Etiology of Noise-Induced Hearing Loss (NIHL) and its Symptomatic Correlation with Audiometry Observations in Type II Diabetes

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Abstract Type II diabetic mellitus (DM) is a chronic metabolic disease that impairs normal insulin production and glucose transport to the liver and muscles. In the India, about 1–5% population suffer from diabetes or related complication. So there is need to cure this disease. DM chronic auditory complications may include spiral ganglia atrophy, degeneration of the vestibulocochlear nerve myelin sheath, reduction of the number of spiral lamina nerve fibres, and thickening of the capillary walls of the stria vascularis and small arteries. This study aims to know the incidence of common parameters, blood sugar levels, levels of lipids and the hearing thresholds of individuals. It is a Noise-Induced Hearing Loss research study featuring hearing impairment in transport workers diagnosed as type II diabetic. All individuals were interviewed by various questioners related to listening ability of subjects and underwent a physical examination, blood investigations and audiometry. Hearing impairment was more prevalent among adults with diabetes. Sensory neuron hearing loss is predominant in both study groups. Mixed Bilateral Hearing Loss showed significant *p* value in ($>.001$) by audiometry. The percentage of hearing loss in diabetes (ranges 5.3–28.1%) and in non-diabetics (ranges 3.4–24.1%) and risk factors in diabetes (ranges 22.8–35.1%) over nondiabetics (ranges 17.2–20.1%) which is eye opener. The correlation between type II diabetes and hearing impairment was independent of known risk factors for hearing

impairment, such as noise exposure, build-up wax, ototoxic medication, smoking, tobacco chewing etc.

Keywords Type II diabetic mellitus · Noise induced hearing loss · Audiometric analysis

Introduction

Diabetes mellitus is one of the world's major diseases. It currently affects an estimated 143 million people worldwide and the number is growing rapidly. In the India, about 1–5% population suffer from diabetes or related complication. So there is need to cure this disease. Diabetes is a prime risk factor for cardiovascular disease (CVD). Vascular disorders include retinopathy and nephropathy, peripheral vascular disease (PVD), stroke, and coronary artery disease (CAD). Type II diabetes also affects the heart muscle, causing both systolic and diastolic heart failure. The aetiology of this excess cardiovascular morbidity and mortality is not completely clear. Evidence suggests that although hyperglycaemia, the hallmark of diabetes, contributes to myocardial damage after ischemic events, it is clearly not the only factor, because both pre-diabetes and the presence of the metabolic syndrome, even in normoglycemic subjects, increase the risk of most types of CVD [1–4]. Penido et al., observed during follow up of their subjects with sudden sensorineural hearing loss that the worst results in treatment happened to older subjects and those who had associated disorders: systemic arterial hypertension, diabetes mellitus and dyslipidaemia. However it did not differentiate whether these associated diseases and age were factors which had an isolated or joint impact in the evolution of these subjects [5].

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Managing cardiovascular risk factors in subjects with diabetes does not eradicate these complications. We are only just beginning to understand the complex and multifactorial aetiology of CVD in type II diabetes. This review will attempt to provide an explanation of the current scientific knowledge in this field, from defects in the large blood vessels (macrovasculature) and the small blood vessels (microvasculature) to the less well-understood cellular and molecular mechanisms of CVD in subjects with type II diabetes.

Atherosclerosis is the major threat to the macrovasculature for subjects with and without diabetes. The general pathogenesis of atherosclerosis has been reviewed elsewhere [6] but several factors specific to diabetes are worth mentioning here. Clinically, dyslipidaemia is highly correlated with atherosclerosis, and up to 97% of subjects with diabetes are dyslipidaemia [7]. In addition to the characteristic pattern of increased triglycerides and decreased HDL cholesterol found in the plasma of subjects with diabetes, abnormalities are seen in the structure of the lipoprotein particles [8].

Hearing is the ability to perceive sound. A person suffering from hearing impairment has difficulty in perceiving or identifying sound clearly due to auditory problems. The impairment may be unilateral or bilateral. The degree of hearing impairment can be classified into five levels and ability to perceive sound is as listed below:

- *Mild* Difficult to identify soft sound such as whispering.
- *Moderate* Unable to hear clearly what others are saying during conversation. Hearing aids are necessary.
- *Moderately-severe* Unable to clearly hear loud noises such as telephone ring.
- *Severe* Can only hear very loud noises and sounds such as shouting or vacuum cleaner noise.
- *Profound* Difficult to perceive any sound.

Depending on the cause, hearing impairment may be temporary or permanent. Temporary hearing impairments are almost always conducted and are far more common than permanent hearing impairments. Permanent hearing impairments are usually sensorineural, but may also be conducted. The type of hearing impairment that occurs depends on what part of the ear is not working properly. For example, if there is something not working in the ear canal, eardrum, middle ear bones or middle ear space (e.g. Fluid) it may result in a conductive hearing impairment (sometimes called mechanical hearing impairment). If, on the other hand, something is not working in the cochlea, auditory, nerve or brain it more commonly results in a sensorineural hearing impairment (also called nerve hearing impairment). When someone has both sensorineural and conductive hearing impairments, it is called a mixed hearing impairment.

Causes of Hearing Impairment

Congenital Factors

Viral infection during pregnancy, e.g. rubella infection, heredity, congenital defects such as anomalies of the ear, nose or throat, premature birth, birth asphyxia, excessive bilirubin etc.

Acquired Factors

- Eardrum perforation, excessive wax, middle ear effusion or infection, otosclerosis or ear ossicle dislocation, sequelae of childhood diseases (measles and meningitis), head or ear trauma, prolonged exposure to loud noise, medication lead to hearing damage, etc.

Effect of Hearing Impairment on Career Development Parameters

- *Language* Delayed language development with unclear speech and incorrect pronunciation.
- *Emotion and behavior* Easy to have emotional and behavioral problems as a result of difficulties in verbally expressing himself/herself
- *Self-confidence* Lack of self-confidence with poor self-image for being always mistaken to be slow in response
- *Social interaction* Socially excluded by peers due to poor comprehension and expression, or actively avoid social contact and communication
- *Academic performance* Academic performance being affected due to difficulty in receiving the correct messages

Type II diabetic mellitus (DM) is a chronic disease derived from the inadequate production of insulin in the pancreas or from the ineffective use of available insulin. It is characterized by increased blood sugar levels [9] and is a genetically inherited disease [10].

Understanding the difference between a symptom and an aetiology is important in Noise-Induced Hearing Loss (NIHL). In some cases the aetiology is never known. It is common to conduct medical tests to “rule out” pathologies that require further medical attention. Hearing is a complex process, so it should be no surprise that the causes of hearing loss are also complex. Hearing loss can occur because of damage to the ear, especially the inner ear. Hearing occurs when sound waves reach the structures inside your ear, where the sound wave vibrations are converted into nerve signals that your brain recognizes as sound. Ear consists of three major areas: outer ear, middle ear and inner ear. Sound waves pass through the outer ear

and cause vibrations at the eardrum. The eardrum and three small bones of the middle ear (the hammer, anvil and stirrup) amplify the vibrations as they travel to the inner ear. The vibrations pass through fluid in the cochlea, a snail-shaped structure in the inner ear.

Attached to nerve cells in the cochlea are thousands of tiny hairs that help translate sound vibrations into electrical signals that are transmitted to your brain. The vibrations of different sounds affect these tiny hairs in different ways, causing the nerve cells to send different signals to your brain. That's how you distinguish one sound from another.

Diffuse thickening of basal membranes, also observed in the vascular endothelium, is one of the most prevalent morphological findings in DM, referred to as diabetic microangiopathy. Such thickening is more evident on skin capillaries of skeletal muscles, retina, kidney glomeruli, and renal medulla. The pathogenesis of this morphological disorder is yet unclear, but it is directly related to dyslipidaemia. There also are morphological disorders related to the involvement of lower extremity motor and sensory nerves, characterized by injuries to Schwann cells, myelinic degeneration, and axonal damage. The cause of this neuropathy is still controversial, but it may be related to diffuse microangiopathy and the consequent malnourishment of peripheral nerves. Arteriosclerosis, frequently seen in conjunction with DM, may also contribute to the onset of neuropathies, as it interferes with the nutrient transfer rate [11, 12].

Diego et al. showed that DM may cause hearing impairment, but a firm cause-effect correlation has not been described yet. It is known that a series of variables may favour the association of both conditions, but more studies are required to establish the true role these factors play. As seen above, type II diabetic group subjects and hearing impairment may be interdependent components, or even components of a genetic syndrome [10, 13]. The association between DM and hearing impairment is being given a lot of attention. Complaints related to the auditory and vestibular systems and metabolic disorders affecting glycolides and lipids have been reported the main etiologic factors related to hearing impairment, tinnitus, and dizziness [14]. Therefore, the diabetic population must be considered at risk for auditory conditions [15].

An audiogram is a graph that shows the audible threshold for standardized frequencies as measured by an audiometer. The Y axis represents intensity measured in decibels and the X axis represents frequency measured in Hertz. The threshold of hearing is plotted relative to a standardised curve that represents 'normal' hearing, in dB(HL). They are the sets of curves representing equal loudness at different levels, as well as at the threshold of hearing, in absolute terms measured in dB SPL (sound

pressure level). Audiograms are produced using a piece of test equipment called an audiometer, and this allows different frequencies to be presented to the subject, usually over calibrated headphones, at any specified level. The levels are, however, not absolute, but weighted with frequency relative to a standard graph known as the minimum audibility curve which is intended to represent a 'normal' hearing. This is not the best threshold found for all subjects, under ideal test conditions, which is represented by threshold of hearing on the equal-loudness contours, but is standardised in an *American National Standards Institute* (ANSI) standard to a level somewhat higher at 1 kHz [16].

Materials and Methods

A cross-sectional, prospective, analytical study was conducted at Department of Shalakya Tantra, D Y Patil University's School of Ayurveda, Navi Mumbai. Noise-Induced Hearing Loss (NIHL) evaluated by physical examination of ear, validated questioners response and audiometry. All ethical guidelines regarding human research were strictly followed. The subjects were recruited after proper information about this project in local as well as in vernacular language, written set of the same instructions has provided to the subject before taking consent.

The biochemical parameters includes fasting blood sugar measured for screening purpose. Individual subject showing blood sugar level more than 126 mg/dl further investigated thoroughly for confirmation of DM as per WHO guidelines [17, 18]. More recently, there has been substantial interest in using it as a diagnostic test for diabetes and as a screening test for persons at high risk of diabetes [19].

Newly diagnosed type II diabetic subjects & proven metabolic disease subjects were included while uncontrolled type I & II Diabetes mellitus with more than 3 years of diabetic age, history of consumption of ototoxic, antilipidemic and antihypertensive drugs in past three months, history of ear surgeries performed in the past, history of ear infections in the past, history of recent infections in the nose, throat or ear were excluded from this study.

Audiometry of both ear is performed for measurement of hearing ability at 4000 Hz.

Validated questionnaire was used for evaluation of degree hearing loss, subjects are requested to listen and read these questioners in sound proof room and investigator recorded subject's response. If subject responded positively for three of more question, subject has eligibility to for audiometry examination. These questionnaires are

Table 1 Descriptive analysis of common parameters

Observation		Groups				p value
		Diabetic (n = 57)		Non-diabetic (n = 29)		
		Count	%	Count	%	
Smoker	Yes	13	22.8	5	17.2	.549
	No	44	77.2	24	82.8	
Tobacco chewing	Yes	18	31.6	6	20.7	.287
	No	39	68.4	23	79.3	
Alcoholic	Yes	20	35.1	5	17.2	.085
	No	37	64.9	24	82.8	
Driving a car	Yes	16	28.1	10	34.5	.540
	No	41	71.9	19	65.5	
Damage to inner ear	Yes	20	35.1	12	41.4	.568
	No	37	64.9	17	58.6	

Table 2 Descriptive analysis of threshold parameters

Observation	Groups					
	Diabetic (n = 57)		Non-diabetic (n = 29)		p value	
	Count	%	Count	%		
Build-up of wax	Yes	28	49.1	9	31.0	.109
	No	29	50.9	20	69.0	
Infection	Yes	24	42.1	11	37.9	.710
	No	33	57.9	18	62.1	
Treatment taken	Yes	34	59.6	10	34.5	.027*
	No	23	40.4	19	65.5	
Rapture ear drum	Yes	22	38.6	8	28.6	.363
	No	35	61.4	20	71.4	
Muffling of speech and other sounds	Yes	38	66.7	18	62.1	.672
	No	19	33.3	11	37.9	
Difficulty in understanding words especially against background noise/or in crowd	Yes	44	77.2	20	71.4	.562
	No	13	22.8	8	28.6	
Frequently asking to others to speak slowly, clearly and loudly	Yes	45	78.9	21	72.4	.498
	No	12	21.1	8	27.6	
Needing to turn -up the volume of the TV or radio	Yes	43	75.4	22	75.9	.966
	No	14	24.6	7	24.1	
Withdrawal from conversation	Yes	35	61.4	12	41.4	.078
	No	22	38.6	17	58.6	
Evidence of some social settings	Yes	31	54.4	11	37.9	.149
	No	26	45.6	18	62.1	

categorised on the basis of their features. The subject in this study evaluated on the basis of following set of questions.

1. *Common parameters for evaluation of hearing impairment* Smoking, tobacco chewing, alcoholics, damage to the inner ear, buildup of earwax and infections.
2. *Clinical parameters for evaluation of hearing impairment* Muffling of speech and other sounds, difficulty understanding words, especially against background noise or in a crowd of people, frequently asking others to speak more slowly, clearly and loudly, needing to turn up the volume of the television or radio, withdrawal from conversations and avoidance of some social settings.

Table 3 Descriptive analysis of clinical parameters

Observation	Groups					
	Diabetic (n = 57)		Non- Diabetic (n = 29)		<i>p</i> value	
	Count	%	Count	%		
Do you have problem in hearing over the telephone?	Yes	44	77.2	18	62.1	.139
	No	13	22.8	11	37.9	
Do you have trouble following the conversation when two or more people are talking at the same time?	Yes	45	78.9	18	62.1	.095
	No	12	21.1	11	37.9	
Do people complain that you turn the TV volume up too high?	Yes	39	68.4	20	69.0	.959
	No	18	31.6	9	31.0	
Do you have to strain to understand conversation?	Yes	40	70.2	17	58.6	.284
	No	17	29.8	12	41.4	
Do you have trouble hearing in a noisy background?	Yes	37	64.9	13	44.8	.074
	No	20	35.1	16	55.2	
Do you find yourself asking people to repeat themselves?	Yes	36	63.2	15	51.7	.038
	No	21	36.8	14	48.3	
Do many people you talk to seem to mumble (or not speak clearly)?	Yes	33	57.9	10	35.7	.05*
	No	24	42.1	18	64.3	
Do you misunderstand what others are saying and respond inappropriately?	Yes	35	61.4	13	44.8	.143
	No	22	38.6	16	55.2	
Do you have trouble understanding the speech of women and children?	Yes	32	56.1	13	44.8	.321
	No	25	43.9	16	55.2	
Do people get annoyed because you misunderstand what they say?	Yes	33	57.9	10	35.7	.05*
	No	24	42.1	18	64.3	

* The Chi square statistic is significant at the 0.05 level. All *p* values are greater than that of 0.05 indicates no significance of difference in the observed proportion of diabetic and non-diabetic except treatment taken (*p* value less than that of 0.05)

Table 4 Noise induced hearing loss (NIHL) percentage analysis by audiometry

Ear affected	Conductive hearing loss (%)			Sensory hearing loss (%)			Mixed hearing loss (%)		
	Mild	Moderate	Severe	Mild	Moderate	Severe	Mild	Moderate	Severe
Right ear	3.1	6.3	4.7	1.6	9.4	15.6	3.1	1.6	10.9
Left ear	9.4	6.3	1.6	10.9	6.3	12.5	1.6	1.6	15.5
Bilateral	3.1	3.1	0.0	4.7	3.1	12.5	1.6	1.6	1.6

3. *Common questions to be asked to subject for hearing impairment evaluation* (1) Do you have a problem hearing over the telephone?, (2) Do you have trouble following the conversation when two or more people are talking at the same time?, (3) Do people complain that you turn the TV volume up too high?, (4) Do you have to strain to understand conversation?, (5) Do you have trouble hearing in a noisy background?, (6) Do you find yourself asking people to repeat themselves?, (7) Do many people you talk to seem to mumble (or not speak clearly)?, (8) Do you misunderstand what others are saying and respond inappropriately? (9) Do you have trouble understanding the speech of women

and children? and (10) Do people get annoyed because you misunderstand what they say?

Results and Discussions

Type II diabetic mellitus (DM) is a genetically inherited disease in which blood glucose and lipid levels are abnormally high due to relative or absolute insulin deficiency. Its clinical manifestation is characterized by metabolic disorders, and vascular and neuropathic complications [16]. Capillary wall thickening and the

Table 5 Noise induced hearing loss (NIHL) percentage analysis by audiometry

Observation		Groups				<i>p</i> value
		Diabetic (n = 57)		Non-Diabetic (n = 29)		
		Count	%	Count	%	
Conductive hearing loss-right ear	Yes	8	14.0	6	20.7	.429 ^a
	No	49	86.0	23	79.3	
Sensory neuron hearing loss-right ear	Yes	13	22.8	6	20.7	.823
	No	44	77.2	23	79.3	
Mixed hearing loss-right ear	Yes	8	14.0	3	10.3	.628 ^a
	No	49	86.0	26	89.7	
Conductive hearing loss-left ear	Yes	11	19.3	2	6.9	.129 ^a
	No	46	80.7	27	93.1	
Sensory neuron hearing loss-left ear	Yes	16	28.1	5	17.2	.269
	No	41	71.9	24	82.8	
Mixed hearing loss-left ear	Yes	9	15.8	4	13.8	.807 ^a
	No	48	84.2	25	86.2	
Conductive bilateral hearing loss	Yes	4	7.0	1	3.4	.504 ^a
	No	53	93.0	28	96.6	
Sensory neuron bilateral hearing loss	Yes	13	22.8	6	20.7	.823
	No	44	77.2	23	79.3	
Mixed bilateral hearing loss	Yes	3	5.3	7	24.1	.010 ^{a,*}
	No	54	94.7	22	75.9	

* The Chi square statistic is significant at the 0.05 level

^a More than 20% of cells in this sub-table have expected cell counts less than 5. Chi square results may be invalid

consequently reduced vessel lumen will more intensely affect the internal auditory artery [17]. Some researchers believe that antipathy is the primary injury connected to hearing loss, while others credit such role to neuropathy, arguing that vessel wall thickening is quite unspecific and also found in other diseases.

More than 20% of cells in this sub-table have expected cell counts less than 5. Chi square results may be invalid. *. The Chi square statistic is significant at the 0.05 level.

Human audiology studies indicate that the thresholds of subjects with peripheral neuropathy were always worse than control group individuals in any frequency. [18]. Average age of other than type II diabetic group subjects is 41.03 years and type II diabetic group subjects are about 42.06 years. Diabetes is associated with an increased risk of hearing loss, and this difference is manifest particularly in adults <50 years old [19]. A paper published by Sakuta et.al., showed that DM is associated with hearing loss in middle-aged individuals [20] concluded that diabetes is associated with an increased risk of hearing loss, and this difference is manifest particularly in adults more than 50 years age, which is not validated absolutely by outcomes of this study.

Observation reported in this study contradict from Sakuta et al., could be because of age group (18–60) years

and type of population (transport workers). Average blood sugar in non-diabetic group is 92.93 mg/dL and in diabetic group is 186.51 mg/dL. PallaviPanchu found the relationship between diabetes and hearing loss was controversial [21]. The age factor plays important role on auditory thresholds in diabetic subjects was found to be clinically and statistically insignificant. Researcher Kakarlapudi [22], Dalton [23] and Yadav et al. [24] conclude similar findings but Taylor and Irwin [25] found a correlation between hearing levels and age of the subjects in the diabetic group. Similar conclusions were drawn by Axelson and Fagerberg concluded that any hearing loss due to diabetes will be additional to that due to age alone [26] which was partial output of this study.

Common parameters enlisted in Table 1 has no significant difference between diabetic and non-diabetic subjects. Smoking is risk factor for type II diabetes development due to insulin resistance [27]. Though smoker, tobacco chewing and alcoholics are risk factors in hearing loss in type II diabetics cases found in this study was less and could not conclude any concrete outcome. Descriptive analysis (Table 2) of threshold parameters showed that significant number ($p > .027$) of patients taken treatment due to hearing loss in diabetic and non-diabetics. Percentage of diabetic versus non-diabetics in other threshold parameters

has no much difference so statistically they are non-significant. Similar observations found in clinical parameters (Table 3) except “Do many people you talk to seem to mumble (or not speak clearly)?” and “Do people get annoyed because you misunderstand what they say?” showed significant p value ($>.05$).

It was also observed that (Table 4) sensory neuron hearing loss in type II diabetics is more predominant followed by mixed hearing loss and conductive hearing loss. Proportion of right, left and both ear hearing loss is equal in sensory neuron hearing loss, other types showed un-predictive trend.

Noise induced hearing loss (NIHL) percentage analysis by audiometry (Table 5) showed significant p value in mixed bilateral hearing loss ($>.01$). All p values are greater than that of 0.05 indicates no significance of difference in the observed proportion of diabetic and non-diabetic except mixed bilateral hearing loss (p value less than that of 0.05).

Conclusion

It was concluded that type II diabetic mellitus is associated with an increased risk of hearing loss. Risk factors predominate severity of ear pathology disturb glucose metabolism, wax buildup, neural problems and ultimate hearing loss. Tendency of verbal questioner feedback may encounter with inter personal understanding of objectives concluded into vague outcome. Hearing loss in controlled diabetic and non-diabetic subjects has not shown any differences except few parameters. Considering scope of subject, number of subjects under sub-titles are inadequate and refrained from conclusion from audiometric measurements.

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Author's Contribution Yadav Meena K, analytical work, data entry, IEC presentation and manuscript writing. Yadav KS, topic guidance, study design, protocol design and supervision of work.

Compliance with Ethical Standards

Ethical Approval All authors are here by declared that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Informed Consent All authors declare that ‘written informed consent was obtained from patients for publication of outcome of this study’ copy of written consent may retrieve from us, if required.

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