Original Article

Evaluation of the Auditory Effects of Hyperlipidaemia and Diabetes Mellitus by Using Audiometry

Physiology Section

ANANDHALAKSHMI SWAMINATHAN, RAJENDRAN SAMBANDAM, MYTHILI BHASKARAN

ABSTRACT

Background: Hyperlipidaemia is a common disease of lipid metabolism, whereas diabetes mellitus (DM) is a chronic disease which is caused due to the relative or absolute lack of insulin, which results in elevated blood glucose levels. Hearing loss is the total or partial inability in hearing sound in one or both the ears. Although the relationship between hearing loss and hyperlipidaemia or diabetes mellitus has been shown in many clinical investigations, this concept is still controversial.

Objective: The aim of the study was to evaluate the auditory effects of hyperlipidaemia and diabetes mellitus by using audiometry.

Materials and Methods: The study group consisted of 30 normal subjects (group I), 30 subjects with hyperlipidaemia (group II), 30 Type II diabetic patients (group III) and 30 subjects with both diabetes and hyperlipidaemia (group IV) of the age group of 40-50 years, who attended the Diabetology Outpatients Department and the Master Health Check Up Scheme at the Stanley Medical College and Hospital, Chennai. The subjects underwent blood pressure examination and the laboratory evaluation of the serum lipid profile, fasting and post prandial blood glucose levels, serum urea levels and creatinine levels. Pure tone audiometry was done for both the ears of all the subjects.

Results: The prevalence of hearing loss in group IV was 63.3%, in group III, it was 56.7%, in group II, it was 40% and in group I, it was 6.7%. There was also an increased association of hearing loss in people with high total cholesterol, high triglycerides and high LDL levels. The audiogram analysis showed a high frequency of hearing loss.

Conclusion: Our study reports that the prevalence of sensorineural deafness was increased in the subjects with diabetes and in subjects with hyperlipidaemia and the subjects having both diabetes and hyperlipidaemia had the highest risk of developing sensorineural deafness. The hearing loss was a progressive, bilateral, sensorineural deafness of gradual onset, which affected mainly the higher frequencies.

Key Words: Hyperlipidaemia, Type 2 diabetes mellitus, Sensorineural hearing loss, Audiometry

INTRODUCTION

The relationship between sensorineural hearing loss (SNHL) and hyperlipidaemia has been investigated for more than 35 years and that between sensorineural hearing loss and diabetes mellitus has been investigated for more than 150 years. It is believed that hyperlipidaemia and diabetes mellitus may lead to auditory dysfunction. Although the relationship between hearing loss and hyperlipoproteinaemia has been shown in many clinical investigations, this concept is still controversial [1]. Hyperviscosity of the blood serum, vascular occlusion or the increased susceptibility to noise may be reasons for the auditory dysfunction which is seen in hyperlipoproteinaemia [2, 3].

It has been postulated that the microvascular complications also affect the hearing of individuals with diabetic dyslipidaemia. Histo-pathological studies have shown damage to the nerves and vessels of the inner ear of the individuals with diabetes and hyperlipidaemia, which have been theorized to be an important causative factor for neuronal degeneration in the auditory system [4, 5].

Hearing loss is the impairment of hearing and its severity may vary from mild to severe or profound and in general, the hearing loss may be conductive, sensorineural or mixed. Varying ranges of the prevalence of sensorineural deafness in subjects with diabetes and hyperlipidaemia has been reported by authors from outside our country, but however, no work has been carried out in our country with respect to the same.

In the literature, many different types of hearing loss which are found in diabetic patients have been reported. Some reported a progressive, gradual, bilateral sensorineural loss which affected especially the high frequencies [6, 7] and the elderly and others had reported hearing loss in the low and medium frequencies [8]. The present study was undertaken to determine whether or not diabetes and hyperlipidaemia induced auditory dysfunction. If hyperlipidaemia was a cause of some form of hearing loss, then there could be a place for the primary or secondary prevention of this damage.

AIMS

The purpose of the study was to find the association between hyperlipidaemia and type 2 diabetes with hearing loss and to find out the combined effect of diabetes and dyslipidaemia on hearing.

MATERIALS AND METHODS

The study group consisted of 30 normal subjects (group I), 30 subjects with hyperlipidaemia (group II), 30 subjects with type 2 diabetes (group III) and 30 subjects with both diabetes and hyperlipidaemia (group IV) of the age group of 40-50 years, who attended the Diabetology Outpatients Department and the Master Health Check-up Scheme at Stanley Medical College and Hospital, Chennai, Tamilnadu, India.

Patients who were already on treatment for hyperlipidaemia, those with a family history of deafness, those with a history of chronic suppurative otitis media, meningitis, head or ear trauma, a history of ototoxic drug intake, chronic smoking, radiotherapy, autoimmune diseases and systemic diseases like hypertension, cardiac diseases, renal failure and those with occupational noise exposure were excluded from the study.

This study was approved by the ethical committee of Stanley Medical College and Hospital, Chennai. Informed consent was obtained from all the subjects. The subjects underwent the following tests: Blood pressure examination to rule out hypertension, estimation of the serum lipid profile, evaluation of the fasting and post-prandial blood glucose levels and evaluation of the serum urea and creatinine levels to rule out diabetic nephropathy. The patients were considered as diabetics when their fasting blood glucose level was ≥ 126 mg/dL and their post-prandial plasma glucose was ≥ 200 mg/dL. The patients were said to have high cholesterol if the blood cholesterol level was > 260 mg/dL, to have high LDL if the LDL level was > 160mg/dL and to have high triglyceride levels (TGL) if the TGL level was > 200mg/dl and to have low HDL levels if the HDL level was < 40mg/dL [9].

The blood was obtained by venipuncture after an overnight fast for fasting glucose and 2 hours after breakfast for postprandial glucose. The Glucose oxidase/ Peroxidase (GOD/ POD) method was used for the in vitro determination of glucose in the serum or plasma. For the evaluation of the lipid profile, the blood was removed by venipuncture from the patients who had previously eaten their regular diet and had fasted for not less than 12 hours. The serum was separated and the samples were estimated on the same day. The total cholesterol, HDL- C, LDL – C, VLDL- C and triglycerides were determined.

Serum total cholesterol was estimated by method of Allain et al (1974), by using the Autopak test kit which was supplied by Bayer Diagnostics India Limited, Baroda and the fully automatic chemistry analyser, Bayer Express Plus. The Phosphotungstate method was used for the in vitro determination of HDL- C and serum triglycerides were estimated by an enzymatic colorimetric method by using the same kit. LDL- Cholesterol was calculated, based on Friedewald’s equation:

$$\text{LDL cholesterol (mg/dl)} = \frac{\text{Total Cholesterol} - \text{Triglycerides} - \text{HDL} - \text{C}}{5}$$

All the patients underwent clinical examination of ear, nose and throat. The ear canals of the patients were examined through an otoscope and it was made sure that they were free of obstructive wax. The tuning fork tests- the Weber test, the Rinne test, the Absolute bone conduction tests and pure tone audiometry were done for both the ears of all the subjects.

Pure Tone Audiometry

Pure Tone Audiometry is the most routine audiometric evaluation and the resulting pure tone audiogram is widely used as a basic description of the degree of hearing loss. An audiometer is an electronic device that produces pure tones, the intensity of which can be increased or decreased in 5-dB steps. The audiological examination was performed by using a Pure Tone Audiometer, model 500 MK III of the Arphi Company in a sound proof room in the ENT department, Stanley Medical College and Hospital. Ear phones were used to test the hearing by air conduction and a small vibrator which was placed over the mastoid was used to test the hearing by bone conduction. The testing of the hearing loss was up to 120dB, with a +20 dB switch and to maintain this sensitivity of the audiometer, a biological calibration was done every day before starting the test. Both the air and bone conduction were tested for each ear.

Pure Tone Audiometry: Air Conduction Threshold

This test was based on the measurement of the hearing thresholds for a range of pure tones which were presented through earphones according to the ascending method (Hughson – Westlake, up 5, down 10 method) [10]. The air conduction thresholds were measured for the tones of 250, 500, 1000, 2000, 4000 6000 and 8000 Hertz.

Pure Tone Audiometry: Bone Conduction Threshold

Pure Tone Bone Conduction Audiometry is a complement to air conduction audiometry and it provides information about the conductive element of the hearing loss. The pure tones were presented by means of the bone vibrator. The measurement was performed according to the Hughson Westlake, up 5, down 10, method. The bone conduction thresholds were measured for 250, 500, 1000, 2000 and 4000Hz. Masked Pure Tone Audiometry was done if there was a difference of more than 40 dB between the air conduction threshold of the test ear and the bone conduction threshold of the opposite ear or when the air bone gap of the poor ear which was under the test was more than 10 dB [11].

The data which were thus collected were entered into a spreadsheet and were analyzed by using the SPSS software. Descriptive tables were generated and the Chi square test and the ANOVA statistical techniques were used to demonstrate the findings. A p value of less than 0.05 was considered to be statistically significant.

RESULTS

[Table/Fig-1] compares the lipid levels and the hearing loss in the different groups. In group I, out of 30 individuals, only two individuals had deafness (6.7%) and in group II, out of 30 subjects with hyperlipidaemia, 12 had deafness (40%). Group III showed that out of 30 subjects with diabetes and normal lipid levels, 17 had deafness (56.7%) and in group IV, out of 30 subjects with both diabetes and hyperlipidaemia, 19 had deafness (63.3%). The p value was 0.001, which was statistically significant.

[Table/Fig-2] shows the distribution of the hearing loss in the subjects with hyperlipidaemia. Out of 60 subjects with high cholesterol levels, 31 had deafness (51.7%). In 60 subjects with normal cholesterol levels, 19 had deafness (31.7%) and the p value was 0.026, which was significant. Out of 54 patients with high triglyceride levels, 35 had deafness (64.8%) and the p value was 0.001 (significant). Out of 16 patients with low HDL levels, 8 had deafness (50%) and the p value was 0.38, which was statistically not significant. Out of 23 subjects with increased LDL levels, 15 had deafness (65.2%) and the p value was 0.011, which was statistically significant.

AUDIOGRAM ANALYSIS

The audiogram analysis of the mean air conduction thresholds of all the groups at various frequencies is shown in [Table/Fig 3]. For the groups III and IV, even though the hearing loss started at 4000 Hz, the mean air conduction threshold was maximum at 8000 Hz. The audiogram analysis of the mean bone conduction thresholds of all the groups at various frequencies is given in [Table/Fig 4]. For

	Total cholesterol (Mean ± SD)	P value	Number of subjects with hearing loss
Group I (normal subjects, n = 30)	209 ± 44	0.001	2 (6.7%)
Group II (subjects with hyperlipidemia , n = 30)	320.42 ± 38.21		12 (40%)
Group III (diabetics with normal lipid levels, n = 30)	212 ± 25		17 (56.7%)
Group IV (diabetics with hyperlipidemia, n = 30)	293 ± 27		19 (63.3%)

[Table/Fig-1]: Hearing loss in the groups
χ^2 = 23.73; P = 0.001

	No. of subjects with normal hearing	No. of subjects with hearing loss	Statistical values
Subjects with normal cholesterol (n =60)	41 (68.3 %)	19 (31.7%)	χ^2 = 4.94 P = 0.026
Subjects with high cholesterol (n = 60)	29 (48.3%)	31 (51.7%)	
Subjects with normal triglyceride (n = 66)	51 (77.3%)	15 (22.7%)	χ^2 = 21.65 P = 0.001
Subjects with high triglyceride (n =54)	19 (35.2%)	35 (64.8%)	
Subjects with normal LDL-C (n = 97)	62 (63.9%)	35 (36.1%)	χ^2 = 6.49 P = 0.01
Subjects with high LDL-C (n = 23)	8 (34.8%)	15 (65.2%)	
Subjects with normal HDL-C (n = 104)	62 (59.62%)	42 (40.38%)	χ^2 = 0.527 P = 0.467
Subjects with low HDL-C (n = 16)	8 (50%)	8 (50%)	

[Table/Fig-2]: Distribution of hearing loss in hyperlipidemia

Frequencies in Hertz	Mean air conduction thresholds (db) ± SD				F value
	Group I	Group II	Group III	Group IV	
250	15 ± 0.0	15 ± 0.0	15 ± 0.0	15 ± 0.0	F =0.00 ; P= 1.00
500	15 ± 0.0	15 ± 0.0	15 ± 0.0	15 ± 0.0	F=0.00 ; P=1.00
1000	15.19 ± 0.69	15.43 ± 2.44	15 ± 0.0	15 ± 0.0	F=1.14 ; P=0.34
2000	19.29 ± 2.50	20.29 ± 5.35	21.14 ± 6.31	21.51 ± 6.52	F=1.47 ; P=0.23
4000	20.28 ± 2.06	22.14 ± 9.06	23.64 ± 5.43	25.56 ± 5.98	F=7.15 ; P=0.0002
6000	21.38 ± 6.65	23.29 ± 7.7	26.82 ± 7.48	28.56 ± 8.51	F=6.45 ; P=0.0004
8000	22.47 ± 3.44	26.43 ± 14.35	28 ± 9.52	31.63 ± 11.24	F=6.80 ; P=0.0003

[Table/Fig-3]: Audiogram analysis of mean air conduction threshold at different frequencies

	Mean bone conduction thresholds (db) ± SD				F test
	Group I	Group II	Group III	Group IV	
250	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	F =0.000 ; P= 1.000
500	11.11 ± 1.33	11.24 ± 2.67	11.82 ± 2.52	11.86 ± 0.5	F=1.43 ; P=0.24
1000	11.38 ± 1.66	12.39 ± 5.38	13.38 ± 5.68	14.12 ± 6.01	F=2.45 ; P=0.06
2000	11.92 ± 2.16	13.02 ± 8.02	14.10 ± 6.34	14.98 ±4.43	F=2.53 ; P=0.06
4000	12.47 ± 2.82	15.29 ± 11.7	16.66 ± 9.67	20.81 ± 9.3	F=5.85 ; P=0.0009

[Table/Fig-4]: Audiogram analysis of mean bone conduction threshold at different frequencies

the groups III and IV, the hearing threshold increased at 2000 Hz and it was maximum at 4000 Hz.

DISCUSSION

Our study has evaluated the auditory effects of hyperlipidaemia, diabetes and diabetic dyslipidaemia. We found that the prevalence of hearing loss in subjects with hyperlipidaemia was 40% and that in subjects with diabetes, it was 56.7%, while that in subjects with both diabetes and dyslipidaemia, it was 63.3%.

Hyperlipidaemia and Hearing Loss

On analyzing all the groups, the prevalence of hearing loss among the subjects with hypercholesterolaemia was found to be 51.7% [Table/Fig 2] and the results of the present study showed that hyperlipidaemia was a risk factor for hearing loss, which was in concordance with the findings of the study by Michael A. Sikora et al [3], who concluded that the maintenance of chinchillas on a high cholesterol diet can cause a high frequency loss, probably due to the vascular pathology which results from the hyperlipidaemic state.

The analysis of the auditory functions of subjects with hypertriglyceridaemia showed that 64.8% of them were associated with hearing loss [Table/Fig 2]. This was in concordance with the findings of the study by Pan HG et al [12], who found a decrease in the amplitude and the latency of distortion product otoacoustic emissions (DPOAE) in the people with hypertriglyceridaemia. The evaluation of the auditory function in subjects with low HDL showed that 8 out of 16 subjects had deafness, with a p value of 0.38, which was not significant. The prevalence of hearing loss in subjects with high LDL-C was 65.2%, with a p value of 0.01, which was significant. Some authors found a higher incidence of hearing loss in patients with high serum cholesterol level, high triglycerides and increased VLDL levels [13].

The possible mechanism is that hypercholesterolaemia induces phenotypic changes in the microcirculation, that are consistent with oxidative and nitrosative stresses. The superoxides which are generated, participate in a number of reactions, yielding various free radicals. This leads to platelet activation and lipid peroxidation, which are both involved in the initiation and the progression of the atherosclerotic lesions. Thus, therapeutic strategies that act to maintain the normal balance in the oxidant status of the vascular bed may prove to be effective in reducing the deleterious consequences of hypercholesterolaemia [14].

Diabetes and Hearing Loss

We found that the prevalence of hearing loss in subjects with diabetes was 56.7%, which was in concordance with the findings of other studies. According to Friedman et al [15], 55% diabetic subjects had hearing loss. Weng SF et al [16] noted that among the 67 diabetic subjects who were examined, 44.8% of them had profound hearing loss. According to Rozanska – Kudelska et al [17], the diabetic subjects were found to have a 95% incidence of hearing loss by audiometry and they evoked otoacoustic emissions.

Microvascular pathological changes occur in the diabetic states through the following molecular mechanisms: formation and accumulation of advanced glycation end products; increased oxidative stress; activation of the protein kinase C pathway; increased activity of the hexosamine pathway; vascular inflammation and the impairment of insulin action in the tissues [18].

Effect of Both Hyperglycaemia and Hyperlipidaemia on Hearing Loss

We found that diabetes and hyperlipidaemia were the independent risk factors for sensorineural hearing loss and that the combination of these two had the greatest effect on hearing. The increased incidence of hearing loss in the diabetics when there was associated hyperlipidaemia, could possibly be due to the vascular complications which were produced by diabetic dyslipidaemia. The subjects with diabetes have a predisposition to dyslipidaemia. The lipoproteins get glycated, which predisposes them to atherosclerosis. Glycated low-density lipoproteins (LDL) are not recognized by the normal LDL receptors. This increases the plasma half-life of LDL, but the turnover of the glycated high-density lipoproteins (HDL) is twice as fast as that of normal HDL. The advanced glycation end-products (AGEs) bind to the macrophage receptors and stimulate them to secrete Interleukin-1 (IL-I) and Tumour Necrosis Factor (TNF) which cause vessel wall damage, resulting in microvascular disease, atherogenesis and macrovascular disease [9]. Cadoni et al. (2010) [19] hypothesized that saturated fatty acids may play a role in determining the dysmetabolic state in a subset of sensorineural hearing loss patients.

The results of our study are in concordance with the findings of the study by Chapman T. Mc. Queen et al [4], who also analyzed the effect of diabetes, hyperlipidaemia and noise on hearing and found a significant thickening of the basement membrane of the stria vascularis in diabetic rats, which when combined either with hyperlipidaemia or noise, had a very high significance.

Evaluation of the Type of Hearing Loss

The analysis of the auditory function of healthy subjects showed that out of 30, only two of them had hearing loss. Out of these two, one showed hearing loss at the lower and mid frequencies (250Hz-2000Hz) and the other showed hearing loss at higher frequencies (above 2000Hz). The analysis of the mean air and bone conduction threshold of the subjects with diabetes and the subjects with diabetic dyslipidaemia showed that in both the ears, the hearing threshold increased at 2000 Hz and even more so at 4000Hz, with the mean air conduction threshold being maximum at 8000 Hz. These results are in concordance with the findings other studies [6],[7],[13]. Cunningham et al [20] reported lipidosis on the basilar membrane with a greater deposition near the basal turn.

Limitations and Scope for Future Research

The sample size of the present study was relatively small to measure the actual incidence of the hearing loss due to diabetes and dyslipidaemia or both in a particular group of the population. Further studies in this field should include the measurement of otoacoustic emissions and brain stem auditory evoked response for obtaining a clear understanding on the same and for localizing the pathology behind the hearing loss.

CONCLUSION

The subjects with hyperlipidaemia and diabetes had a poorer hearing threshold than the healthy controls. The subjects who had both diabetes and hyperlipidaemia were at an even more increased risk of developing hearing loss. The audiograms of the subjects with diabetes and hyperlipidaemia had no significant air bone gap. The hearing loss was a mild to moderate, progressive, bilateral, sensorineural type of gradual onset which affected predominantly the higher frequencies. The decrease in the hearing acuity was similar to presbyacusis but those who were affected showed a hearing loss which was greater than that which could be expected at their age.

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AUTHOR(S):

1. Dr. Anandhalakshmi Swaminathan
2. Dr. Rajendran Sambandam
3. Dr. Mythili Bhaskaran

PARTICULARS OF CONTRIBUTORS:

1. Assistant professor, Department of Physiology, SRM Medical College Hospital and Research Centre, SRM University, Kattankulathur - 603 203. Tamilnadu, India.
2. Assistant professor, Institute of Otorhinolaryngology, Madras Medical College, Chennai, Tamilnadu, India.
3. Assistant professor, Department of Physiology, Saveetha Medical College, Chennai, Tamilnadu, India.

NAME, ADDRESS, TELEPHONE, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. S. Anandhalakshmi, MD,
Department of Physiology,
SRM Medical College Hospital and Research Centre,
SRM University, Kattankulathur,
Tamilnadu, India.
E-mail: ssathyan2003@gmail.com

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