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`Hearing impairment in Chronic Kidney Disease with and without Diabetes MellitusType2

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Abstract
Hearing impairment is common in chronic kidney disease (CKD)patients. Studies have observed that when diabetes coexists with CKD, the auditory thresholds become still worse. However, certain other studies differ and claim that CKD, Hypertension and Diabetes independently impact the hearing capacity. Hence, there is a need for further studies. The aim of our study was to find out 'whether among CKD patients, there is an association of diabetes on hearing impairment'. If so, whether other parameters confound the association. The design of the study was simple and focussed. It had a large sample. In this study, we had taken care to employ the current and latest definitions and guidelines for hearing impairment, diabetes and CKD.

Our study had 140 subjectswho were undergoing dialysis for CKD. They were divided into two groups: 70 in the Diabetes groupand 70 in the 'No-diabetes' group. Within the two groups, the gender proportion was equal, 35 in each group. Subjects of all ages were included in a consequential manner.The age ranges between the two groups were comparable. After relevant history and clinical examinations, all the subjects had general laboratory tests and pure tone audiometry. As per the latest World Health Organisation 2019 guidelines, PTA ≥ 20 dB HL was taken as Hearing impairment.

Result: We found general worsening of the auditory thresholds in the Diabetes group, when compared to No-diabetes group. The Odds Ratio of having hearing impairment was 1.78 in the diabetes group. By appropriate statistical tests, the duration of diabetes and its control status (HbA1c) were observed to worsen the presence of hearing impairment. In this study, we did not find any association of the other factors viz. duration of dialysis, hypertension, Body Mass Index, socio economic status, personal habits. However, the confounding effect of age could not be factored into our analysis.

We conclude that routine audiometry must become a part of periodic assessment protocol for dialysis patients and for diabetes patients.

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I. Introduction

Hearing impairment (HI) greatly affects daily living and occupation. But, the hearing-impaired persons do not get the empathy that they deserve.In 2019, in an effort to promote uniformity, World Health Organisation (WHO) simplified the classification[1] of HI (Table 1).

Table 1. WHO 2019 (current) classification of Hearing Impairment[1]

Grade	Name of category	Corresponding PTA value (average of auditory thresholds at 0.5, 1, 2 and 4 kHz in the better ear)
0	No impairment	Better than 20 dB
1	Mild	20 – 34 dB
2	Moderate	35 – 49 dB
3	Moderately severe	50 – 64 dB
4	Severe	65–79 dB
5	Profound	80–94 dB

WHO estimates that worldwide 466 million persons live with HI. This is projected to exceed 630 million in 2030 and 900 million in 2050 (WHO 2018[2]). In India, the National Sample Survey Organisation estimates the prevalence of 'disabling' HI to be 0.3% of the general population (NSSO 75th report 2018[3]). Consistent with the global trend, hearing disability is bound to increasein India also.

HI impairment occurs frequentlyin CKD patients. The reasons are the similarities in the ultra-structure of cochlea and nephron (Gatland 1991[4]). Some studies indicate that dialysis patients who have co-existing diabetes have a higher predilection for HI (Pereira 2019[5]). But, there are conflicting studies also (Hill 2016[6]). They hold that the hearing impairments in CKD, diabetes and hypertension occur independent of each other. Obviously, further studies are required.

Aim

The primary aim of this study was to ascertain the prevalence, the type, the degree of the hearing impairment (HI) in patients with chronic kidney disease (CKD).

Objectives

The severity of CKD is globally assessed by the Glomerular Filtration Rate (GFR). Patients who have a GFR worse than 60 ml/min/1.73m^2 require dialysis (KDIGO 2012[7]). As a worse-case scenario, we decided to do out study in the worst of CKD patients i.e., those who undergo dialysis. The second objective was to identify the association of co-existing diabetes, withhearing impairment in dialysis patients.

II. Methods

This was a prospective observational study of 140 patients undergoing dialysis in a large tertiary teaching hospital namely Government Rangaraya Hospital in the Indian city of Kakinada, Andhra Pradesh. Subjects of all ages and gender were included in a consequential manner. Those having middle ear disease, ear surgery, previous cerebro-vascular accident, meningitis, measles, mumps, and rubella were excluded. The study lasted for 14 months from June 2021. For each of the subjects, we obtained informed consent.

The total sample was divided into two groups: 70 in the 'Diabetes' group and 70 in the 'No-diabetes' group. Within the two groups, the proportion of males and females was equal, 35 in each group. The age ranges between the two groups were comparable. Throughout this study, we followed the latest and current guidelines. For assessing the hearing impairment we followed the latest WHO 2019[1] criteria. For diagnosing and classifying CKD and Diabetes, we adhered to the Clinical practice guidelines 2020[7,8] of National Kidney foundation, Guidelines 2021 by International Diabetes Foundation[9] and Standards of care 2021 of American Diabetes Association[10].

By a questionnaire, the profile of each subject was documented. The durations of dialysis, duration of diabetes, control status of diabetes (HbA1c values) and any complications of diabetes were specifically recorded.The patient's own perception of any hearing loss was recorded. Each subject had a clinical examination.Following that, apure tone audiometry was done conforming to the ISO standards. Air conduction hearing thresholds in the octave frequencies from 250 Hz to 8000 Hz were obtained by the modified Hughson-Westlake procedure. The Pure Tone Average (PTA) was calculated as the average of 0.5, 1, 2 and 4 kHz thresholds for each ear individually. Hearing Impairment was defined as 'PTA worse than 20dBHL in the better ear' .A PTA value of ≥40 dB HL was considered 'disabling' degree of hearing impairment (WHO 2019 criteria[1]). For the purpose of further meaningful analysis, we calculated two mean values of combined auditory thresholds of (i) speech frequencies namely 0.5, 1 & 2 KHz (ii) high frequencies namely 4, 6 & kHz. This strategy of segregated analysis employed in our study, is expected to add meaningful insight.

Statistical Analysis

The profile of the participants wasdone by descriptive statistics. The categorical variables viz. presence of diabetes, hypertension and patient's own awareness of HI, were analysed by Chi-squared test and two tailed Student t test. For statistical testing, we formed a null hypothesis: 'Dialysis patients who have co-existing diabetes, do not show any increase in the prevalenceof hearing impairment, when compared to the dialysis patients without diabetes'.A p value of 0.05 or less,was set as the cut-off to reject the null hypothesis, throughout the entire study.

III. Results and Discussion

There were 140 subjects in the study, divided into two groups: 70 diabetics and 70 non-diabetics. Within the two groups, the proportion of males and females was equal, 35 in each group. Subjects of all ages were recruited in a consequential manner. In the total sample of 140 subjects, more patients belonged to the age band of ≥ 60 years (n = 60, 43 % of the total sample). The next common age-band was 40-59 years (n=50, 36%). The least number, namely 30 patients (21%) were in the age band of ≤ 39 years (Fig 1 and 2).

Fig 1. Age and gender of the subjects (n=140)
The arabic numerals in the pie indicate the no. of subjects

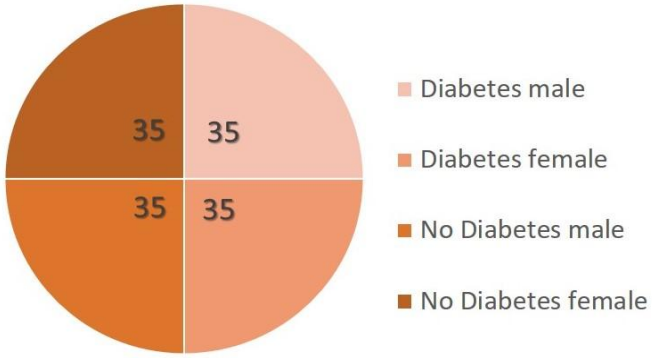
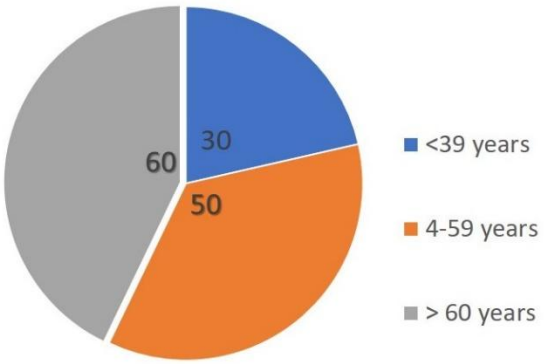


Fig 2. Age-distribution of the study subjects (n=140)
The arabic numerals in the pie indicate the no. of subjects



The Auditory thresholds in the Diabetes group and the No-diabetes group: We did audiometry for allsubjects. The frequency-wise auditory thresholds of each person were entered in the Master chart. Within each group i.e., within Diabetes and No-diabetes groups, we calculated the both-ear-mean of the auditory thresholdsin each frequency (Table 2).

Table 2. The mean auditory thresholds of subjects of both groups, for each frequency.

Tested frequency	Side of ear	The mean auditory thresholds in dB HL		
		Entire study(140)	D group (n 70)	ND group (n70)
500 Hz	Right ear	36.14	48	24
	Left ear	40	53	27
	Mean of both ears	38.07	50.5	25.5
1000 Hz	Right ear	46.6	57.3	35.8
	Left ear	42.7	57.1	28.4
	Mean of both ears	44.65	57.2	32.1
2000 Hz	Right ear	47	61.5	32.5
	Left ear	52	66.5	37.5
	Mean of both ears	49.5	64	35
4000 Hz	Right ear	57.5	70.7	44.2
	Left ear	57.5	70.7	44.2
	Mean of both ears	57.5	70.7	44.2
6000 Hz	Right ear	52.7	62.6	42.7

	Left ear	54.7	66.6	42.7
	Mean of both ears	53.7	64.6	42.7
8000 Hz	Right ear	67.7	76.6	58.7
	Left ear	68	77.2	58.7
	Mean of both ears	67.85	76.9	87.7
p value				0.0246

We observed that the auditory thresholds in the subjects of the Diabetes group were worse when compared to the No-diabetes group. This reduction was noticed at all frequencies and in both the ears. The p value of the differences was 0.0246. Hence, the null hypothesis was rejected. The worsening of auditory thresholds in Diabetes patients were statistically significant. Thus, the presence of diabetes had an additional risk for hearing impairment.

Theodds ratio of diabetics to get Hearing impairment when compared to the non-diabetics: We counted the number of hearing impaired persons(PTA $\geq$ 20 dB HL). Among the 140 subjects of the study, 119 personshad hearing impairment. The remaining 21 subjects had normal hearing. Within the Diabetes group, there were 62 hearing-impaired persons, whereas in the No-diabetes group there were 57 persons cf. Table 3. The Odds Ratio (OR) of having hearing impairment in Diabetes group, when compared to the No-diabetes group was 1.78.

Table 3. The odds of hearing-impaired persons in Diabetes-group and in No-diabetes group

Group	Hearing impaired persons	Normal hearing persons	Odds
Diabetes group n=70	62	8	62/8 = 0.0775
No-diabetes group n=70	57	13	57/13 = 0.0438
Odds Ratio of Diabetic individuals to get hearing impairment		0.0775/ 0.0435 = 1.78	

Association of Hearing impairment with duration of dialysis: On the basis of the number of years on dialysis, the 70 subjects of diabetes group and the 70 subjects of no-diabetes group were divided into two categories within their respective group: short-duration (the number of years lapsed since the first dialysis $\leq$ 4.9 years) category and long-duration (the number of years lapsed since the first dialysis $\geq$5 years) category.

Among the total study sample of 140 subjects,119 persons had hearing impairment. Within the diabetes group, the short-duration category had 28 hearing impaired persons and 6 normal hearing persons. The long duration category had 34 hearing impaired persons and 2 normal hearing persons. The percentage proportions of hearing impaired persons and normally hearing persons within the Diabetes group were tested. The p value was 0.0996 (Table 4). By a similar process, the corresponding p value within the No-diabetes group was 0.1257. Hence, we accept the null hypothesis. Thus, in our study, the number of years lapsed since the first dialysis had no impact on the prevalence of hearing impairment, as such.

Table 4. Percentage proportions of hearing impaired persons in the long-term and short-term dialysis patients (within the respective Diabetes-group and No-diabetes group)

Duration of dialysis & the number of persons with this duration	%age of persons with Hg impairment in this category	%age of persons with normal hearing in this category	Probability values (two tailed Student t test)
Diabetes group, Short-term dialysis $\leq$ 4.9 y: Total 34 subjects – 28 cases were Hg impaired	28/34 *100 = 82.3 %	17.7 %	p value of differences between long term / short term within the Diabetes group 0.0996
Diabetes group, Long-term dialysis $\geq$ 5 y: Total 36 subjects - 34 cases were Hg impaired	34/36*100= 94.4 %	5.6 %	
No-diabetes group, Short-term dialysis $\leq$ 4.9 y: Total 28 subjects - 25 cases were Hg impaired	25/28*100= 89.3 %	10.7 %	p value of differences between long term / short term within the No-diabetes group 0.1257
No-diabetes group, Long-term dialysis $\geq$ 5 y: Total 42 subjects - 32 cases were Hg impaired	32/42*100= 76.2 %	23.8 %	

Association of Hearing impairment with the duration of hypertension: In the entire sample of 140 subjects, the total number of hypertensive patients was 84. Out of them, 60 (71.4%) had hearing impairment. In the next step of analysis, we divided the 84hypertensive patients into short-duration (≤4.9 years) and long-duration (≥ 5 years) categories. Among the 36 short-duration hypertensives, 22 had hearing impairment. Among the 48 long-duration hypertensives, 38 were hearing-impaired cf. Table 5. The probability value 'p' was 0.269 i.e., more than set value of 0.05. Hence, the null hypothesis was accepted. Thus, duration of hypertensiondid not have significant association with hearing impairment, in our study.

Table 5. No. of Hearing-impaired persons by the duration of hypertension

Durationof Hypertension	Proportion of persons with hg impairment	Proportion of persons with normal hearing	p value
Short duration ≤4.9 y Total 36 subjects Hg impaired 22 cases	22/36*100= 61.1 %	38.9 %	
Long duration ≥ 5 y Total 48 subjects Hg impaired 38 cases	38/48*100= 79.2 %	20.8 %	0.269

Association of Hearing impairment with the duration of diabetes: Among the 70 subjects of the diabetes group, the duration of diabetes was less than 5 years in 31 subjects. The remaining 39 patientshad been having diabetes for more than 5 years. Within the 31 short-duration diabetic subjects, 26 subjects (83.9 %) had hearing impairment. Among the 39 long-duration diabetic subjects, 36 (92.3%) patientshad hearing impairment cf. Table 6.

Table 6. Proportion of Hearing-impaired persons as per the duration of diabetes

Duration of diabetes & the number of persons with this duration	%age proportion of Hg impaired persons	%age proportion of Normal-hearing persons	p value
Short-duration diabetes ≤ 4.9 y 31 subjects - 26 Hg impaired	83.9 %	16 %	0.0668
Long-duration diabetes ≥ 5 y 39 subjects - 36 Hg impaired	92.3 %	8 %	

Because the p value was 0.0668, we accepted the null hypothesis, and concluded that the duration of diabetes (the number of years elapsed since the first detection of diabetes) had no association with the occurrence of hearing impairment. However, it should be kept in mind that 'as the duration of diabetes increased, the age of the individual also would have increased'. Hence, the confounding effect of age could not be ruled out. A larger study factoring in the age related hearing impairment may clarify this conundrum.

Association of Hearing impairment with diabetic control, i.e., Hb1Ac levels: HbA1c value ≤ 7.0% is considered good control. Levels 7.1 to 8.4 (poor control) are liable for vascular and neurological complications. Levels of 8.5 and above indicate very poor control.

Among the 70 diabetic subjects of our study, 30 persons had good control of diabetes. Out of them, 26 cases (86%) had hearing impairment. Out of the 26 persons who had poor control, 23 cases (88%) had hearing impairment. Out of 14 cases who had very poor control, 13 cases (92%) had hearing impairment (Table 7). The p value of the differences was 0.0020, much less than 0.05. Hence, the null hypothesis was rejected. Thus, Good control of diabetes gives significant benefit, by way of reduced occurrence of hearing impairment.

Table 7. Number of Hearing impaired persons in each category of HbA1c levels.

Control status & no. of persons having this level	Percentage proportion of Hearing-impaired persons at this level of diabetic control	Percentage proportion of Normal-hearing persons at this level of diabetic control
Good control (HbA1c ≤ 7) 30 subjects - 26 Hg impaired	86%	14%
Poor control (HbA1c 7.1 to 8.4) 26 subjects - 23 Hg impaired	88%	12%
Very poor control (HbA1c ≥ 8.5) 14 subjects – 13 Hg impaired	92%	8%
Probability value of the differences in the number of hearing impaired persons at different levels of diabetic control (p value associated with two tailed Student t test)		0.0020

Association of Hearing impairment with presence of other complications of diabetes:We found 14 subjects had one of the following complications viz. neuropathic pain, impaired vision, foot-ulcer or imbalance. Because of

the small numbers getting fragmented, we did not venture into analysing their association with hearing impairment. A larger study sample might shed light on this issue.

The curious instanceof patients denying any hearing impairment, but showing poor thresholds in audiometry:

In the Diabetes group, 58 subjects were aware of their hearing impairment and 12 denied the same. But, on doing audiometry, only 8 out of the 12 deniers had normal thresholds in both speech frequencies and high frequencies; three had normal thresholds in the speech frequencies and worse thresholds in the high frequencies; one patient had worse thresholds in both frequencyranges.

In the No-diabetes group, 46 persons were aware of their hearing impairment and 24 denied the same. But, on doing audiometry, out of the24 deniers only 13 had normal thresholds in both speech frequencies and high frequencies; 10 had normal thresholds in the speech frequencies and worse thresholds in the high frequencies; one person had worse thresholds in both frequency ranges (Table 8). .

Table 8. Proportion of dialysis subjects who deny any hearing impairment but showing poor thresholds ≥ 20 dB HL in the speech-range frequencies and in the high-range frequencies.

	Number of persons (% in parenthesis)		
	Entire study	Diabetes	No Diabetes
Persons denying HI	36 (26%)	12 (9%)	24 (17%)
Audiometry, Normal in both frequency ranges	21 (15%)	8 (6%)	13 (9%)
Audiometry Normal in speech freq + poor in high freq.	13 (9.5%)	3 (2.25%)	10 (7.25%)
Audiometry Poor in both frequency ranges	2 (1.5%)	1 (0.75%)	1 (0.75%)

We became curious, as to the reason why! We delved deeper. Simply put, many of the deniers had adequate thresholds in the speech frequencies. Because of that, they never had any difficulty in hearing ordinary conversations. That was the reason for their denial of hearing impairment. Percentagewise, this tendency was more evident in patients who had diabetes.

This phenomenon indicates that routine audiometry is essential in all dialysis patients, particularly in those who have co-existing diabetes.

Strength of this study

This study assessed the presence of Hearing impairment (HI) in dialysis patients who also had diabetes. It had a large sample size and was focussed. Global and consensually accepted criteria and guidelines employed throughout the study.

Limitation of this study

Limitation of this study: being a cross-sectional study, causal relationships could not be determined. For that purpose prospective cohorts would be required.

IV. Conclusion

Summary findings of this study were (i)in dialysis patients, the Odds Ratio of having HI to be 1.78 when they also had diabetes, when compared to those without diabetes (ii) good control of diabetes conferred some protection against hearing impairment and (iii)some patients might not even be aware of their HI, because the reduced auditory thresholds HI might be in the frequencies higher than speech frequencies.

We conclude that we can pick up hearing impairment earlier, if we do routine audiometry in all dialysis subjects. Such earlier case-finding will enable us to take guard and start closer control of diabetes.

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