Aging Medicine and Healthcare
https://www.agingmedhealthc.com

Review Article

Should We Screen Patients with Type 2 Diabetes Mellitus for Hearing Loss?

*Abin M Abraham¹, Jubbin Jagan Jacob², Ashish Varghese³

¹Department of Medicine, Christian Medical College and Hospital, Ludhiana, Punjab, India
²Department of Endocrinology, Christian Medical College and Hospital, Ludhiana, Punjab, India
³Department of Otorhinolaryngology, Christian Medical College and Hospital, Ludhiana, Punjab, India

ABSTRACT

Several cross-sectional and longitudinal studies have proven that type 2 diabetes mellitus is associated with hearing impairment. Hearing impairment is an independent risk factor for dementia, social withdrawal, anxiety, depression, cognitive decline, functional decline, and falls. Although hearing impairment is common, 30% of individuals with hearing aids do not use them regularly and up to 75% of adults who could benefit from hearing aids do not even acquire hearing aids.

The Centre for Disease Control and Prevention recommends a baseline hearing evaluation upon diagnosis of diabetes and a complete audiological evaluation every 2 years following that. The American Speech-Language-Hearing Association and the World Health Organization’s Guidelines on Integrated Care for Older People recommend screening and provision of amplification among older adults.

Screening of patients with diabetes at high risk of developing hearing impairment should be considered to prevent the further worsening of quality of life associated with hearing loss. Questionnaires like Hearing Handicap Inventory for the Elderly – Screening Version (HHIE-S) or single question screening can be used for the initial screening of patients with diabetes in resource-limited settings which can then be followed by complete audiological evaluation if the patients report having hearing loss.

ISSN 2663-8851/Copyright © 2022, Asian Association for Frailty and Sarcopenia and Taiwan Association for Integrated Care. Published by Full Universe Integrated Marketing Limited.

1. INTRODUCTION

The prevalence of type 2 diabetes mellitus (T2DM) has been rising worldwide and it is one of the major health problems with global estimates of more than 463 million affected individuals.¹ Multiple factors like ageing of populations, socio-economic development, and associated cultural and lifestyle changes have led to the increase in the prevalence of T2DM.² Paradoxically, the increase in the burden of diabetes which is attributed to the western lifestyle has the greatest effect on developing countries, and more than 80% of the total number of people with diabetes belongs to the developing countries.³,⁴ Diabetes leads to microvascular complications like retinopathy, neuropathy, and nephropathy. The macrovascular complications associated with diabetes include cerebrovascular disease, peripheral vascular disease, and coronary heart disease. T2DM can directly or indirectly affect other systems including the hepatic and digestive system, musculoskeletal system, mental health and cognitive functioning.⁵,⁶ The micro and macrovascular complications associated with T2DM are responsible for a major burden associated with
the disease. The increasing prevalence of T2DM is likely to result in an increased number of individuals with diabetes-related complications. A similar pathophysiological mechanism may lead to injury to the neural system or vasculature of the inner ear and can lead to hearing impairment in patients with diabetes. Several population-based studies have shown a significant association between hearing loss and T2DM. Sensorineural type of hearing loss is seen in patients with diabetes and the severity of hearing impairment seemed to correlate with the progression of T2DM.

Hearing loss affects the quality of life and has a significant economic and emotional impact. Hearing loss is proven to be an independent risk factor for dementia, cognitive decline, social withdrawal, anxiety, depression, walking difficulty, functional decline and falls particularly among older adults. T2DM and hearing loss are independent risk factors for the development of dementia. The risk of developing dementia is threefold in a patient with moderate hearing loss and fivefold in a patient with severe hearing loss when compared to a person with normal hearing. The complications associated with diabetes significantly affect patients’ quality of life and it imparts a great financial burden on the affected population. Identification of people at high risk for developing complications like hearing loss can help in early diagnosis and initiation of rehabilitative measures. In this article, we discuss the association of hearing loss with diabetes, the guidelines and the instruments for screening for hearing loss that can be used in patients with diabetes.

2. EPIDEMIOLOGY

A significant association between hearing loss and T2DM has been reported in several studies. Multiple studies have analysed the association of diabetes with hearing from the National Health and Nutrition Examination Study (NHANES). The studies done by Bainbridge et al which analysed the data of patients who completed audiometric testing in the National Health and Nutrition Examination Survey (NHANES) published in 2008 (included 5140 adults aged 20-69 years) and 2010 (included 1508 adults aged 40-69), concluded that adults with diabetes have a higher occurrence of hearing impairment. The study published in 2008 concluded that the adjusted odds ratio for low or mid-frequency hearing impairment was 1.82 [Confidence interval (CI), 1.27 to 2.60] and high-frequency hearing impairment was 2.16 [CI, 1.47 to 3.18]. The prevalence of age-adjusted hearing loss was 21.3% among diabetics compared to 9.4% among those without diabetes. In the study published in 2010, which analysed data from 1,508 participants aged 40-69 years, diabetes was associated with a 67% increased odds of high-frequency hearing loss (1.67 [1.14–2.44]) and 100% increased odds of hearing loss in the low-mid frequency (odds ratio 2.03 [95% CI 1.32–3.10]).

Another cross-sectional study by Bainbridge et al in 2011, analysed the data from 536 subjects who completed audiometric evaluation from 1999 to 2004 in the NHANES, and the study concluded that low high-density lipoprotein (HDL), coronary artery disease, and peripheral neuropathy were the risk factors associated with hearing impairment in patients with diabetes.

A longitudinal study conducted in 2019, among 139,909 women, examined the association between T2DM and the risk of self-reported hearing loss. It was concluded that T2DM was associated with a higher risk of moderate or worse hearing loss. However, in this study, pure tone audiometry (PTA) was not done for the subjects and the primary outcome was moderate or worse hearing loss which was self-reported. Another cross-sectional study by Gong et al which included 6,596 patients without diabetes and 388 patients with diabetes concluded that diabetes was associated with higher odds of hearing loss (odds ratio [OR] = 1.85).

In a large prospective study by Kim et al in 2017, which included 253,301 adult participants, the multi-variable adjusted hazard ratio for incident hearing loss for participants with T2DM was 1.36 (95% confidence interval 0.95-1.14) and the risk of hearing loss increased progressively with an increase in glycated haemoglobin (HbA1c) levels. In this large cohort study among adults more than 18 years of age, which included 1,285,704 person-years of follow-up, 2,817 participants developed incident hearing loss. The median follow-up duration was 4 years and the maximum follow-up duration was 12.7 years. The rate of hearing impairment among participants with normal blood glucose levels, pre-diabetes and diabetes mellitus were 1.8, 3.1 and 9.2 per 1000 person-years, respectively. There was a significant association of diabetes with hearing loss after adjusting potential confounders like demographic profile, lifestyle-related risk factors, noise exposure, and deranged metabolic parameters. The risk of hearing impairment increased with increasing glycated haemoglobin (HbA1c) levels above 5%.

Another longitudinal study published in 2015, consisting of 1,925 participants with normal hearing at baseline which analysed the 15-year cumulative incidence of hearing impairment showed that poorly controlled diabetes was associated with increased risk of hearing impairment (hazard ratio (HR)=2.03, p=0.048). A cross-sectional analysis including 2,052 individuals by Helzner et al in 2005 concluded that T2DM was associated with a 42% higher risk of hearing loss (Multivariable adjusted odds ratio: 1.42).

Another cross-sectional study by In-Hwan et al (included 37,773 participants) showed that diabetes
was a significant predictor of hearing loss with an odds ratio of 1.398.

A cross-sectional study by Konrad-Martin et al. analysed the effects of severity of diabetes mellitus on auditory brain stem response and concluded younger patients with insulin-dependent diabetes mellitus (IDDM) were at increased risk of auditory brainstem dysfunction. The study subjects included 166 patients with diabetes and 138 subjects without diabetes. The patients who were diagnosed to have diabetes mellitus and required insulin for treatment were classified under the IDDM group. Another cross-sectional study by Austin et al concluded that younger patients (age < 50) with diabetes mellitus had greater hearing loss compared to those without diabetes mellitus. In a retrospective database review conducted by Kakarlapudi et al in 2003, by recruiting 53,461 age-matched adults without diabetes and 12,575 adults with diabetes from Veteran Affairs Healthcare System showed that the prevalence of hearing loss among patients with diabetes was 23% and 19% among those without diabetes and the severity of the hearing loss correlated with the rise in serum creatinine level. Studies have also demonstrated that poor glycaemic control is associated with hearing disturbances in patients with T2DM.

### 2.1. Association with Ageing and Sex-Specific Association

Ageing is associated with an increase in the prevalence of hearing impairment and diabetes mellitus. Studies have shown that among diabetics, older people were more likely to have hearing loss. There is the possibility that the association between hearing impairment and diabetes mellitus can be merely a phenomenon of ageing. However, several stratified analyses have confirmed a stronger association among studies including younger participants (mean age of participants ≤ 60 years) compared with studies of older adults (age more than 60). However, the odds ratio remained significant even when studies were restricted to those with subjects having a mean age of more than 60 years. These studies suggest a significant association of hearing loss with T2DM.

On evaluating the sex-specific association of hearing loss in patients with diabetes, Wang et al concluded that women with diabetes were at increased risk of hearing impairment compared to male patients with diabetes. The study evaluated self-reported hearing loss among 16,140 participants with age more than 45. The prevalence of hearing impairment was higher among the female participants in the study conducted by Bainbridge et al. However, in the Studies by Gong et al and Helzner et al., the prevalence of hearing impairment was higher among males. In the systematic review and meta-analysis by Akinpelu, comparing the sex-specific associations, it was noted that the odds ratio was high in studies including only male participants; however, the results were inconclusive on sex-specific associations.

### 2.2. Frequencies Involved in Patients with T2DM

Studies by Bainbridge et al., Vaughan et al., and a systematic review by Akinpelu concluded that patients with diabetes had hearing impairment across all frequencies however the hearing loss was more prominent in the higher frequencies (3000 Hz, 4000 Hz, 6000 Hz and 8000 Hz). These studies suggest that the mean PTA hearing thresholds (dBHL) were higher for all frequencies but were more clinically relevant at higher frequencies. In the meta-analysis by Akinpelu, seven studies which provided the data on mean pure tone audiometry (PTA) thresholds for all the participants were analysed. Pooled PTA averages at 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz were analysed, which demonstrated that PTA thresholds increased with increasing frequencies and the hearing impairment was more in the higher frequencies among patients with diabetes. The standardized mean difference (SMD) between patients with diabetes and controls was more in the higher frequencies.

However, there are inconsistent findings in few other studies regarding the frequencies that are affected in patients with diabetes. Few studies have reported hearing loss in the lower frequencies. In a study by Frisina et al. in 2006, including 30 adults (age: 59 to 92), worse hearing was observed in the low frequencies. A cross-sectional analysis by Tay et al. among 102 participants (age: 18 to 80 years), worse hearing loss was reported in the low and middle frequencies in patients with diabetes. The inclusion of older adults (age more than 60) and the presence of presbycusis in the participants might explain the absence of diabetes-related hearing loss in higher frequencies among diabetics compared to controls.

### 2.3. Meta-Analysis on T2DM and Hearing Impairment

A meta-analysis done by Akinpelu in 2013 screened 2,650 articles and identified 18 articles with adequate scores. The incidence of Hearing loss ranged between 44% to 69.7% with an odds ratio of 1.91 among patients with diabetes. Another meta-analysis done by Horikawa, included 13 eligible studies with 20,194 participants and 7,377 cases. The overall pooled odds ratio of hearing impairment for diabetic participants compared with non-diabetic participants was 2.12. The odds ratio was higher (OR-2.61) in younger participants with mean age less than 60 years. The studies done on hearing impairment in diabetes along with the findings of the studies are summarised in Table 1.
The majority of the articles analysed for this review article showed a significant association of hearing loss with diabetes. However, there are few studies which did not show any significant association between hearing impairment and diabetes. A cross-sectional study of 200 adults conducted by Harner et al in 1981 found no evidence of increased prevalence of hearing impairment in patients with diabetes. However, in this study, pure-tone audiometry was performed for 200 adults with diabetes and the data was compared with data from a population-based study on the prevalence of hearing impairment in a normal population conducted 12 years earlier. The difference in the exclusion criteria in both the studies, confounding factors like age, history of smoking, and the difference in the time period of 12 years between the studies makes the comparison less effective. In another study conducted in 1981, 28 participants with diabetes were included in the study. However, this study was originally designed to investigate the effects of noise exposure and blood pressure on hearing impairment. The inclusion of patients with noise exposure, confounding factors like age and history of smoking, and the lower number of participants with diabetes might have reduced the power of the study in comparing the prevalence of hearing impairment in patients with diabetes.

Another cross-sectional study in 1993 by Gates et al, among 1662 adult participants (Framingham cohort) did not show any significant association between hearing impairment and diabetes. In this study, the mean age of the males was 72.7±6.2 years and for females was 73.0±6 years. However, in this study, all the ambulatory subjects from the Framingham cohort were offered hearing tests at their 18th biennial examination and the compliance rate was 95.2% which yielded a sample size of 1662 subjects. Participants with noise exposure or hearing impairment due to other diseases like conductive hearing loss, patients with history of ototoxic drug use, ear infections and middle ear diseases were not excluded. A study conducted in 2011 by Lin et al examined the risk factors for hearing impairment in older adults (aged 70 years and older). The prevalence of hearing loss was not associated with diabetes in this study. The study included participants from National Health and Nutrition Examination Survey (NHANES) 2005-2006 cycle. However, patients with hearing impairment due to other diseases like ear infections, conductive hearing loss or middle ear diseases were not excluded. The study participants were adults more than 70 years of age and the smaller sample size compared to other studies might have limited the statistical power to detect weaker associations. In this study, the total number of patients diagnosed with diabetes was not mentioned and the diagnosis of diabetes was based on self-reported diagnosis or use of diabetic medications. The presence of stronger risk factors like age in the study by Lin et al and Gates et al comprising of older adults (age more than 70 years) is another likely explanation for this result.

The “Comprehensive Medical Evaluation and Assessment of Comorbidities: Standards of Medical Care in Diabetes—2020” by the American Diabetes Association lists hearing impairment as one of the complications associated with diabetes based on the existing evidence. Considering the evidence from all the research done on diabetes and hearing loss, diabetes appears to have a significant correlation with hearing impairment and the correlation was higher in the studies with younger participants. Future longitudinal studies including a larger number of study participants of younger age groups can help in a better understanding of the relationship between diabetes and hearing impairment.

3. PATHOPHYSIOLOGY

Proposed pathophysiological mechanisms involved in the development of hearing impairment in T2DM include microangiopathy, neuropathy, and mitochondrial damage. Angiopathy occurs in diabetes as a result of glycoprotein accumulation in the tunica intima and endothelial damage. As cochlea is a highly microvascular structure, it is considered vulnerable to the effects of microangiopathy. Factors of microangiopathy such as microalbuminuria, serum creatinine levels, Hba1c levels and duration of diabetes were found to have some association with hearing loss among diabetics in the study by Sugimoto et al and Kurt et al. Studies have demonstrated that Hba1c, uncontrolled blood sugars, diabetic retinopathy, and diabetic nephropathy were associated with a higher risk of hearing impairment among patients with diabetes. Studies have shown a significant correlation between cardiovascular disease and low-frequency hearing loss. Studies have also demonstrated that low-frequency hearing loss would be an early indicator of cardiovascular disease or a predictor of ongoing or developing cardiovascular disease. The probability and risk for cardiovascular events and cerebrovascular diseases such as stroke and transient ischemic attacks can be assessed from the study of low-frequency audiometric patterns observed on sensitive audiological equipment. The inner ear is loaded with blood vessels and it is extremely sensitive to the blood supply, and any abnormalities in the body may show up here before they can be noticed elsewhere.

The highly vascularized tissue lining the lateral wall of the cochlea is called the stria vascularis. The stria vascularis maintains the fluid homeostasis and generates the endocochlear potential that is required for the transduction of sound. The stria vascularis acts as a blood-labyrinth barrier, thereby regulating the movement of molecules from the blood into the cochlea. The marginal cells of the stria vascularis...
# Table 1. Studies done on association between T2DM and hearing loss

<table>
<thead>
<tr>
<th>Year</th>
<th>Study</th>
<th>Study Design</th>
<th>Number of participants and participant characteristics</th>
<th>Association of T2DM with hearing loss</th>
<th>Summary and other associated factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>Association of NIDDM and hearing loss</td>
<td>Data from longitudinal studies of aging conducted in Beaver Dam, Wisconsin.</td>
<td>Of 3,571 study participants, 344 were classified as having NIDDM</td>
<td>NIDDM were more likely to have a hearing loss than subjects without diabetes (59 vs. 44%). There was an association between NIDDM and hearing loss when controlling for potential confounders (odds ratio [OR] 1.41, 95% CI 1.05-1.88). After results were adjusted for age, this difference was not statistically significant.</td>
<td>Individuals with NIDDM and nephropathy were more likely to have a hearing loss than those with NIDDM but no nephropathy (OR 2.28, 95% CI 1.04-5.00).</td>
</tr>
<tr>
<td>2003</td>
<td>The effect of diabetes on sensorineural hearing loss</td>
<td>Retrospective database review, 1989 to 2003.</td>
<td>53,461 non-diabetic age-matched patients and 12,575 diabetic patients</td>
<td>Sensorineural hearing loss was more common in the diabetic patients than in age matched nondiabetic patients.</td>
<td>Increasing serum creatinines, but correlated with worsening hearing in patients with diabetes who had sensorineural hearing loss.</td>
</tr>
<tr>
<td>2005</td>
<td>Race and sex differences in age-related hearing loss: the Health, Aging and Body Composition Study</td>
<td>Cross-sectional analysis of a longitudinal cohort study</td>
<td>Study included 2,052 individuals, 371 patients with T2DM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>Diabetes and Hearing Impairment in the United States: Audiometric Evidence from the National Health and Nutrition Examination Surveys, 1999–2004.</td>
<td>Cross-sectional analysis.</td>
<td>5,140 non-institutionalized adults aged 20–69 years.</td>
<td>For low/mid frequency hearing impairment, age-adjusted prevalence estimates were 21.3% among adults with diabetes and 9.4% among adults without diabetes. For high frequency hearing impairment, age-adjusted prevalence estimates were 54.1% among those with diabetes and 32.0% among those without. Adjusted odds ratios (95% confidence limits) of hearing impairment (Multivariable adjusted odds ratio: 1.42)</td>
<td>Adults with diabetes have a higher occurrence of hearing impairment in low/mid frequency and high frequency than those without diabetes.</td>
</tr>
<tr>
<td>2009</td>
<td>Diabetes-Related Changes in Hearing</td>
<td>cross-sectional study among Veterans</td>
<td>166 patients with T2DM and 137 patients without T2DM</td>
<td>There was greater hearing loss in younger patients with DM compared to those without DM. Significant hearing differences were present at all frequencies for NIDDM subjects, but for IDDM subjects, differences were at 1,000 Hz and below, and 10,000 Hz and above.</td>
<td>Diabetes is associated with an increased risk of hearing loss, and this difference is manifest particularly in adults &lt;50 years old.</td>
</tr>
<tr>
<td>2010</td>
<td>Diabetes-Related Changes in Auditory Brainstem Responses</td>
<td>cross-sectional study</td>
<td>166 patients with T2DM and 138 without T2DM</td>
<td>DM-associated auditory brainstem dysfunction was present among younger patients with more severe IDDM.</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Potential Mediators of Diabetes-Related Hearing Impairment in the U.S. Population</td>
<td>Cross-sectional study</td>
<td>1,508 participants, aged 40–69 years</td>
<td>Diabetes was associated with a 100% increased odds of low/mid-frequency hearing impairment (odds ratio 2.03 [95% CI 1.32–3.10]) and a 67% increased odds of high-frequency hearing impairment (1.67 [1.14–2.44]) in preliminary models after controlling for age, sex, race/ethnicity, education, smoking, and occupational noise exposure.</td>
<td>T2DM is associated with hearing impairment in low/mid and high frequencies</td>
</tr>
<tr>
<td>2011</td>
<td>Risk Factors for Hearing Impairment Among U.S. Adults With Diabetes</td>
<td>Cross-sectional study</td>
<td>536 participants with diabetes, aged 20–69 years</td>
<td>Odds ratios for associations with low/mid-frequency hearing impairment were 2.20 (95% CI 1.28–3.79) for HDL &lt;40 mg/dL and 3.56 (1.57–8.03) for poor health. Controlling for age, race/ethnicity, sex, and income-to-poverty ratio, odds ratios for associations with high-frequency hearing impairment were 4.39 (1.26–15.26) for history of coronary heart disease and 4.42 (1.26–15.45) for peripheral neuropathy.</td>
<td>Low HDL, coronary heart disease, peripheral neuropathy, and having poor health are potentially preventable correlates of hearing impairment for people with diabetes.</td>
</tr>
<tr>
<td>2013</td>
<td>Diabetes and Risk of Hearing Impairment in Adults: A Meta-Analysis.</td>
<td>Meta-analysis</td>
<td>Data were obtained from 13 eligible studies (20,194 participants and 7,377 cases).</td>
<td>Overall pooled OR (95% confidence interval) of hearing impairment for diabetic participants compared with nondiabetic participants was 2.15 (1.72–2.68). OR was higher in younger participants (mean age, 60 year) than in those over 80 (2.61 and 1.58, P=0.008).</td>
<td>Higher prevalence of hearing impairment was seen in diabetic patients compared with nondiabetic patients. The association was consistent regardless of age</td>
</tr>
</tbody>
</table>
Table 1. Studies done on association between T2DM and hearing loss

<table>
<thead>
<tr>
<th>Year</th>
<th>Study</th>
<th>Study Design</th>
<th>Number of participants and participant characteristics</th>
<th>Association of T2DM with hearing loss</th>
<th>Summary and other associated factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Is type 2 diabetes mellitus associated with alterations in hearing? A systematic review and meta-analysis Akinpelu OV</td>
<td>systematic review and meta-analysis</td>
<td>A total of 2,650 articles were identified; Eighteen of these obtained adequate scores and were included for data extraction and further review.</td>
<td>The incidence of HL ranged between 44% and 69.7% for type 2 diabetics, significantly higher than in controls (OR 1.91; 95% confidence interval 1.47–2.48). The mean PTA (pure tone audiometry) thresholds were greater in diabetics than in controls for all frequencies [test or overall effect Z=3.68, P=0.0002]. Auditory brainstem response (ABR) wave V latencies were also statistically significantly longer in diabetics when compared to control groups [OR 3.09, 95% CI 1.82–4.37, P &lt;0.00001].</td>
<td>Type 2 diabetic patients had significantly higher incidence for mild degree of HL when compared with controls. Mean PTA thresholds were greater in diabetics for all frequencies but were more clinically relevant at 6000 and 8000 Hz.</td>
</tr>
<tr>
<td>11</td>
<td>Hearing Loss as a Function of Aging and Diabetes Mellitus: A Cross Sectional Study. In-Hwan Oh</td>
<td>cross sectional study</td>
<td>37,773 individuals who visited the Health Promotion Center for health screening from 2006 to 2012.</td>
<td>The prevalence of hearing loss was significantly higher for subjects with T2DM than subjects without DM (17.3% vs. 6.5%, p &lt;0.05). In addition, multivariate analysis showed that DM was a significant predictor of hearing loss (OR 1.398).</td>
<td>Aging and DM were correlated with the prevalence of hearing loss (p &lt;0.05). Smoking, central adiposity and poorly controlled diabetes predicted incident HL. These well-known CVD risk factors, suggest vascular changes may contribute to HI in aging.</td>
</tr>
<tr>
<td>12</td>
<td>Smoking, Central Adiposity, and Poor Glycemic Control Increase Risk of Hearing Impairment Cruikshanks KJ</td>
<td>longitudinal population-based cohort study</td>
<td>1,925 participants with normal hearing at baseline.</td>
<td>The role of hearing loss in participants with normal glucose levels, pre-diabetes and DM were 1.8, 3.1 and 9.2 per 1,000 person-years, respectively (P &lt;0.001). The multivariable-adjusted hazard ratios for incident hearing loss for participants with pre-diabetes and DM compared with those with normal glucose levels were 1.04 (95% confidence interval 0.95–1.14) and 1.36 (1.19-1.56), respectively. In spline regression analysis, the risk of incident hearing loss increased progressively with HbA1c levels above 5%.</td>
<td>In this large cohort study of young and middle-aged men and women, DM was associated with the development of bilateral hearing loss. DM patients have a moderately increased risk of future hearing loss.</td>
</tr>
<tr>
<td>13</td>
<td>Diabetes mellitus and the incidence of hearing loss: a cohort study Min-Beom Kim</td>
<td>Prospective cohort study</td>
<td>253,301 adults with normal hearing tests who participated in a regular health-screening exam between 2002 and 2014.</td>
<td>Controlling for age and Hispanic/Latino background, prevalence ratios for hearing impairment in the high plus low/inulin frequencies were 3.35 (95% CI 1.07, 1.71) for current smoking, 1.64 (1.14, 2.38) for alcohol consumption and 1.29 (1.06, 1.56) for triglycerides ≥150 mg/dL.</td>
<td>Current smoking, alcohol consumption, high triglycerides, and chronic kidney disease are potentially preventable correlates of hearing impairment for persons with diabetes.</td>
</tr>
<tr>
<td>14</td>
<td>Risk factors for hearing impairment among adults with diabetes: The Hispanic Community Health Study/Study of Latinos Kathleen E. Bainbridge</td>
<td>Cross-sectional study</td>
<td>3,384 participants aged 18–76 years</td>
<td>Women with type 2 diabetes were at higher risk for incident moderate or worse hearing loss (pooled multivariable-adjusted HR 1.16 [95% CI 1.07, 1.27]). Participants who had type 2 diabetes for &gt;8 years had a higher risk of moderate or worse hearing loss compared with those without type 2 diabetes (pooled multivariable-adjusted HR 1.24 [95% CI 1.10, 1.40]).</td>
<td>T2DM was associated with a modestly higher risk of moderate or worse hearing loss. Longer duration diabetes was associated with a higher risk of moderate or worse hearing loss.</td>
</tr>
<tr>
<td>15</td>
<td>Hearing loss prevalence and risk factors among older adults in China. Rui Gong</td>
<td>Cross-sectional study</td>
<td>6,984 adults (age &gt;60 years)</td>
<td>Among 388 patients with diabetes 279 had hearing impairment. Among 6598 patients without diabetes, 3831 patient had hearing impairment (71.91% vs 58.68%). Patients with diabetes had Odds ratio 1.86 (1.47–2.32) for hearing impairment</td>
<td>Hearing impairment was associated with T2DM</td>
</tr>
<tr>
<td>16</td>
<td>Type 2 diabetes and the risk of incident hearing loss Shruti Gupta</td>
<td>Longitudinal study</td>
<td>139,909 women</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Form the lateral wall of the scala media and are important for maintaining the endocochlear potential and passage of potassium ions into the endolymph. In a study by Fukushima et al cochlear microangiopathy and degeneration of the stria vascularis were noted in patients with type 2 diabetes mellitus. Presence of Periodic acid–Schiff (PAS) stain positive precipitates were seen in the capillary walls in the region of stria vascularis which caused thickening of the walls 10 to 20 times than normal in the study by Jorgensen et al. The corresponding thickening of arterial and venous walls in the modiolus and internal auditory
increased production of free radicals leads to a reduction in dendritic branching and can result in neural damage and microglial activation. The vestibule-cochlear nerve shows the degradation of vasa vasorum of blood vessels. In a study conducted by Makishima et al. the myelin sheaths had a beaded and blister-like appearance which was suggestive of neural damage. Studies have shown that patients with diabetes have significantly delayed latencies along different parts of the neural conduction pathways which suggests that neurological transmission is delayed in patients with T2DM.

The level of glucose in endolymph reflects the ambient blood glucose and can lead to deficits in the pure-tone audiometry. The pure-tone audiometry (PTA) hearing threshold was significantly related to glucose levels measured 1 hour before the hearing test according to a study by Austin et al which concluded that hyperglycemia can lead to chronic cochlear damage or impaired endolymph homeostasis.

Among patients with T2DM, oxidative stress and increased production of free radicals leads to a reduction in dendritic branching and can result in neural damage and microglial activation. The vestibule-cochlear nerve shows the degradation of vasa vasorum of blood vessels. In a study conducted by Makishima et al. the myelin sheaths had a beaded and blister-like appearance which was suggestive of neural damage. Studies have shown that patients with diabetes have significantly delayed latencies along different parts of the neural conduction pathways which suggests that neurological transmission is delayed in patients with T2DM.

The level of glucose in endolymph reflects the ambient blood glucose and can lead to deficits in the pure-tone audiometry. The pure-tone audiometry (PTA) hearing threshold was significantly related to glucose levels measured 1 hour before the hearing test according to a study by Austin et al which concluded that hyperglycemia can lead to chronic cochlear damage or impaired endolymph homeostasis.
Reactive Oxygen Species (ROS) like nitric oxide were found to be at higher levels in diabetics with hearing loss, which suggested an impact of oxidative stress in hearing loss. Studies by Frisina et al and Sakuta et al suggested the role of oxidative stress in hearing loss. The lack of oxidant protection in basal cells in the inner ear may result in hearing loss. Microangiopathic changes due to hyperglycemia can also lead to glycoprotein deposition in the capillaries which can impair the neurological and auditory function. Other factors like dyslipidemia, insulin resistance, and hypertension can also have a negative effect on hearing in diabetics.\textsuperscript{60,61}

4. SCREENING FOR HEARING LOSS IN ADULTS WITH DIABETES

In a recent study by Maidment et al, it was demonstrated that the odds of using hearing aids were lower in older adults (age $\geq$65 years) with diabetes or hypertension which emphasizes the need to identify older adults living with hearing impairment and diabetes.\textsuperscript{63} Studies have validated that even subclinical hearing loss leads to cognitive impairment and depressive symptoms. A minimal increase in the PTA hearing threshold of even up to 10 dB was associated with 52\% increased odds of social isolation and cognitive decline.\textsuperscript{64,65} Strong evidence supports that timely diagnosis and use of hearing aids can significantly improve the quality of life, reduce depression, improve communication, and reduce the rate of cognitive decline among patients with hearing loss.\textsuperscript{66–68} A recent study which analysed the full dataset of participants aged 50-89 years from the English Longitudinal Study of Ageing concluded that early detection of hearing loss and use of hearing aid alleviates depressive symptoms, and it promotes better hearing and psychosocial well-being.\textsuperscript{69} Despite the prevalence and burden of hearing loss in society, it is underdiagnosed and undertreated\textsuperscript{54,65,69} which reiterates the need for screening high-risk patients with diabetes.

Due to the gradual onset of hearing impairment, many older adults are unaware of their hearing impairment and increasing age is associated with the underestimation of the severity of hearing impairment. With increasing age, it becomes progressively difficult to use hearing aids\textsuperscript{70} and the onset of cognitive decline among these patients further worsens the challenges of using a new hearing aid regularly. The delay in diagnosis can lead to reluctance in starting treatment, poor compliance, inadequate maintenance of the hearing aids and unsatisfactory treatment outcomes. Hence early diagnosis, rehabilitation, and therapeutic interventions are important for adequate compliance and optimal treatment outcome in patients with diabetes who are at a higher risk of developing hearing impairment.

Although hearing impairment is common, 30\% of adults with hearing aids do not use them regularly and up to 75\% of adults who could benefit from hearing aids do not even acquire hearing aids.\textsuperscript{71} When comparing hearing-impaired adults who are not using a hearing aid with hearing aid users, hearing aid users have less depression, less social isolation, increased cognitive function and better relationships. With improvements in fit and technology, hearing aids have become smaller, more comfortable and produce more natural sounds.\textsuperscript{72} The number of undiagnosed cases and reluctance in using hearing aid further adds to the social and economic burden due to hearing loss and diabetes. Screening for hearing loss in patients with diabetes who are at a higher risk of developing hearing loss can help in better rehabilitation and therapeutic interventions and lead to the patient’s overall well-being.\textsuperscript{73,74}

The Centre for Disease Control and Prevention (CDC) recommends a baseline hearing evaluation upon diagnosis of diabetes and a comprehensive audiological evaluation at least every 2 years following that. Annual or frequent evaluation is recommended for patients who are at higher risk of developing hearing loss or if the patient reports a change in hearing status. Patients with a history of high noise exposure, tinnitus, ear pain, ear discharge or ototoxic drug use (aminoglycosides, furosemide) are at higher risk of developing hearing loss. According to the recommendations by The American Speech-Language-Hearing Association (ASHA) adults should be screened by an audiologist once per decade and once every 3 years after the age of 50 years. Frequent screening is recommended for people with known risk factors associated with hearing loss.\textsuperscript{75} The World Health Organization’s Guidelines on Integrated Care for Older People recommend screening and provision of amplification among older adults.\textsuperscript{76,77} The Comprehensive Medical Evaluation and Assessment of Comorbidities by the American Diabetes Association reports that hearing loss is commoner among patients with T2DM however does not recommend screening for hearing impairment.\textsuperscript{78}

Even though screening for hearing impairment has been recommended by several organisations, there has been a difference in opinion regarding the screening of all adults for hearing impairment. In a recent evidence report by the US Preventive Service Task Force, it was concluded that current evidence is insufficient to assess the balance of benefits and harms of screening for hearing impairment among asymptomatic adults more than 50 years of age. The American Academy of Family physicians also supports this conclusion.\textsuperscript{79} The UK National Screening Committee does not recommend a national screening program for hearing loss in adults 50 years or older.

As suggested by Nieman et al although definitive
recommendations have yet to be developed, the appropriate clinical practice would be to screen any person with perceived hearing loss and persons with risk factors for developing hearing loss. 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. Considering the association of hearing loss with diabetes and the benefits of early diagnosis and treatment, and the various guidelines recommending screening for hearing loss, screening for hearing impairment should be considered in patients with diabetes who are at high risk for developing hearing loss to prevent the further worsening of quality of life due to hearing impairment.

5. TOOLS THAT CAN BE USED FOR SCREENING FOR HEARING LOSS IN PATIENTS WITH DIABETES

Studies have evaluated clinical tests like whispered voice test or finger rub tests, Single question screening, Hearing Handicap Inventory for the Elderly- Screening version (HHIE-S) and hand-held audiometer for screening for Hearing loss. In single question screening, the patient is asked a single screening question like “Do you have difficulty with your hearing?”. Single question screening has a pooled specificity of 74% and pooled sensitivity of 80% for detecting moderate hearing impairment (>35 to 40 dB). HHIE-S is another well-studied self-report questionnaire with 10 questions which has attracted widespread interest. Among the older adults (aged more than 60), the diagnostic accuracy of HHIE-S was found to be 86.2%, with a specificity of 75.0% and sensitivity of 89.1%. It has been proven to be highly accurate in several studies and it has been recommended as a screening tool for hearing impairment. The components of the HHIE-S questionnaire which can be used for screening are shown in Table 2. Using HHIE-S, patients with a score above 10 are considered to have moderate handicap due to hearing impairment and are advised for further audiological evaluation. Recent studies have evaluated the accuracy of smartphone-based self-hearing test applications (apps) for screening for hearing loss. Smartphone-based applications like uHear app (iPhone-based application), uHearingTest app (iPhone based), hear ZA (the smartphone digits-in-noise hearing test), hearWHO smartphone application, and HearTest and HearScreen can be considered for screening for hearing impairment as they have significant values of specificity and sensitivity (between 75 and 100%).

Single question screening and HHIE-S questionnaires are simple and effective tools that can be used in resource-limited settings by a clinician for screening for hearing loss in patients with diabetes. 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. Pure tone audiometry and further evaluation of patients should be planned for patients who are found to have hearing impairment based on screening questionnaires.

There are few studies which evaluated the long term effects of treating hearing impairment among adults. Further studies on using self-reported questionnaires and the benefits of screening among high-risk populations including patients with diabetes can guide us in making recommendations on screening patients with Diabetes. Future randomised control trials evaluating the long term benefits of treating patients identified to have hearing impairment on screening in patients with diabetes can give us a better understanding of the benefits of screening and therapeutic interventions.

Table 2. Hearing handicap inventory for the elderly – screening version (HHIE-S)

<table>
<thead>
<tr>
<th>Item (Question)</th>
<th>Yes (4 points)</th>
<th>Sometimes (2 points)</th>
<th>No (0 point)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Score (0-40)

0 to 8 = 13% probability of hearing impairment (no handicap/no referral)
10 to 24 = 50% probability of hearing impairment (mild-moderate handicap/refer)
26 to 40 = 84% probability of hearing impairment (severe handicap/refer)
6. CONCLUSION

Several studies have concluded that there is a significant association between hearing loss and T2DM. Studies have reported that duration of diabetes, HbA1c levels, presence of diabetic nephropathy, diabetic retinopathy and diabetic neuropathy were associated with hearing loss among diabetics. According to some studies, the prevalence of hearing loss among diabetics is twice as compared to a normal population. The American Speech-Language Association and WHO guidelines on integrated care for older people recommend screening adults for hearing loss. CDC recommends baseline hearing evaluation for all patients diagnosed with Diabetes and comprehensive audiological evaluation every 2 years. Although definitive recommendations have yet to be developed, screening of persons with perceived hearing loss and persons at high risk of developing hearing loss including patients with diabetes should be considered to prevent the worsening of quality of life due to hearing loss. Single question screening or self-reported questionnaires can be used for the initial screening of patients with T2DM in resource-limited settings which can then be followed by audiometric and comprehensive audiological evaluation if the patients report having hearing loss.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare that are relevant to the content of this article.

REFERENCES


