Int J Biol Med Res. 2011; 2(4): 982 – 987

BioMedSciDirect Publications

Contents lists available at BioMedSciDirect Publications

International Journal of Biological & Medical Research

Journal homepage: www.biomedscidirect.com

Original Article

Evaluation of the Incidence of Sensorineural hearing loss in Patients with Type 2 Diabetes Mellitus

Rajendran S[a], Anandhalakshmi[b], Mythili B[c], Viswanatha Rao[d]

[a]*Institute of otorhinolaryngology, Madras medical college, Chennai, Tamilnadu, India.*
[b]*Department of physiology, SRM medical college hospital and research centre, SRM university, Kattankulathur – 603 203. Tamilnadu, India.*
[c]*Department of physiology, Saveetha medical college, Chennai, Tamilnadu, India*
[d]*Institute of physiology and experimental medicine, Madras medical college, Chennai, Tamilnadu, India*

ARTICLE INFO

Keywords:
Audiometry
HbA1C
Sensorineural hearing loss
Type 2 diabetes mellitus

ABSTRACT

Aim: The aim of this study is to find out the incidence of hearing loss in diabetes mellitus among the type 2 diabetes mellitus patients. Methods: A study was done with sixty type 2 diabetes mellitus patients of age 40-50 years attending the diabetic OP, Stanley Medical College, Chennai, Tamilnadu, India. The control group was sixty non diabetic people matched with age and sex, attending the master health check up scheme and medicine out patient department. All the patients were subjected to the following tests such as fasting, postprandial blood sugar, glycosylated hemoglobin (HbA1C) and audiometry. Results: The number of people affected with sensorineural deafness among the diabetics is 73.3% when compared to that of the controls 6.7%, which is highly significant (P = 0.001). The audiograms of the diabetics were suggestive of mild to moderate sensorineural deafness and the hearing loss was more towards the higher frequencies. Conclusion: The diabetic subjects showed significant high frequency, bilateral, mild to moderate sensorineural hearing loss (73.3%) as compared to controls of similar age. The glycemic status and duration of diabetes have no significant correlation with hearing loss and both the sexes were equally affected.

1. Introduction

Diabetes Mellitus is a metabolic disorder, due to relative or absolute lack of insulin resulting in elevated blood glucose levels associated with long term vascular and neurological complications [1]. Among glucose metabolism disorders, diabetes mellitus is the one most commonly related with auditory disorders. Diabetes also affects lipid and protein metabolism. Though Diabetes Mellitus is of varied etiology, the common manifestation is hyperglycemia. The pathophysiological basis of the type 2 Diabetes Mellitus is a combination of impaired Beta cell function, with marked increase in the peripheral insulin resistance at receptor/post receptor levels and increased hepatic glucose output production. Even several years after the discovery of insulin, diabetic patients still have considerably reduced life expectancy despite a significant reduction in the incidence of acute metabolic events like ketoacidosis. The excess mortality is mainly due to long term micro and macro vascular complications affecting the blood vessels of eyes, kidneys, heart and nerves [1].

It has been postulated that the micro vascular complications also affect the hearing of individuals with diabetes. Studies in diabetic animals have demonstrated thickening of the basement membrane of the capillaries of stria vascularis [2]. Histopathological studies have shown damage to the nerves and vessels of the inner ear of the individuals with diabetes. These vascular changes have been theorized to be an important causative factor for neuronal degeneration in the auditory system [3]. Hearing loss is defined as a pure tone average of the frequencies 250,500,1000,2000,4000,6000,8000 Hz when the hearing threshold is greater than 25 decibel in that ear. Hearing loss is impairment of hearing and its severity may vary from mild to severe or profound and in general hearing loss may be conductive, sensorineural or mixed [4]. The typical hearing impairment described in diabetics is a bilateral sensorineural hearing loss. Diabetes mellitus has been implicated as independent causative factor of sensorineural hearing loss [5].

* Corresponding Author : Dr.S. Rajendran
M.S (ENT), Institute of otorhinolaryngology,
Madras medical college,
Chennai, Tamilnadu, India.
Email:rajendran_sambandam@yahoo.com

There are many different types of hearing loss found in diabetic patients. One of them is progressive, gradual bilateral sensorineural loss, affecting especially high frequencies and the elderly. It would be similar to presbyacusis, but with more severe losses than those expected by aging [6]. Conversely, there are authors who report the possibility of having early sensorineural loss [7] and others that reported hearing loss in low and medium frequencies [2]. Some studies described diabetes as the possible cause of unilateral sudden hearing loss [8]. Since many studies have reported contradicting results regarding hearing impairment in diabetic patients and only a few studies are done in India, the present study is undertaken to determine the incidence of auditory dysfunction in type 2 diabetes patients and whether or not such auditory dysfunction could be correlated with the severity of hyperglycemia. The objective of the study is to evaluate the incidence of auditory dysfunction in patients with type 2 diabetes of age between 40 to 50 years and to study the correlation between the degree of hearing loss and the duration and severity of hyperglycemia and also to evaluate whether the hearing loss affects one particular gender predominantly.

2. Materials and Methods

This study included 60 type 2 diabetic patients attending the Diabetology outpatient department and 60 non – diabetic healthy subjects attending the Master Health check up Scheme and the Medicine Outpatient Department, Stanley Medical College and Hospital, Chennai, Tamilnadu, India. This Descriptive correlation study was carried out for a period of one year. Before the medical examination, subjects completed self administered questionnaires about medical history and life style including smoking habit, average number of cigarettes smoked daily and the weekly frequency of alcohol intake as none or regularly (at least once a week) . Smokers and non smokers were defined as subjects who had smoking habit at the time of annual health examinations and those who did not, and the smokers are further categorized according to the number of cigarettes smoked per day (light 1 to 9, moderate 10 to 19, heavy ≥20). Those with a demonstrated history of noise damage or audiograms signifying the noise damage were excluded as were subjects exhibiting middle ear hearing loss. Inclusion criteria were type 2 diabetic patients of age 40 to 50 years with no previous history of ear diseases. Non diabetic, age and sex matched healthy subjects with no previous history of ear diseases. Exclusion criteria were family history of deafness, history of chronic suppurative otitis media, meningitis, head or ear trauma, chicken pox / small pox, malaria, jaundice, thypoid, cholera, history of ear surgeries performed in the past, history of ototoxic drug intake, chronic smoking, radiotheraphy, autoimmune diseases and systemic diseases like hypertension, cardiac diseases and renal failure and occupational noise exposure. Group I (n=60): 60 non – diabetic healthy subjects attending the Master Health check up Scheme and the Medicine Outpatient Department, Stanley Medical College and Hospital. Group II (n =60): 60 type 2 diabetes patients attending the Diabetology out patient department, Stanley Medical College and Hospital. Written consent was obtained from all the subjects enrolled in the study after explaining to them in detail about the study in their own language. The study was approved by the institutional Ethical committee, Stanley Medical College and Hospital, Chennai, Tamil Nadu, India.

2.1.Sample collection for estimation of biochemical parameters

The blood was obtained by venupuncture after an overnight fast for fasting glucose and two hours after breakfast for postprandial glucose. The samples were immediately mixed with EDTA Sodium Fluoride to inhibit glycolysis [9] and the glucose level estimated using random assess fully auto chemistry analyzer Bayer express plus. The Glucose oxidase / Peroxidase (GOD/ POD) method was used for in vitro determination of Glucose in serum or plasma. The fasting and postprandial blood glucose levels were estimated to find out the glycemic status and serum urea and creatinine levels to rule out diabetic nephropathy. The new cases were considered as diabetics when their fasting blood glucose value was > 126 mg/dL and post prandial plasma glucose was > 200 mg/dL.

The subjects also underwent the following tests, (i) Blood pressure examination to rule out hypertension, (ii) HbA1C level to find out the glycemic control, and (iii) all subjects underwent an ENT examination, routine hearing tests and a pure tone Audiogram.

2.2. Tests for hearing

The tunning fork tests- Weber test, Rhinne test and Absolute bone conduction tests were done for both the ears of all subjects.

2.3. Pure Tone Audiometry

Pure Tone Audiometry is the most routine audiometric evaluations and the resulting pure tone audiogram is widely used as a basic description of the degree of hearing loss. Audiological examination was performed using a Pure Tone Audiometer model 500 MK III of Arphi company in a sound proof room in the ENT department, Stanley Medical College and Hospital. Ear phones were used to test hearing by air conduction and a small vibrator placed over the mastoid was used to test hearing by bone conduction. All audiometers incorporate a calibration circuit, which allows the output sound level to be set at each frequency. The signals presented to the subject by an audiometer were characterized by its frequency, sound pressure level and wave form which were all controlled. The patient was described what will happen during the test and the purpose of the test. Biological calibration was done everyday before starting the test. Both air and bone conduction were tested for each ear.

2.4.Pure Tone Audiometry: Air Conduction Threshold

This test was based on the measurement of hearing thresholds for a range of puretones presented through earphones according to the ascending method (Hughson – Westlake, up 5, down 10 method) [10].

2.5.Test frequencies

An audiometer [ARPHI 500 MK 1] is an electronic device that produces pure tones, the intensity of which can be increased or decreased in 5-Db steps. Air conduction thresholds are measured for tones of 250, 500, 1000, 2000, 4000 6000 and 8000 Hertz. Bone conduction thresholds are measured for 250, 500, 1000, 2000, 4000 Hz.

The patient was instructed that he would hear tones of short duration in either the left or the right ear to start with and the tones might become very faint. He was expected to signal by raising his finger corresponding to the side of the ear, as soon as the tone was heard and keep it raised as long as it is heard, no matter how faint it was.

2.6.Threshold determination

The test was started at 1000 Hz. A clearly audible signal, about 40 dB HL (decibel hearing level) was presented if the hearing threshold of the subject was assumed to be normal and if there was difficulty in hearing, 60 dB HL was given. The level of the tone was then reduced in steps of 10 dB until the tone became inaudible and the patient did not respond. Then the level of the tone was increased in steps of 5 dB, presenting one pulse at each level until a response was obtained. The level at which the subject gave a response after the raise of 5 dB was the threshold. Then the test was continued at the next higher frequency till 8000 Hz. Again returned to 1000 Hz and then tested at 500 Hz and 250Hz. The other ear was tested in the same way.

2.7.Pure Tone Audiometry: Bone Conduction Threshold

Pure tone bone conduction audiometry is a complement to air conduction audiometry and provides information about the conductive element of hearing loss. This test consists of the measurement of hearing thresholds for pure tones presented by means of a bone vibrator placed on the mastoid process behind the outer ear. The measurement was performed according to the ascending method (Hughson Westlake, up 5, down 10,method). In conventional audiometers, bone conduction thresholds are measured upto 4000Hz only

2.8. Procedure

Bone conduction thresholds are measured for 250, 500, 1000, 2000, 4000Hz. The patient was instructed that he would hear short tones and the tones might be very faint and might be heard in either ear or both ears simultaneously. He should raise the finger corresponding to the side of the ear, as soon as the tone was heard and he should not touch the bone vibrator after its final placement.

2.9.Threshold determination

The test was started with the better ear if the side difference was known or with that ear to which the test tones were lateralized in Weber's test. The bone vibrator was placed over the mastoid process. The test was started with 1000 Hz. A continuous, clearly audible tone was switched on and the position of the bone vibrator was adjusted until the patient indicated when the tone was the loudest. Any contact between the vibrator and the outer ear was avoided. The patient should not wear earphone during the test [11]. A test tone of 1 to 2 seconds duration was presented at about 40 dB HL and if the level was inaudible, the test tone was increased in steps of 10 dB until a response was obtained. Then the level was reduced in steps of 20 dB, until the tone was inaudible and the patient did not respond. The level was then increased in steps of 5 dB, until a response was obtained. The level at which he responded was the threshold. Then the test was continued with other test frequencies and also in the other ear. Masked pure tone audiometry is done if there is a difference of more than 40 dBs between air conduction threshold of the test ear and the bone conduction threshold of the opposite ear or when the air bone gap of the poorer ear under test is more than 10 dB. Student t test habeen used to find the significance of auditory thresholds (dB) between various categories of parameters. Analysis of variance [ANOVA] has been used to find the significance of auditory thresholds in different groups. The statistical soft ware namely SPSS 11.0 was used for the analysis of the data and Microsoft Word and Microsoft Excel have been used to generate graphs, tables, etc.

3. Results

Table.1. Compares the glycemic levels in groups I & II which is highly significant (P = 0.001). Using the chisquare test the number of people affected with sensorineural deafness among the diabetics is 73.3% (44/60) when compared to that of the controls (6.7%, 4/60) which is highly significant (P = 0.001).

Table 1. Hearing loss in groups I & II

	Fasting blood sugar (mg/dL) Mean ± SD	p value	Postprandial blood sugar (mg/dL)	p value	Number of subjects with hearing loss
Group I controls (n = 60)	80.8 ± 11.43	0.001	106.7 ± 14.8	0.001	4 (6.7%)
Group II Diabetics (n = 60)	181.47 ±9.93		286.8 ± 103.3		44(73.3%)

$\chi 2$ =58.79 P= 0.001 (Significant)

Table.1. Compares the glycemic levels in groups I & II which is highly significant (P = 0.001). Using the chisquare test the number of people affected with sensorineural deafness among the diabetics is 73.3% (44/60) when compared to that of the controls (6.7%, 4/60) which is highly significant (P = 0.001).

Table 2(a) Mean air conduction threshold (right ear) at different frequencies

Frequencies in hertz	Right ear Mean air conduction thresholds (dB) ± SD		t value	p value
	Group I (controls, n=60)	Group II (diabetics, n=60)		
250	20.42 ± 2.65	20.0 ± 0.00	1.218	0.226
500	20.42 ± 2.65	20.0 ± 0.00	1.218	0.226
1000	20.25 ± 1.94	20.0 ± 0.00	1.00	0.319
2000	20.42 ± 1.91	22.5 ± 2.52	5.105	0.000
4000	20.5 ± 2.20	25.5 ± 3.87	8.697	0.000(HS)
6000	20.5 ± 2.38	28.92 ± 5.97	10.139	0.000(HS)
8000	20.6 ± 2.98	31.83 ± 7.97	10.956	0.000(HS)

HS-highly significant

Table 2(b). Mean air conduction threshold (left ear) at different frequencies

Table 2(a) & (b) shows the comparison of mean air conduction threshold at different frequencies(250,500,1000,2000,4000,6000,8000 Hz) which was done for right and left ear. Eventhough the hearing loss started at 4000Hz(mean 27.39 for right and mean 28.43 for left ear) in both the ears, it was maximum at 8000Hz(mean is 38.62 for right ear and 38.13 for left ear).

Table 3(a). Mean bone conduction threshold (right ear) at different frequencies

Frequencies in hertz	Left ear Mean air conduction thresholds (dB) ± SD		t value	p value
	Group I (controls, n=60)	Group II (diabetics, n=60)		
250	10.42 ± 2.65	10.0 ± 0.00	1.218	0.226
500	10.42 ± 2.65	10.0 ± 0.00	1.218	0.226
1000	10.25 ± 1.94	10.0 ± 0.00	1.000	0.319
2000	10.42 ± 1.91	14 ± 3.42	7.08	0.001 (HS)
4000	10.83 ± 3.21	20.58 ± 7.08	9.71	0.001 (HS)

HS-highly significant

Table 3(b). Mean bone conduction threshold (left ear) at different frequencies

Frequencies in hertz	Left ear Mean air conduction thresholds (dB) ± SD		t value	p value
	Group I (controls, n=60)	Group II (diabetics, n=60)		
250	10.75 ± 3.30	10 ± 0.00	1.76	0.08
500	10.5 ± 1.77	10 ± 0.00	2.18	0.06
1000	10.42 ± 1.67	10.08 ± 0.65	1.44	0.15
2000	10.67 ± 1.95	15.25 ± 3.84	8.24	0.001 (HS)
4000	11 ± 3.77	22.25 ± 7.45	10.44	0.001 (HS)

HS-highly significant

Comparison of mean bone conduction threshold at different frequencies for right and left ear was done and results tabulated in Table 3(a) & (b). In both the ears the hearing threshold increased at 2000 Hz and showed the maximum at 4000 Hz (mean is 20.58 for the right ear and 22.25 for left ear).

Table 4. Comparison of hearing loss between males and females

	Mean at 8000 Hz right ear ± SD in threshold in dB	p value	Mean threshold in dB at 8000 Hz left ear + SD	p value
Males (n= 17)	30.59 ± 8.45	0.4701 (NS)	31.76± 9.34	0.2621 (NS)
Females (n= 43)	32.33 ± 7.81		34.77 ± 8.65	

NS-Not significant

In Table 4, comparison of hearing loss between the males and females for the right and the left ears was made. This shows no significant difference in hearing loss for right and left ears among males and females.

The audiograms of the diabetics were suggestive of mild to moderate sensorineural deafness, with no significant air bone gap and the hearing loss was more towards the higher frequencies.

4. Discussion

This study has evaluated the hearing loss in the patients with diabetes and the influence of hyperglycemia on hearing and it shows that the diabetics had a 73% incidence of deafness when compared to the non- diabetics of the same age group (6.7%,Table 1). Previous studies show incidence of hearing loss ranging from 30% to 95%. Friedman et al [12] showed a 55% incidence of hearing loss in diabetic patients. Kakarlapudi et al [13] found that hearing loss was more common in diabetic patients (13.1% prevalence) than the control non diabetic healthy subjects. Weng et al [14] noted that among the 67 diabetic subjects examined, 44.8% of them had profound hearing loss.

The duration of diabetes (above or below 10 years) as well as the glycemic control (HbA1C level above or below 8) were found to have no effect in the incidence of hearing loss in the diabetic group. Celik et al [15] observed that as the duration of diabetes increased to 15 years, the incidence of hearing loss also increased. After 15 years of diabetes, the influence on hearing loss was not significant. Taylor and Irwin (1978) [6] observed that female patients with diabetes had significantly greater hearing loss when compared with male patients with diabetes. According to Cullen and Cinnamond (1993) [16], male patients with diabetes had worse hearing than female patients with diabetes. In this study we observed no differences between the sexes.

Many studies suggested that diabetes causes hearing loss. Many have tried to identify the cause and based on their conclusions, the probable mechanisms are microangiopathy of the inner ear, neuropathy of the cochlear nerve, a combination of both, outer hair dysfunction and distruption of endolymphatic potential. The tissue effects of diabetes are thought to be related to the polyol pathway, where glucose is reduced to sorbitol. Sorbitol accumulation is implicated in neuropathy by causing a decrease in myo inositol content, abnormal phosphoinositide metabolism and decrease in Na+ K+ ATPase activity [17]. Makishima and Tanaka (1971)[18] observed severe atrophy of the spiral ganglion in the basal and middle turns of the cochlea in diabetic patients with sensorineural hearing loss. They also observed that 8th nerve showed changes of myelin degeneration with fibrosis of perineurium.

Jorgensen (1961) [19] observed thickening of the walls of the vasa nervorum of 8th nerve, leading to acoustic neuropathy. Wackym and Linthicum (1986) [20] observed microangopathic changes in the endolymphatic sac, stria vascularis and basilar membrane.

Van den Ouweland et al [21] observed a mutation in mitochondrial tRNA in a small subset of patients with maternally inherited diabetes with sensorineural hearing loss. Lisowska et al [22] demonstrated abnormalities of outer hair cell function and abnormal auditory brain stem responses in patients with diabetes. Fukushima et al [23] concluded that Type 2 Diabetes results in changes in cochlea, such as significant atropy of stria vascularis & otic loss in basal turn, which likely results in hearing loss.

In this study, the audiogram analysis of controls and diabetics showed that 4 of the controls had hearing loss (Table I) and 44 of the diabetics had hearing loss. Analysis of the controls with hearing loss shows that one of them had hearing loss at lower and mid frequencies(250Hz - 2000Hz) and the others had the hearing loss at higher frequencies (above 2000Hz). For all the diabetic subjects with hearing loss, the threshold of hearing in both the air conduction and bone conduction started to increase from 2000 Hz. The analysis of the mean air conduction thresholds of the group I (controls) and group II(diabetics) for the right and left ears (Table 3a & 3b) at the frequencies 250,500,1000,2000,4000,6000,8000 Hz shows that in the right ear of diabetics, the hearing loss started at 4000 Hz.(mean 27.39dB), the mean threshold was maximum at 8000 Hz (mean 35.62 dB) and in the left ear of diabetics the hearing loss started at 4000Hz.(mean 28.43dB) and the mean air conduction threshold at 8000 Hz was the maximum (mean 38.13dB)

The analysis of the mean bone conduction threshold of groups I and II of the right and left ears at 250, 500, 1000, 2000, 4000Hz was made (Table 4a & 4b) which shows that in both the ears of the diabetic patients with hearing loss, the hearing threshold increased at 2000Hz and was even more at 4000Hz(mean 20.58 for the right ear and 22.25 for the left ear). In the present analysis, hearing loss was observed at higher pure tone frequencies at 4000 to 8000 Hz. Audiograms of the diabetic patients had no significant air bone gap and the hearing loss was of the sensorineural type. This result was in concordance with previous studies [16, 17, 20]. But Fangchao Ma et al [24] and Friedman et al [12] observed the strongest association of hearing loss at lowest frequency at 500 Hz. Gibbin and Davis [25] found a statistically significant incidence of type II tone decay in the overall group of diabetics at 2000Hz. According to Frisina et al [26] the greatest deficit of hearing in the diabetics tended to be at low frequencies.. Vaughan et al [27] suggest that diabetic patients 60 years old or younger may show early high frequency loss similar to early presbyacusis.

Our study reports that the incidence of sensorineural deafness is increased in diabetics. The hearing loss is a progressive, bilateral, sensorineural deafness of gradual onset which affects predominantly the higher frequencies. The decrease in hearing acuity is similar to presbyacusis but those affected show a hearing loss greater than could be expected at that age.

5. Conclusions

In conclusion, the type 2 diabetic subjects had a higher hearing threshold than the healthy controls. The diabetics showed significant high frequency, bilateral, mild to moderate sensorineural hearing loss (73.3%) as compared to controls of similar age. The duration of diabetes and the glycemic status had no significant co-relation with hearing loss and the hearing was affected in both sexes equally. Therefore the auditory health of diabetic patients is to be more carefully followed up by health care professionals.

6. References

[1] Gareth Williams, John C. Pickup. Text book of diabetes mellitus. Blackwell publishing Ltd, Oxford, Third edition, 2003.

[2] Jorgensen,M.B.Buch,N.H.. Studies on inner ear function and cranial nerves in diabetics. Arch Otolaryngol.1961;74:373-381.

[3] 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;132(9):934-8.

[4] Dhingra P.L. Diseases of Ear, Nose and Throat. Elsevier. Fourth edition,2009.

[5] Maia CA, Campos CA. Diabetes mellitus as etiological factor of hearing loss. Rev Bras Otorrinolaringol.2005;71:208-214.

[6] Taylor,I.G.,Irwin,J. Some audiological aspects of diabetes mellitus. J Laryngol Otol.1978;92:99-113.

[7] Friedman SA, Schulman RH, Weiss S. Hearing and diabetic neuropathy. Arch Intern Med. 1975;135(4):573-6.

[8] Fukui M, Kitagawa Y, Nakamura N, Kadono M, Mogami S, Ohnishi M, Hirata C, Ichio N, Wada K, Kishimoto C, Okada H, Miyata H,Yoshikawa T. Idiopathic sudden hearing loss in patients with type 2 diabetes. Diabetes Res Clin Pract. 2004;63(3):205-11

[9] Carl A Burtis, Edward R Ashwood, David E Brun, Tietz textbook of clinical chemistry and molecular diagnostics. Elsevier Saunders. Fourth edition .2006.

[10] Deborah Ballantyne, Rita Troisio . Handbook of audiological Techniques. Butterworth-Heinemann Ltd.London.1990.

[11] Arlinger S. Manual of Practical Audiometry(Practical aspects of audiology). Whurr Publishers Ltd; London, England: 1991.

[12] Friedman SA, Schulman RH, Weiss S. Hearing and diabetic neuropathy. Arch Intern Med. 1975 ;135(4):573-6.

[13] Kakarlapudi V, Sawyer R, Staecker H. The effect of diabetes on sensorineural hearing loss. Otol Neurotol. 2003 ;24(3):382-6.

[14] Weng SF, Chen YS, Hsu CJ, Tseng FY. Clinical features of sudden sensorineural hearing loss in diabetic patients. Laryngoscope.2005 ;115(9):1676-80.

[15] Celik O, Yalçin S, Celebi H, Oztürk A. Hearing loss in insulin dependent diabetes mellitus. Auris Nasus Larynx.1996;23:127-32.

[16] Cullen JR, Cinnamond MJ. Hearing loss in diabetics. J Laryngol Otol.1993;107(3):179-82.

[17] Dennis L. Kasper, Anthony S. Fauci, Dan L.Longo, Eugene Braunwald, Stephen L. Hauser, J.Larry Jameson and Joseph Loscalzo. Harrison's Principles of Internal Medicine. McGraw-Hill Companies Inc. United States of America.17th Ed.2008

[18] Makashima,K.,Tanaka,K. Pathological changes of the inner ear and central auditory pathways in diabetics. Ann Otol Rhinol Laryngol.1971;80:218-288.

[19] Jorgensen,M.B. The inner ear in diabetes mellitus. Arch Otolaryngol Head Neck Surg;1961;74:31-39.

[20] Wackym,P.A.Linthicum,F.H.(1986)Diabetes mellitus and hearing loss: Clinical and histopathologic relationships. Am J Otolaryngol.1986;7:176-182.

[21] Van den Ouweland JM, Lemkes HH Gerbitz KD, Maassen JA. Maternally inherited diabetes and deafness (MIDD): A distinct subtype of diabetes associated with a mitochondrial tRNALeu(UUR) gene point mutation. Muscle Nerve. 1995; 3:S124-30

[22] Lisowska G, Namyslowski G, Morawski K, Strojek K. Otoacoustic emissions and auditory brain stem responses in insulin dependent diabetic patients. Otolaryngol Pol. 2002;56(2):217-25.

[23] 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; 132(9): 934-8.

[24] Fangchao Ma, Orlando Gomez- Marin,David J. Lee, Thomas Balkany. Diabetes and hearing impairment in Mexican American adults: a population – based study. J Laryngol Otol. 1998;112: 835 – 839.

[25] Gibbin KP, Davis CG. A hearing survey in diabetes mellitus. Clin Otolaryngol Allied Sci. 1981;6(5):345-50.

[26] Frisina ST, Mapes F, Kim S, Frisina DR, Frisina RD. Characterization of hearing loss in aged type II diabetics. Hear Res. 2006 ;211(1-2):103-13.

[27] Bamanie AH, Al-Noury KI. Prevalence of hearing loss among Saudi type 2 diabetic patients. Saudi Med J. 2011 ;32(3): 271 – 4.

[28] Vaughan N, James K, McDermott D, Griest S, Fausti S. A 5-year prospective study of diabetes and hearing loss in a veteran population. Otol Neurotol. 2006 ;27(1):37-43.

[29] Ren J, Zhao P, Chen L, Xu A, Brown SN, Xiao X. Hearing loss in middle-aged subjects with type 2 diabetes mellitus. Arch Med Res. 2009 ;40(1): 18-23.

[30] Bainbridge KE, Hoffman HJ, Cowie CC. Diabetes and hearing impairment in the United States: audiometric evidence from the National Health and Nutrition Examination Survey, 1999 to 2004. Ann Intern Med. 2008 ;149(1):1-10.

[31] Frisina ST, Mapes F, Kim S, Frisina DR, Frisina RD. Characterization of hearing loss in aged type II diabetics. Hear Res. 2006 ;211(1-2):103-13.

[32] Diniz TH, Guida HL . Hearing loss in patients with diabetes mellitus. Braz J Otorhinolaryngol. 2009;75(4):573- 8.

[33] Kashyap AS, Kashyap S. Increased prevalence of impaired hearing in patients with type 2 diabetes in western India. Postgrad Med J. 2000;76(891): 38.

[34] Panchu P. Auditory acuity in type 2 diabetes mellitus. Int J Diabetes Dev Ctries. 2008 ;28(4):114-20.

[35] Dalton SD, Cruickshanks KJ, Klein R, Klein BE, Wiley TL. Association of NIDDM and hearing loss. Diabetes Care. 1998;21:1540–4

[36] Salvenelli F, Miele A, Casale M, Greco F, D'Ascanio L, Firrisi L, et al. Hearing thresholds in patients with diabetes. Int J Otorhinolaryngol. 2004; volume 3:Number 1.

[37] Rozanska-Kudelska M, Chodynicki S, Kinalska I, Kowalska I. Hearing loss in patients with diabetes mellitus type II. Otolaryngol Pol. 2002;56:607 - 610.

[38] Diaz de Leon-Morales LV, Jauregui-Renaud K, Garay-Sevilla ME, Hernandez-Prado J, Malacara-Hernandez JM. Auditory impairment in patients with type 2 diabetes mellitus. Arch Med Res. 2005;36: 507 – 510.

[39] Hammes HP. Pathophysiological mechanisms of diabetic angiopathy. : J Diabetes Complications. 2003 ;17(2 Suppl):16-9.

[40] Jakus V, Rietbrock N. Advanced glycation end-products and the progress of diabetic vascular complications. Physiol Res. 2004;53(2):131-42.

[41] Triana R.J, Suits G.W, Garrison S. et al. Inner ear damage secondary to diabetes mellitus. Arch.Otolaryngol.Head Neck Surg.1991;117:635-640.

[42] Konrad-Martin D, Austin DF, Griest S, McMillan GP, McDermott D, Fausti S. Diabetes-related changes in auditory brainstem responses. Laryngoscope.2010 ;120(1):150- 8.

[43] Vaughan N, James K, McDermott D, Griest S, Fausti S. A 5-year prospective study of diabetes and hearing loss in a veteran population. Otol Neurotol. 2006 ;27(1):37-43.

[44] Mozaffari M, Tajik A, Ariaei N, Ali-Ehyaii F, Behnam H. Diabetes mellitus and sensorineural hearing loss among non-elderly people. East Mediterr Health J. 2010 ;16(9):947- 52.

[45] Chasens ER, Enock M, DiNardo M. Reducing a barrier to diabetes education: identifying hearing loss in patients with diabetes. Diabetes Educ. 2010 ;36(6):956-64. [46] Cheng YJ, Gregg EW, Saaddine JB, Imperatore G, Zhang X, Albright AL. Three decade change in the prevalence of hearing impairment and its association with diabetes in the United States. Prev Med. 2009 ;49(5):360-4.

[47] Uchida Y, Sugiura S, Ando F, Nakashima T, , Shimokata H. Diabetes reduces auditory sensitivity in middle-aged listeners more than in elderly listeners: a population- based study of age-related hearing loss. Med Sci Monit. 2010;16(7):63 – 8.

[48] Austin DF, Konrad-Martin D, Griest S, McMillan GP, McDermott D, Fausti S. Diabetes-related changes in hearing. Laryngoscope. 2009 ;119(9):1788- 96.

[49] 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 ;75(2):229-34.