Ceriello A. Oxidative stress and diabetes-associated complications. Endocr Pract. 2006 Feb;12(Suppl 1):60–2.
8. Austin DF, Konrad-Martin D, Griest S, McMillan GP, McDermott D, Fausti S. Diabetes-related changes in hearing. Laryngoscope. 2009 Sep;119(9):1788–96.
9. Jorgensen MB. The Inner Ear in Diabetes Mellitus: Histological Studies. Arch Otolaryngol. 1961 Oct 1;74(4):373–81.
10. Makishima K, Tanaka K. Pathological Changes of the Inner Ear and Central Auditory Pathway in Diabetics. Ann Otol Rhinol Laryngol. 1971 Apr 1;80(2):218–28.
11. Vasilyeva ON, Frisina ST, Zhu X, Walton JP, Frisina RD. Interactions of hearing loss and Diabetes Mellitus in the middle age CBA/CaJ mouse model of presbycusis. Hear Res. 2009 Mar;249(1–2):44–53.
12. Sasso FC, Salvatore T, Tranchino G, Cozzolino D, Caruso AA, Persico M, et al. Cochlear dysfunction in type 2 diabetes: a complication independent of neuropathy and acute hyperglycemia. Metab Clin Exp. 1999 Nov;48(11):1346–50.
13. Contrera KJ, Betz J, Li L, Blake CR, Sung YK, Choi JS, et al. Quality of life after intervention with a cochlear implant or hearing aid. Laryngoscope. 2016;126(9):2110–5.
14. Amieva H, Ouvrard C, Giuliani C, Meillon C, Rullier L, Dartigues J-F. Self-Reported Hearing Loss, Hearing Aids, and Cognitive Decline in Elderly Adults: A 25-Year Study. J Am Geriatr Soc. 2015 Oct;63(10):2099–104.
15. Juster-Switlyk K, Smith AG. Updates in diabetic peripheral neuropathy. F1000Res. 2016 Apr 25;5:F1000 Faculty Rev-738.
16. Feldman EL, Stevens MJ, Thomas PK, Brown MB, Canal N, Greene DA. A Practical Two-Step Quantitative Clinical and Electrophysiological Assessment for the Diagnosis and Staging of Diabetic Neuropathy. Diabetes Care. 1994 Nov 1;17(11):1281–9.
17. Manchaiah VKC, Freeman B. Audiogram: Is there a need for change in the approach to categorize the degree/severity of hearing loss? International Journal of Audiology. 2011 Sep 1;50(9):638–40.
18. Clark JG. Uses and abuses of hearing loss classification. ASHA. 1981 Jul;23(7):493–500.
19. Sugimoto S, Teranishi M, Fukunaga Y, Yoshida T, Sugiura S, Uchida Y, et al. Contributing factors to hearing of diabetic patients in an in-hospital education program. Acta Oto-Laryngologica. 2013 Nov 1;133(11):1165–72.
20. Konrad-Martin D, Reavis KM, Austin D, Reed N, Gordon J, McDermott D, et al. Hearing Impairment in Relation to Severity of Diabetes in a Veteran Cohort. Ear Hear. 2015;36(4):381–94.
21. Sakuta H, Suzuki T, Yasuda H, Ito T. Type 2 diabetes and hearing loss in personnel of the Self-Defense Forces. Diabetes Res Clin Pract. 2007 Feb;75(2):229–34.
22. Akinpelu OV, Mujica-Mota M, Daniel SJ. Is type 2 diabetes mellitus associated with alterations in hearing? A systematic review and meta-analysis: Hearing Function in Type 2 Diabetes Mellitus. Laryngoscope. 2014 Mar;124(3):767–76.

23. Nash SD, Cruickshanks KJ, Klein R, Klein BEK, Nieto FJ, Huang GH, et al. The Prevalence of Hearing Impairment and Associated Risk Factors: The Beaver Dam Offspring Study. Archives of Otolaryngology–Head Neck Surgery. 2011 May;16(5):432–9. 137(.

24. Zhang J, Chen C, Hua S, Liao H, Wang M, Xiong Y, et al. An updated meta-analysis of cohort studies: Diabetes and risk of Alzheimer’s disease. Diabetes Res Clin Pract. 2017 Feb;124:41–7.

25. Mick P, Pichora-Fuller MK. Is Hearing Loss Associated with Poorer Health in Older Adults Who Might Benefit from Hearing Screening? Ear Hearing. 2016 May;37(3):e194–201.

26. Tahden MAS, Gieseler A, Meis M, Wagener KC, Colonius H. What Keeps Older Adults With Hearing Impairment From Adopting Hearing Aids? Trends Hear. 2018 Nov 19;22:2331216518809737.

27. Nieman CL, Oh ES. Hearing Loss. Ann Intern Med. 2020 Dec 1;173(11):ITC81–96.

28. Howarth A, Shone GR. Ageing and the auditory system. Postgrad Med J. 2006 Mar;82(965):166–71.

29. Feltner C, Wallace IF, Kistler CE, Coker-Schwimmer M, Jonas DE. Screening for Hearing Loss in Older Adults: Updated Evidence Report and Systematic Review for the US Preventive Services Task Force. JAMA. 2021 Mar;23(12):1202–15. 325(.

### Tables

**Table 1**- Baseline profile of patients in the study
| Presence of diabetic peripheral sensory neuropathy (DSPN) | No DSPN (n=48) | Mild DSPN (n=47) | Moderate to Severe DSPN (n=105) | p-value |
|----------------------------------------------------------|----------------|------------------|---------------------------------|---------|
| Age (in years)                                           | 46 ±9.4        | 49 ± 8.0         | 51±7.6                          | 0.001   |
| Males -n (%)                                             | 27 (56.3)      | 21 (44.7)        | 52 (49.5)                       | 0.524   |
| BMI (in Kg/m\(^2\))                                     | 24.2±3.0       | 25.0±4.5         | 25.4±3.2                        | 0.183   |
| Duration of DM (in years)                                | 4.7±4.0        | 6.0±4.1          | 6.6±4.9                         | 0.067   |
| Blood Sugar (FBS) (mg/dl)                                | 174.8±55.9     | 183.9±64.8       | 183.7±58.5                      | 0.660   |
| HbA1c (%)                                                | 8.9±2.7        | 10.3±2.9         | 10.2±2.7                        | 0.073   |
| eGFR (ml/min/1.73 m\(^2\))                              | 100.5±25.4     | 84.0±32          | 79.4±27.2                       | <0.001  |
| Treated Hypertension -n (%)                              | 5 (10.4)       | 10 (21.3)        | 36 (35.0)                       | 0.004   |
| Established CV disease n (%)                            | 3 (6.3)        | 6 (12.8)         | 10 (9.5)                        | 0.556   |

**Table2** - Univariate binary logistic regression with hearing loss as outcome.
### Univariate Binary logistic regression with hearing loss as outcome

| Predictors       | Coefficient $\beta$ | p-value | Odds ratio | 95% CI     |
|------------------|----------------------|---------|------------|------------|
|                  |                      |         |            | Lower      | Upper      |
| **Age**          | 0.06                 | **0.004** | 1.062      | 1.019      | 1.107      |
| **Gender**: Male |                      |         |            |            |            |
| Female           | -0.802               | **0.033** | 0.448      | 0.214      | 0.938      |
| **MDNS Score**   | 0.093                | **0.002** | 1.097      | 1.035      | 1.163      |
| **MDNS Grade**   | 1.775                | **0.017** |            | 0.326      | 3.224      |
| 0                |                      |         |            |            |            |
| 1                | 0.52                 | 0.272   | 1.682      | 0.665      | 4.252      |
| 2                | 1.168                | **0.007** | 3.217      | 1.385      | 7.47       |
| **Neuropathy**   |                      |         |            |            |            |
| Absent           |                      |         |            |            |            |
| Present          | 1.045                | **0.006** | 2.843      | 1.344      | 6.012      |

### Multivariate Binary logistic regression with hearing loss as outcome

| Predictors       | Coefficient $\beta$ | p-value | Odds ratio | 95% CI     |
|------------------|----------------------|---------|------------|------------|
| **Age**          | 0.055                | **0.018** | 1.056      | 1.01       | 1.105      |
| **Gender**: Male |                      |         |            |            |            |
| Male             |                      |         |            |            |            |
| Female           | -1.143               | **0.006** | 0.319      | 0.141      | 0.723      |
| **MDNS Score**   | 0.107                | **0.005** | 1.113      | 1.041      | 1.191      |

### Figures
Patients with Type 2 DM with age between 30 to 60 years were identified (n = 200)

Grading of Peripheral sensory-motor neuropathy using Michigan Diabetic Neuropathy Score

Group 1: Patients without peripheral neuropathy were identified (n= 48)
Group 1: Patients with mild peripheral neuropathy were identified (n=47)
Group 3: Patients with moderate and severe neuropathy were identified (n=105)

ENT examination and Diagnostic Pure Tone Audiometry and Classification according to Goodmans classification.

Patients without neuropathy
Patients with mild neuropathy
Patients with moderate to severe neuropathy:

Patients with hearing loss: n=32 (66.7%)
Patients with hearing loss: n=38 (80.9%)
Patients with hearing loss: n=92 (87.6%)

Results were analysed according to protocol (n=200)

Figure 1

Flow of patients in the study
Figure 2

A) Prevalence of hearing loss and clinically significant hearing loss in patients with neuropathy and without neuropathy, B) Prevalence of hearing loss and clinically significant hearing loss in patients without neuropathy (MDNS* Grade 0), mild neuropathy (MDNS Grade 1) and moderate to severe neuropathy (MDNS Grade 2) *MDNS- Michigan Diabetic Neuropathy Score
Comparison of hearing threshold across various frequencies for patients without neuropathy, mild neuropathy and moderate to severe neuropathy in right ear (Figure 3A) and left ear (Figure 3B)