

Research Article

Evaluation of hearing loss in patients with type 2 diabetes mellitus

Ramlakhan Meena*, Divij Sonkhya, Nishi Sonkhya,

Department of Oto-Rhino-Laryngology and Head and Neck surgery, SMS Hospital, Jaipur, Rajasthan, India

Received: 12 April 2016

Accepted: 09 May 2016

***Correspondence:**

Dr. Ramlakhan Meena,

E-mail: dramlakhan.meena168@gmail.com

Copyright: © the author(s), publisher and licensee Medip Academy. This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial License, which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

ABSTRACT

Background: This study had been undertaken to examine the relationship between diabetes mellitus and hearing loss quite debated for many years.

Methods: Hearing status in fifty patients of type 2 diabetes mellitus, aged within 50 years and duration of diabetes less than 120 months was compared to fifty ages and sex matched healthy volunteers using pure-tone audiometry, transient evoked otoacoustic emissions, and auditory brainstem responses.

Results: In diabetic patients, compared to healthy subjects, the mean hearing threshold in the pure-tone audiometry was significantly higher at all frequencies, the mean amplitude of TEOAE was lower, and latency times of waves III, V and intervals I-III, III-V and I-V in ABR were longer.

Conclusions: This study confirms the presence of SNHL in relatively young type 2 diabetes mellitus. The use of audiological tests to monitor hearing in diabetic patients should be considered as a routine procedure.

Keywords: Type 2 diabetes mellitus, SNHL, Pure-tone audiometry, Otoacoustic emissions, Auditory brainstem responses

INTRODUCTION

The relationship between hearing loss and diabetes mellitus remains debated for many years.¹ Diabetes mellitus is a chronic metabolic disorder characterized by high blood glucose in the context of insulin resistance and relative insulin deficiency.² Diabetes mellitus is associated with numerous complications. One of the lesser known complications of diabetes is auditory organ dysfunction and tinnitus, which leads to a decreased quality of life among those affected.³⁻⁶ Globally, as of 2013, an estimated 382 million people have diabetes worldwide, with type 2 diabetes making up about 90% of the cases.^{7,8} Diabetes mellitus has been implicated as an independent causative factor of sensorineural hearing loss.³

Most audiometric studies of hearing in patients with diabetes show a mild to moderate high frequency SNHL.⁹

The typical hearing loss is described as a progressive, bilateral, sensorineural deafness of gradual onset that affects predominantly the higher frequencies.^{10,12} However, not all authors agree that diabetes mellitus can lead to a sensorineural hearing impairment.¹³⁻¹⁵ The effects of different variables such as duration of diabetes, blood sugar control, and presence of end-organ damage on hearing loss have yet not been clarified despite several studies on this topic.⁹ Although there is mounting evidence for a relationship between diabetes and hearing impairment the awareness of auditory organ involvement in the course of diabetes is still not widespread among healthcare providers involved in diabetes care.^{16,17} Moreover, different authors have proposed different types of hearing loss in diabetic patients. One of them is progressive, gradual bilateral sensorineural loss, affecting especially high frequencies and the elderly. Conversely, there are authors who report the possibility of having early sensorineural loss and others that reported hearing

loss in low and medium frequencies.^{18,19} Some studies have also described diabetes as the possible cause of unilateral sudden hearing loss.²⁰

This study had thus been undertaken to examine the relationship between type 2 diabetes mellitus and hearing loss, and if found; to determine its type, to find whether it is cochlear or retro cochlear; and to assess a possible relationship, if any between hearing impairment and age, duration of diabetes and metabolic control from the results obtained during the study.

METHODS

The design of this study was hospital based observational cross sectional study carried out from February 2013 to January 2014. Institutional ethics committee approval was taken for the study as a part of post-graduation dissertation.

Inclusion criteria

The participants in this study was patients of type 2 Diabetes Mellitus aged below 50 years (to avoid the impact of presbycusis) who have had diabetes for less than 10 years (for the diabetic group) to exclude patients with advanced diabetic complications.

Exclusion criteria

History of chronic suppurative otitis media and other infectious diseases; Autoimmune diseases and other systemic diseases like hypertension; prolonged exposure to noise; history of exposure to ototoxic medications; and, family history of deafness. The study group included 50 cases of type 2 diabetes mellitus randomly selected from the patients attending the endocrinology (diabetes clinic) and outpatient department of SMS Hospital, Jaipur, India and out and in-patients of department of otorhinolaryngology and head and neck surgery, who satisfied the inclusion and exclusion criteria (ranging from 25 to 50 years; mean age 43.2 years) and an equal number of non-diabetic healthy age and sex matched control population picked up from the attending population of those patients to match the socioeconomic status of both the groups, also satisfying the inclusion and exclusion criteria. Few controls were picked up from healthy volunteers from amongst the hospital staff. The cases and controls included in the study were those who consented for the same in writing.

In each case and control, routine investigations and general oto-rhino-laryngological examination was performed followed by a detailed ear examination to exclude abnormalities in the external ear and the middle ear leading to impaired hearing. The metabolic control of diabetes was determined by fasting and post-meal blood sugar levels determined by Glucose oxidase method and HbA1c levels determined using spectrophotometric method with the help of randox imola machine.

Audiological assessment

In all subjects (cases and controls), three audiological tests were performed after the ENT examination viz. Pure tone audiometry, transient otoacoustic emission and, auditory brainstem response audiometry. Pure-tone audiometry is used to determine a hearing threshold, i.e. the softest sound audible to the person being studied. This measure reflects auditory function as a whole, both its peripheral and central parts.²¹ An otoacoustic emission (OAE) test is used to determine the status of the cochlear micromechanics, especially the function of the outer hair cells (OHC).²² Auditory brainstem response audiometry is a neurological test which is used to determine function of the retro cochlear part of the auditory pathway, up to brainstem level.²³ To evaluate the whole auditory pathway, all the three tests were performed in the department of otorhinolaryngology of the institution by trained personnel, kept same for all the participants.

Pure tone audiometry was performed using a pure tone audiometer model AUL 12096 audiometer of Labat company in a sound proof room. Air conduction thresholds were measured for tones of 250, 500, 1000, 2000, 4000 6000 and 8000 Hertz. Bone conduction thresholds were measured for 250, 500, 1000, 2000, 4000 Hz. At each frequency, an initial stimulus of 10 dB was given and 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. Hearing loss is defined as an unaided, measured, bilateral, pure-tone hearing loss at frequencies of 500, 1000, and 2000 hertz averaging 40 decibels (dB) or more in the better ear on the most recent audio logical evaluation conducted by a qualified professional {qualified professional is defined as a licensed or certified audiologist or qualified physician (otolaryngologist/ENT, otologist, neurologist).²⁴ Hearing impairment was graded as slight (26-40 dB); moderate (41-60 dB); severe (61-80 dB) and profound (>81 dB).²⁵

Transient evoked otoacoustic emissions were obtained using the neuro-audio (v-2010) device manufactured by Neurosoft Company with a 'non-linear' click stimulus of 80 µs duration, a repetition rate of 50 Hz, and an intensity of ~80 dB. The results were presented in dB as an average for band range 1.2-3.5 kHz. Mean TEOAE amplitude below 6 dB at band range 1.2-3.5 kHz was considered as a lack of otoacoustic emission.

Auditory brainstem responses were evaluated using the neuro-audio (v-2010) device manufactured by Neurosoft Company with click stimulus of 100 µs duration, a repetition rate of 19.1 Hz, an intensity of 80 dB, and a contralateral ear masking of 30 dB. Electrodes were placed on the forehead (positive), the ipsilateral mastoid (negative), and chin (ground). The latency times of wave I, III, V and the intervals between them were measured.

Statistical analysis

The statistical analysis was further performed using SPSS version 16.0, through a statistician. The results were expressed as percentages and proportions. The data from diabetic and control groups was compared using Z test and linear correlations were done in diabetic subjects between hearing function and age, duration of diabetes, and HbA1c levels using the Pearson product correlation test. A p-value of <0.05 was considered to be statistically significant, and, a p-value <0.001 was considered to be highly significant statistical parameter.

RESULTS

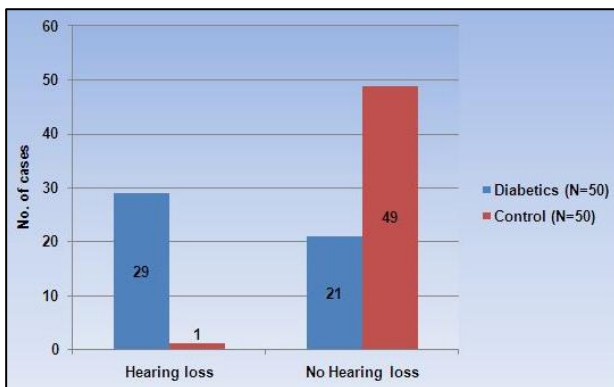


Figure 1: Number of cases with hearing loss in both the groups.

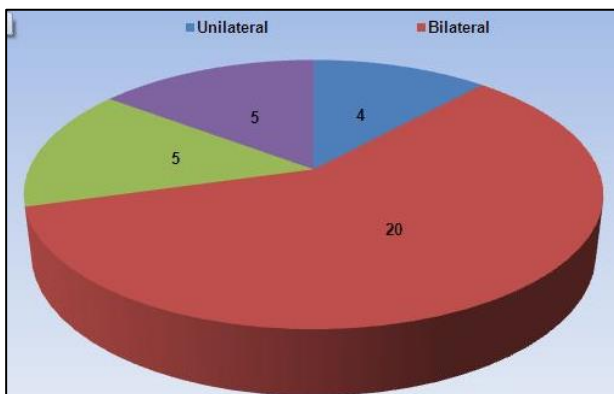


Figure 2: Type of hearing loss in Diabetics with SNHL.

The study group consisted of 50 cases and same number of age and sex matched healthy controls as per the inclusion and exclusion criteria. The participants ranged from 25 to 50 years with a mean age of 43.2 years. There were 36 males (72%) and 14 females (28%) in each group. The prevalence of hearing loss in the diabetic group was 58%, compared with 02% in the group without diabetes, which was statistically significant ($p < 0.05$) (Figure 1). Audiograms of the diabetic patients had no significant air bone gap and the hearing loss was of the sensorineural type; with bilateral hearing loss in more

than three quarters. Four cases presented with unilateral hearing losses (Figure 2). In 20% of the diabetic population, there were increased losses at higher frequencies, and, half of these were the diabetic subjects exhibiting an audiogram with normal hearing thresholds accompanied with increased thresholds for hearing only at higher frequencies.

Pure tone audiometry

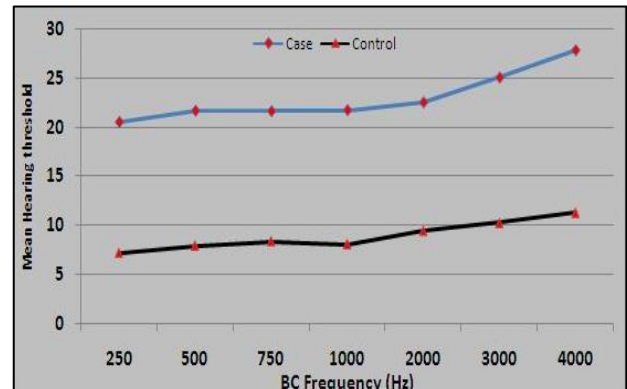


Figure 3: Hearing thresholds for bone conducting in pure tone audiometry.

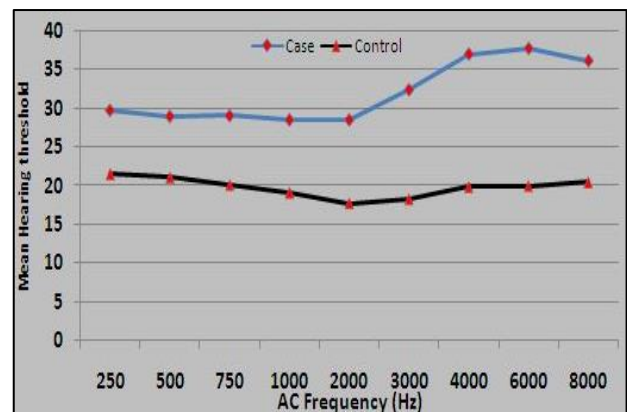


Figure 4: Hearing thresholds for air conduction in pure tone audiometry.

Among the diabetics, 29 patients had mild to moderate SNHL, while only one female patient had SNHL among the non-diabetics. Among the diabetics with SNHL, 16 patients had mild and rest 13 patients presented with moderate hearing losses. In the diabetic group, the mean hearing thresholds at all frequencies; i.e. 250-4,000 Hz for bone conduction and 250-8,000 Hz for air conduction were highly significantly higher as compared to the control group (Table 1, 2 and Figure 3, 4). In multivariate analysis between pure tone audiometric results and age, HbA1c and duration of diabetes; age showed a positive correlation with hearing threshold at all frequencies and was significant at 750 and 1000 Hz (Table 3).

Table 1: Hearing thresholds for bone conduction in pure tone diabetics and controls.

Frequency (Hz)	Hearing threshold (dB) [Mean±St. Dev.]		p-value
	Diabetics	Control	
250 Hz	20.60±9.80	7.20±6.96	<001*
500 Hz	21.75±9.65	7.95±5.58	<001*
750 Hz	21.70±8.81	8.40±5.67	<001*
1000 Hz	21.80±8.62	8.10±5.97	<001*
2000 Hz	22.60±9.55	9.45±6.37	<001*
3000 Hz	25.10±10.45	10.25±6.77	<001*
4000 Hz	27.85±12.59	11.30±7.72	<001*

*Highly significant

Table 2: Hearing thresholds for air conduction in pure tone audiometry diabetics and controls.

Frequency (Hz)	Hearing threshold (dB) [Mean ± St. Dev.]		p-value
	Diabetics	Control	
250 Hz	29.75±8.81	21.55±5.17	<001*
500 Hz	28.95±8.37	21.10±4.93	<001*
750 Hz	29.05±8.32	20.10±5.19	<001*
1000 Hz	28.50±8.11	19.10±5.28	<001*
2000 Hz	28.50±10.04	17.70±6.28	<001*
3000 Hz	32.45±11.21	18.25±7.75	<001*
4000 Hz	37.10±13.45	19.85±8.36	<001*
6000 Hz	37.85±14.39	19.95±11.06	<001*
8000 Hz	36.25±15.00	20.45±11.85	<001*

* Highly significant

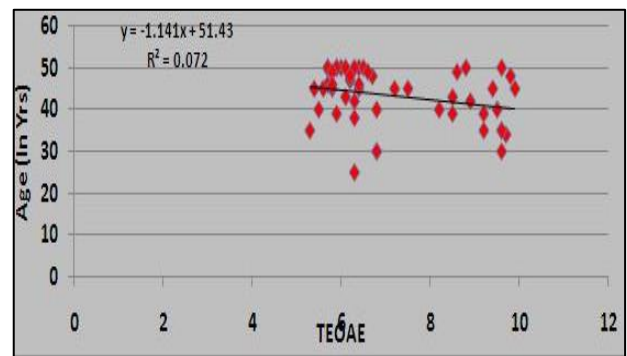
Table 3: Correlation between age and hearing threshold at particular frequency.

AC Frequency (Hz)	r-value	p-value	Significance
250	+ 0.103	>.05	NS
500	+ 0.158	>.05	NS
750	+ 0.227	<.05	Sig
1000	+ 0.225	<.05	Sig
2000	+ 0.179	>.05	NS
3000	+ 0.184	>.05	NS
4000	+ 0.120	>.05	NS
6000	+ 0.048	>.05	NS
8000	+ 0.169	>.05	NS

Table 4: TEOAE amplitudes in the two study groups (diabetics and controls).

	Mean ± Sd		P- value
	Case	Control	
TEOAE amplitude	7.21±1.52	9.71±0.76	<.001*

* Highly Significant

Transient evoked otoacoustic emissions (TEOAE)**Figure 5: Correlation between age and mean TEOAE amplitudes of diabetics**

The otoacoustic emissions in the diabetic group were absent bilaterally in six, and unilaterally in two patients. In the control group, they were absent bilaterally in one subject. The mean amplitude of TEOAE at band range 1.2-3.5 kHz was significantly lower in the study group compared to the control group (Table 4). The mean amplitude of TEOAE showed a negative linear correlation with age (Figure 5). No linear correlation was found between HbA1c and duration of diabetes with the mean TEOAE amplitudes.

Auditory brainstem responses (ABR)**Table 5: Latency time of various waves on ABR of case and control groups.**

Latency Time	Mean±Sd		P-value	Significance
	Case	Control		
Wave I	1.98±0.25	1.92±0.09	>.05	NS
Wave III	3.77±0.32	3.68±0.15	>.05	NS
Wave V	5.92±0.38	5.68±0.18	<001	HS

Table 6: Interval duration between various waves on ABR cases and controls.

Interval Duration	Mean ± Sd		P-value	Significance
	Case	Control		
I-III	1.79±0.24	1.76±0.20	>.05	NS
III-V	2.1±0.40	2.01±0.23	>.05	NS
I-V	3.87±0.44	3.77±0.19	>.05	NS

In the diabetic group, the latencies of III (representing superior olivary complex) and V (representing inferior colliculus) waves were delayed as compared with the control group {(III wave- 3.77±0.32 ms versus 3.68±0.15 ms); (V wave- 5.92±0.38 ms versus 5.68±0.18 ms)} (Table 5). The interpeak intervals I-III, III-V and I-V were also prolonged in the study group (1.79±0.24 ms versus 1.76±0.20 ms; 2.1±0.40 ms versus 2.01±0.23 ms; and, 3.87±0.44 ms versus 3.77±0.19 ms), but did not reach statistical significance (Table 6). Duration of diabetes was statistically significantly positively

correlated with latency of wave V and also showed positive correlation with I-V durations. There was no correlation between glycemic control and ABR results.

DISCUSSION

The present study reports SNHL in 58% of type 2 diabetic subjects and 2% of the healthy non diabetic subjects. Different studies conducted earlier have reported an incidence of hearing loss in patients with diabetes mellitus ranging from 13% to 95%. Our results are similar to those of Nagoshi Y, et al (54%); Friedmann SA, et al (55%); Boomsma LJ and Stolk RP (48%); Weng SF, et al (44.8%); and, Mozaffari M, et al (45%).^{18,26-29} However, our results are quite low as compared to those of Rajendran S, et al (73.3%) and Harkare V, et al (74%); and surprisingly very low in comparison to that proposed by Rózańska-Kudelska M, et al (95%) in diabetics and 65% in non-diabetic healthy controls but higher in comparison to those of Somogyi A, et al (34%) and Saini S, et al (30%).³⁰⁻³⁴ The reported percentage of hearing loss in diabetic population of the present study is quite high as compared to that reported by Kakarlapudi V, et al (13.1%).¹ Some discrepancies of our study with those of other authors can be explained by the fact that these different studies had variations in the period of study, different inclusion and exclusion criteria and the heterogeneity of the study populations. Contradictory to our study, Harner SG and Schuknecht HF had denied a relationship between the two.^{9,35}

The hearing threshold in the pure-tone audiometry in our study was highly significantly higher for all frequencies in type 2 diabetic subjects in comparison with healthy controls. These results are similar to most other studies.^{1,30,31,34} But, two studies observed the strongest association of hearing loss at lowest frequency at 500 Hz.^{8,36} Age correlated positively with audiometric hearing thresholds at all frequencies; but, no correlation was revealed with HbA1c and duration of diabetes.

The mean amplitude of TEOAE at band range 1.2-3.5 kHz was significantly lower in the study group compared to the control group. In the diabetic patients, the mean amplitude of TEOAE showed a negative correlation with age (correlation coefficient, $r = -0.270$) the mean TEOAE amplitude was also higher for the group of diabetics who achieved HbA1c levels less than 7% in comparison to the remaining patients with lesser metabolic control. However, there was no linear correlation of the mean TEOAE amplitudes to the metabolic control or the duration of diabetes; similar to other studies.³⁷

We report that in the diabetic group, the latency time of wave V was significantly longer compared to the control group (5.92 ± 0.38 ms versus 5.68 ± 0.18 ms, $p < 0.001$) similar to other studies.^{38,39} Our study reports variations to these studies as regards to the latencies of I and III waves, which may have probably resulted due to the pathogenetic mechanism involved in the various patients

of the study populations in these studies. We report that both cochlear and retro cochlear pathways were involved which is the same in other studies. In the diabetic patients, this study reports a positive linear correlation between duration of diabetes with the latency of V wave ($r = +0.222$) and I-V duration ($r = +0.116$). The present study reports that duration of diabetes affects the presence of hearing loss in diabetics but, it does not affect the severity of hearing loss in the patients, similar to other studies but, one study reports that the duration and severity of hearing loss are significantly correlated.^{30,34}

Our study found a positive correlation between age and hearing threshold on pure tone audiometry which is significant at 750 and 1000 Hz, as well as a negative correlation between age and TEOAE in the diabetic group. There was increased existence of hearing loss with increasing age in the present study. Axelsson A, et al showed that the incidence of pure tone hearing loss increases with age in patients with diabetes, even after correction for prebycusis.¹¹ The impact of age on hearing function is well documented. The hearing threshold increases, predominantly at middle and high frequencies, whereas amplitude of OAE decreases, with age.^{36,40} Our findings are similar to other studies but contradictory to one study which does not report any correlation with age.^{1,30,32,34}

No differences were observed between the two sexes as regards to the hearing loss in all three audio logical tests. Also, since most previous studies comparing males and females have found no sex differences in audio logical tests, a strict grouping of cases and controls between the two groups to assess gender differences were not tried in this study. Our results are similar to many authors.^{1,30,31,34} Taylor IG and Irwin J reported that females had significantly greater hearing loss when compared to males with diabetes; and, as per the study of Cullen JR and Cinnamon MJ, male patients with diabetes had worse hearing than female patients with diabetes.^{16,17}

In this study, the duration of diabetes had no impact on hearing threshold in diabetic patients. This is contrary to other observations, which have found a higher hearing threshold in longer lasting diabetes; but similar to some other ones.^{16,31} The amplitude of OAE did not show an association with the duration of diabetes. We report a statistically significant positive correlation between diabetes duration and prolongation of interval I-V. A correlation between diabetes duration and prolongation of interval I-III has also been reported in other studies barring few others.^{38,39}

In our study, patients with near-normal glycaemic control (HbA1c <7%) demonstrated higher TEOAE amplitude than subjects with lesser glycaemic control. However, no linear correlation between HbA1c level and TEOAE amplitude was found. We didn't find a relationship between metabolic control and hearing threshold, or ABR results. Most other studies also failed to find such a

correlation.^{38,39} However, few studies showed a correlation between poor metabolic control and higher hearing threshold. However our findings are similar to some other authors.^{30,31,34}

CONCLUSION

Our study confirmed the existence of auditory organ dysfunction in relatively young type 2 diabetic patients with a short duration of the disease. Sex and blood glucose level of diabetic patient had no significant correlation with hearing loss, while age and duration of diabetes had an association with sensorineural hearing loss. Both the cochlear and the retro cochlear part of the auditory pathway, up to brainstem level, were involved. Since hearing loss can be considered to be a consequence of diabetes, a metabolic assessment may be useful for patients presenting with hearing loss so as to reduce the high rate of undiagnosed diabetes mellitus in the community. The use of audio logical tests to monitor hearing in diabetic patients should be considered as a routine procedure as fundus examination so that quality of life can be improved for long standing diabetics with needed therapeutic interventions for hearing improvement.

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

- Kakralapudi V, Sawyer R, Staecker H. The effects of diabetes on sensorineural hearing loss. *Otol Neurol*. 2003;24:382-6.
- Kumar V, Fausto N, Abbas AK, Cotran RS, Robbins SL. Robbins and Cotran: Pathologic Basis of Disease (7th Ed). Philadelphia, Pa.: Saunders; 2005:1194-5.
- Mala CA, Campos CA. Diabetes mellitus as etiological factor of hearing loss. *Rev Bras Otorrinolaringol*. 2005;71:208-14.
- Diaz de Leon-Morales, Jáuregui-Renaud K, Garay-Sevilla ME, Hernández-Prado J, Malacara-Hernández JM. Auditory impairment in patients with type 2 diabetes mellitus. *Archives of Medical Research*. 2005;36:507-10.
- Kazmierczak H, Doroszewska G. Metabolic disorders in vertigo, tinnitus, and hearing loss. *International Tinnitus Journal*. 2001;7:54-58.
- Dalton DS, Cruickshanks KJ, Klein BE, Lein R, Wiley TL, Nondahi DM. The impact of hearing loss on quality of life in older adults. *Gerontologist*. 2003;43:661-8.
- Williams's textbook of endocrinology. (12th Ed.) Philadelphia: Elsevier/Saunders; 1371-1435.
- Shi Y, Hu FB. The global implications of diabetes and cancer. *The Lancet*. 2014;383(9933):1947-8.
- Harner SG. Hearing in adult-onset diabetes mellitus. *Otolaryngol head neck surg*. 1981;89:322-7.
- Axelsson A, Fagerberg S. Auditory function in diabetics. *Acta Otolaryngol*. 1968;66:49-64.
- Axelsson A, Sigroth K, Vertes D. Hearing in diabetics. *Acta Otolaryngol Suppl*. 1978;356:2-21.
- Jorgensen MB. The inner ear in Diabetes Mellitus. *Arch otolaryngol*. 1961;74:373-81.
- Buller N, Shvili Y, Laurian N, Laurian L, Zohar Y. Delayed brainstem auditory evoked responses in diabetic patients. *J Laryngol Otol*. 1988;102(10):857-60.
- Donald MW, Bird CE, Lawson JS, Letemandia FJJ, Monga TN, Surridge DHC, et al. Delayed auditory brainstem responses in diabetes mellitus. *J Neurol Neurosurg Psychiatry*. 1981;44(7):641-4.
- Miller J, Beck L, Davis A, Jones DE, Thomas AB. Hearing loss in patients with diabetic retinopathy. *Am J Otolaryngol*. 1983;4(5):342-6.
- Taylor IG, Irwin J. Some audiological aspects of diabetes mellitus. *J Laryngol Otol*. 1978;92(2):99-113.
- Cullen JR, Cinnamon MJ. Hearing loss in diabetics. *J Laryngol Otol*. 1993;107(3):179-82.
- Friedmann SA, Schulman RH, Weiss S. Hearing and diabetic neuropathy. *Arch Intern Med*. 1975;135(4):573-6.
- Jorgensen MB, Buch NH. Studies on inner ear function and cranial nerves in diabetics. *Arch Otolaryngol*. 1961;74:373-81.
- Fukui M, Kitagawa Y, Nakamura N, Kadono M, Mogami S, Ohnishi M, et al. Idiopathic sudden hearing loss in patients with type 2 diabetes. *Diabetes Res Clin Pract*. 2004;63(3):205-11.
- Kutz Jr JW, Mullin G, Campbell KCM. Audiology, pure-tone testing. Available at <http://emedicine.medscape.com/article/1822962-overview> updated 31 March 2010. Accessed 28 July 2010.
- Campbell KCM, Mullin G. Otoacoustic emissions. Available at <http://emedicine.medscape.com/article/835943-overview> updated 18 December 2009. Accessed 28 July 2010.
- Bhattacharya N. Auditory brainstem response audiometry. Available at <http://emedicine.medscape.com/article/836277-overview>, updated 21 January 2009. accessed 28 July 2010.
- Developmental disabilities case definitions-metropolitan atlanta developmental disabilities surveillance program (CDC). Available at <http://www.cdc.gov/ncbddd/developmentaldisabilities/casedefinitions.html>
- Grades of hearing impairment (World Health Organization Programmes Prevention of blindness and deafness). Available at http://www.who.int/pbd/deafness/hearing_impairment_grades/en/
- Nagoshi Y, Oshita F, Hayakawa K, Nakayama T. The studies of hearing disorder on diabetics. *Audiology Japan*. 1969;12:155-9.

27. Boomsma LJ, Stolk RP. The frequency of hearing impairment in patients with diabetes mellitus type 2. *Ned Tijdschr Geneesk.* 1998;142(32):1823-5.
28. Weng SF, Chen YS, Hsu CJ, Tseng FY. Clinical features of sudden sensorineural hearing loss in diabetic patients. *Laryngoscope.* 2005;115(9):1676-80.
29. Mozaffari M, Tajik A, Ali-Ehyaii F, Behnam H. Diabetes mellitus and sensorineural hearing loss among non-elderly people. *Eastern Mediterranean Health Journal.* 2010;16(9):947-52.
30. Rajendran S, Anandhalakshmi, Mythill B, Viswanatha R. Evaluation of the incidence of sensorineural hearing loss in patients with type 2 diabetes mellitus. *Int J Biol Med Res.* 2011;2(4):982-7.
31. Harkare V, Deosthale N, Khadakkar S, Dhoke P, Gupta A. Hearing status in patients with diabetes mellitus. *PJMS.* 2012;2(1):25-8.
32. Rózańska-Kudelska M, Chodyncki S, Kinalska I, Kowalska I. Hearing loss in patients with diabetes mellitus type II. *Otolaryngol Pol.* 2002;56(5):607-10.
33. Somogyi A, Rosta K, Vaszi T. Hearing impairment and tinnitus in patients with type 2 diabetes. *Orv Hetil.* 2013;154(10):363-8.
34. Saini S, Saini R, Aseri Y, Singh BK, Verma PC. Sensorineural hearing loss in diabetic patients. *Indian Journal of Basic and Applied Medical Research.* 2014;3(3):170-4.
35. Schuknecht HF. *Pathology of ear.* 2nd ed. Philadelphia, Baltimore, Hong Kong, London, Munich: Lea and Febiger; 1993:312-4.
36. Ma F, Gomez- Marin O, Lee DJ, Balkany T. Diabetes and hearing impairment in Mexican American adults: a population-based study. *J Laryngol Otol.* 1998;112(9):835-9.
37. Eren E, Harman e, Arsalong S, Onal K. Effects of type 2 diabetes on otoacoustic emissions and the medial olivocochlear reflex. *Otolaryngol head neck surg.* 2014;150(6):1033-9.
38. Gupta R, Aslam M, Hasan SA, Siddiqi SS. Type-2 diabetes mellitus and auditory brainstem responses- a hospital based study. *Indian J Endocrinol Metab.* 2010;14(1):9-11.
39. Siddiqi SS, Gupta R, Aslam M, Hasan SA, Khan SA. Type-2 diabetes mellitus and auditory brainstem response. *Indian J Endocrinol Metab.* 2013;17(6):1073-7.
40. Brant LJ, Fozard JL. Age changes in pure-tone hearing thresholds in a longitudinal study of normal human ageing. *J Acoust Soc Am.* 1990;88:813-20.

Cite this article as: Meena R, Sonkhya D, Sonkhya N. Evaluation of hearing loss in patients with type 2 diabetes mellitus. *Int J Res Med Sci* 2016;4:2281-7.