

## Original Research Article

# Hearing threshold of patients with chronic kidney disease undergoing haemodialysis

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## ABSTRACT

**Background:** Chronic kidney disease (CKD) has been recognised as a serious public health issue due to its many associated complications, including hearing loss (HL). The study aimed to determine the hearing threshold of adult patients with CKD undergoing haemodialysis.

**Methods:** This was a prospective, hospital-based study of patients with CKD undergoing haemodialysis in a tertiary hospital in Kaduna, carried out between December 2017 and November 2018. Ethical approval and informed consent were obtained. Data was analysed using SPSS version 20. Statistical analysis was with t test and Chi square and level of significance was set at  $p < 0.05$ .

**Results:** Thirty patients with CKD undergoing haemodialysis were age and sex matched with 30 controls (CKD patients not on dialysis). Mean age for subjects and controls were  $44.6 \pm 14.3$  and  $41.7 \pm 12.5$ , respectively. Mean right ear pure tone average (PTAv) among subjects and the controls were  $32.7 \pm 9.6$  and  $25.6 \pm 6.2$ , respectively. Mean left ear PTAv among subjects and controls were  $33.3 \pm 9.7$  and  $25.8 \pm 6.2$ , respectively. Hearing loss was present in 73.3% and 41.7% among the subjects and controls respectively ( $p < 0.001$ ). Of the 22 ears of subjects that had  $\leq 10$  sessions of dialysis, 13 (59.1%) ears had HL and of the 38 ears that had  $> 10$  sessions of dialysis, 30 (78.9%) ears had HL. The difference between hearing threshold and sessions of dialysis was statistically significant ( $p = 0.001$ ).

**Conclusions:** Hearing thresholds of CKD patients on dialysis was higher than those not on dialysis. Haemodialysis significantly affects the hearing thresholds of CKD patients.

**Keywords:** Chronic kidney disease, Haemodialysis, Hearing loss

## INTRODUCTION

The burden of chronic kidney disease (CKD) is huge especially in developing countries where most patients present in the late stages of the disease.<sup>1</sup> The prevalence of CKD in the community was grossly underestimated in

the past.<sup>2</sup> The WHO statistics revealed that the death rate from intrinsic kidney disease in the year 2002 was up to a million, making CKD the twelfth major cause of death.<sup>2</sup> The national kidney foundation estimated that about 20 million Americans have CKD with another 20 million individuals having an increased risk of developing the

disease.<sup>2</sup> Statistics have shown that, in 2013 alone, there were 2.50 million patients on dialysis worldwide and by 2030, the number of CKD patients on dialysis is projected to reach 6.50 million.<sup>3</sup>

The association between CKD and HL was first reported by Alport almost a century ago.<sup>4-6</sup> He described a case of familial kidney disease associated with HL in a 14 year old patient with a strong family history where all the members were affected.<sup>4</sup> Since then, CKD has been recognised as a serious public health issue due to the increase in its prevalence and also its association with HL.<sup>3</sup>

Various other aetiologic factors have also been linked to hearing loss in patients with renal failure. These include hypertension, diabetes, electrolytes derangement, the use of nephrotoxic and ototoxic drugs and haemodialysis (a treatment option for chronic kidney disease).<sup>7-9</sup> The role of haemodialysis in the causation of sensorineural hearing loss (SNHL) is controversial.<sup>10,11</sup> Some authors have reported reduction in hearing threshold after haemodialysis while others are of the opinion that there was no relation between the two.<sup>10,12,13</sup> The study aimed to determine the hearing threshold of adults patients with CKD undergoing haemodialysis.

## METHODS

This was a prospective, hospital-based study of patients with CKD undergoing haemodialysis in a tertiary hospital in Kaduna. The research was carried out between December 2017 and November 2018. CKD patients who were not on dialysis (and never had dialysis) matched for age and sex were enrolled as controls. Patients were recruited at the nephrology unit of the hospital. Convenience sampling technique was used and all consecutive patients aged 18 years and above attending the nephrology unit and dialysis centre of the hospital during the study period who met the inclusion criteria and gave informed consent were recruited for the study until the sample size was obtained. Sample size was calculated using Fisher's formula,

$$n = \frac{Z^2 pq}{d^2},$$

where,

p=prevalence of CKD in Nigeria (which was 3.6%),<sup>14</sup>

q=p-1,

Z=standard normal deviation, which is 1.96 at 95% confidence interval,

d=degree of precision at 95% confidence interval.

The estimated sample size was approximately 60.

The hospital was a state government owned tertiary hospital with 314 bed capacity located in Kaduna metropolis. It is a tertiary hospital that serves as a referral centre to other hospitals in the state and also to other neighbouring states for medical and surgical services. The hospital had a nephrology unit and a dialysis centre.

Ethical approval was obtained from the hospital's health research ethics committee with protocol number HREC reference number 18-0004. Informed consent was obtained from all participants and participation was voluntary. Data was obtained using a structured investigator administered questionnaire which sought information on demography, history, examination and audiometric evaluation of the participants. Audiological assessment with pure tone audiometry using a clinical audiometer (model graphic digi-IS, USA) calibrated to ISO standard was carried out in the quietest room in the hospital where the mean ambient noise level of the test room was 33.2dB (less than 40dB), using a calibrated sound pressure level meter, model TES1350A made in Taiwan.<sup>15</sup>

The results of the audiometric tests for each ear was recorded separately on an audiogram. For air-conduction test, frequencies recorded include 250, 500, 1000, 2000, 4000, 6000 and 8000 hertz while for bone-conduction test, the frequencies recorded include 500, 1000, 2000 and 4000 hertz. The pure tone average was calculated for each ear at 500, 1000, 2000 and 4000 hertz.<sup>16</sup>

The classification of hearing threshold was normal threshold ( $\leq 25$  dB), mild hearing loss (26-40 dB), moderate hearing loss (41-55 dB), moderately-severe hearing loss (56-70 dB), severe hearing loss (71-91 dB) and profound hearing loss ( $> 91$  dB).<sup>3,8,17</sup> All those with 25 dBHL or less were considered to have normal hearing thresholds while those with more than 25 dBHL were considered to have abnormal hearing thresholds. Patients with stage I and II kidney disease, those with history of ear pathology, hearing impairment preceding onset of renal pathology, patients who were too ill to undergo an audiometric test and those who were below the age of 18 years were excluded from the study.

The data collected was analysed using the statistical product and service solutions (SPSS) software IBM SPSS statistics for windows, version 20 (IBM Corp, Armonk, NY, USA). Descriptive statistics was used to ascertain the frequencies and distribution of the variables. Student t test and Chi square test were used for statistical analysis. The level of statistical significance was set at  $p < 0.05$ .

## RESULTS

Thirty patients with CKD undergoing haemodialysis who were age and sex matched with 30 controls (CKD patients who were not on dialysis) were assessed.

The age range of the subjects on dialysis was 20-67 years with the mean age of 44.6±14.3 while the age range of the controls was 23-68 years with the mean age of 41.7±12.5 years and there was no statistically significant difference between the mean ages of CKD patients on dialysis (subjects) and CKD patients not on dialysis (controls) (t=1.218, p=0.226). Table 1 shows that most of the subjects, 22 (73.3%) and the controls, 20 (66.7%) were above 35 years. The male:female ratio was 2.3:1 in both groups.

The range of PTA<sub>v</sub> among subjects (CKD patients on dialysis) on the right ear was 18.7-57.5 dB with mean PTA<sub>v</sub> of 32.7±9.6 while the range of PTA<sub>v</sub> among the controls (CKD patients not on dialysis) on the right ear was 15.0-41.2 dB with mean of 25.6±6.2. The results

showed that the subject group (CKD patients on dialysis) had higher PTA<sub>v</sub> on the right (mean=32.7, SD=9.6) than the control group (CKD patients not on dialysis) (mean=25.6, SD=6.2). The mean difference (7.1) between the two groups was statistically significant (t=3.385, p=0.001). Similarly, the range of PTA<sub>v</sub> among the subjects (CKD patients on dialysis) and the controls (CKD patients not on dialysis) on the left ear were 17.5-56.2 dB and 15.0-41.2 dB with means of 33.3±9.7 and 25.8±6.2, respectively. The results revealed that the subject group (CKD patients on dialysis) had higher PTA<sub>v</sub> on the left ear (mean=33.3, SD=9.7) than the controls (CKD patients not on dialysis) (mean=25.8, SD=6.2). The mean difference (7.5) between the two groups was statistically significant (t=3.572, p=0.001).

**Table 1: Age and sex distribution of subjects (on dialysis) and controls (not on dialysis).**

Distribution	Subjects (on dialysis)		Controls (not on dialysis)	
	Frequency	%	Frequency	%
<b>Age group (in years)</b>				
≤35	8	26.7	10	33.3
>35	22	73.3	20	66.7
Total	30	100	30	100
<b>Gender</b>				
Male	21	70.0	21	70.0
Female	9	30.0	9	30.0
Total	30	100	30	100

≤=less than or equal to; >=more than.

**Table 2: Hearing threshold of subjects (those on dialysis) and controls (those not on dialysis).**

Hearing threshold (in dBHL)	Subjects (on dialysis)		Controls (not on dialysis)		χ <sup>2</sup>	P value
	Number of ears	%	Number of ears	%		
NHT (≤25)	16	26.7	35	58.3	12.310	<0.001
AHT (>25)	44	73.3	25	41.7		
Total	60	100	60	100		

NHT=normal hearing threshold; AHT=abnormal hearing threshold; dBHL=decibel hearing level.

**Table 3: Degree, type and frequency involvement among subjects and controls.**

	Subjects (on dialysis) (n=44)		Controls (not on dialysis) (n=25)	
	Number of ears	%	Number of ears	%
<b>Degree of hearing loss</b>				
Mild	29	65.9	23	92.0
Moderate	13	29.6	2	8.0
M/severe	2	4.5	0	0.0
Total	44	100	25	100
<b>Type of hearing loss</b>				
Conductive	0	0.0	0	0.0
Sensorineural	42	95.5	25	100
Mixed	2	4.5	0	0.0
Total	44	100	25	100
<b>Frequency involved (kHz)</b>				
Low (0.25-0.5)	6	13.6	12	48.0
Mid (1-2)	7	15.9	0	0.0
High (4-8)	31	70.5	13	52.0
Total	44	100	25	100

**Table 4: Stage of CKD and hearing threshold among CKD patients on dialysis and CKD patients not on dialysis.**

CKD patients	Stage 3		Stage 4		Stage 5	
	Hearing threshold (dB)		Hearing threshold (dB)		Hearing threshold (dB)	
	≤25	>25	≤25	>25	≤25	>25
	Number of ears (%)	Number of ears (%)	Number of ears (%)	Number of ears (%)	Number of ears (%)	Number of ears (%)
<b>On dialysis</b>	0 (0.0)	0 (0.0)	0 (0.0)	8 (100)	16 (30.8)	36 (69.2)
<b>Not on dialysis</b>	21 (65.6)	11 (34.4)	14 (50.0)	14 (50.0)	0 (0.0)	0 (0.0)
<b>Total</b>	21	11	14	22	16	36

CKD=chronic kidney disease; ≤25 dB=normal hearing threshold; >25 dB=abnormal hearing threshold.

**Table 5: Duration of diagnosis of CKD and hearing threshold among CKD patients on dialysis and CKD patients not on dialysis.**

Duration (in years)	CKD patients on dialysis		CKD patients not on dialysis	
	Normal HT	Abnormal HT	Normal HT	Abnormal HT
	Number of ears (%)	Number of ears (%)	Number of ears (%)	Number of ears (%)
<1	8 (30.8)	18 (69.2)	35 (58.3)	25 (41.7)
≥1	8 (23.5)	26 (76.5)	0 (0.0)	0 (0.0)
<b>Total</b>	16	44	35	25

CKD=chronic kidney disease; HT=hearing threshold.

**Table 6: Hearing threshold versus sessions of dialysis.**

Hearing threshold (in dBHL)	≤10 sessions of dialysis		>10 sessions of dialysis		χ <sup>2</sup>	P value
	Number of ears	%	Number of ears	%		
<b>NHT (≤25)</b>	9	40.9	8	21.1	10.705	0.001
<b>AHT (&gt;25)</b>	13	59.1	30	78.9		
<b>Total</b>	22	100	38	100		

NHT=normal hearing threshold; AHT=abnormal hearing threshold; dBHL=decibel hearing level.

Of the 60 ears in the subject group (CKD patients on dialysis), 44 (73.3%) ears had HL and the remaining 16 (26.7%) ears had normal hearing threshold while of the 60 ears in the control group (CKD patients not on dialysis), 35 (58.3%) ears had normal hearing and 25 (41.7%) ears had HL. The difference between the two groups was statistically significant (χ<sup>2</sup>=12.310, p<0.001). Table 2 gives details of hearing thresholds of the subjects (CKD patients on dialysis) and the controls (CKD patients not on dialysis).

Majority of those with HL among the subjects (29/44 ears, 65.9%) and controls (23/25 ears, 92.0%) had mild HL. Sensorineural HL accounted for 95.5% among the subjects and 100% among the control group. Table 3 above shows details of the degree and type of HL and frequency involved.

Of the 30 subjects (60 ears) that were on dialysis, 4 (8 ears) were in stage 4 CKD and 26 (52 ears) were in stage 5 CKD while of the 30 controls (CKD patients that were not on dialysis), 16 (32 ears) were in stage 3 CKD and 14 (28 ears) were in stage 4 CKD. None of the subjects (CKD patients on dialysis) was in stage 3 CKD and none

of the controls (CKD patients not on dialysis) was in stage 5 CKD.

All the 4 CKD patients (8 ears) on dialysis that were in stage 4 CKD had HL. Of the 26 (52 ears) of the CKD patients on dialysis (subjects) that were in stage 5 CKD, 16 (30.8%) ears had normal hearing threshold and 36 (69.2%) ears had hearing loss. For the 16 CKD patients (32 ears) not on dialysis (controls) that were in stage 3 CKD, 21 (65.6%) ears had normal hearing threshold and the remaining 11 (34.4%) ears had HL while 14 (50.0%) ears of the controls that were in stage 4 CKD had normal hearing threshold and the remaining 14 (50.0%) ears had hearing loss. Table 4 above gives details of stage of CKD and hearing loss among participants.

Among the subjects (CKD patients on dialysis), the duration of CKD was less than one year in 13 subjects (26 ears) and in 17 (34 ears) the duration was one year and above while in the control group (CKD patients not on dialysis), the duration of CKD was less than one year in all the 30 controls (60 ears).

For those with duration less than one year among the subject group (26 ears), 8 (30.8%) ears had normal hearing threshold ( $\leq 25$  dB) and the remaining 18 (69.2%) ears had hearing loss ( $> 25$  dB). For those with duration of 1 year and above among the subjects (34 ears), 8 (23.5%) ears had normal hearing threshold and the remaining 26 (76.5%) ears had HL. For those with duration less than one year among the control group (60 ears), 35 (58.3%) ears had normal hearing threshold ( $\leq 25$  dB) and 25 (41.7%) ears had HL ( $> 25$  dB). All the controls (CKD patients not on dialysis) had duration of CKD less than one year. Table 5 shows duration of CKD and hearing loss among subjects and controls.

Of the 30 subjects on dialysis (60 ears), 11 subjects (22 ears) had 10 or less sessions of dialysis and 19 subjects (38 ears) had more than 10 sessions of dialysis.

Of the 11 subjects (22 ears) that had 10 or less sessions of dialysis, 13 (59.1%) ears had hearing loss and the remaining 9 (40.9%) ears had normal hearing threshold. Of the 19 subjects (38 ears) that had more than 10 sessions of dialysis, 30 (78.9%) ears had hearing loss and the remaining 8 (21.1%) ears had normal hearing threshold. The difference between hearing threshold and sessions of dialysis was statistically significant ( $\chi^2=10.705$ ,  $p=0.001$ ). Table 6 gives details of hearing thresholds and sessions of dialysis.

## DISCUSSION

The role of haemodialysis in the causation of SNHL is controversial.<sup>10,11</sup> Some authors have reported reduction in hearing threshold after haemodialysis while others are of the opinion that there was no relation between the two.<sup>10,12,13</sup> Risvi reported a patient with progressive impairment of hearing parallel to progression of CKD, peritoneal dialysis and haemodialysis and they discovered changes in the anatomy of the labyrinth (atrophy, oedema and collapse of the endolymphatic system); they ascribed these changes to osmotic-dysequilibrium induced by the haemodialysis.<sup>18</sup>

This study found 73.3% of subjects (CKD patients on dialysis) had hearing loss compared to 41.7% of the controls (CKD patients not on dialysis) with hearing loss. Lasisi et al reported that 67.0% of the patients they studied had hearing loss at recruitment and 79.0% had hearing loss after three sessions of haemodialysis and they concluded that there was significant deterioration of hearing in CKD patients following haemodialysis.<sup>10</sup> Adekwu et al in a different study in Jos on the effect of haemodialysis on hearing functions in adult patients with CKD reported 69.2% of SNHL among subjects at recruitment and 76.9% after six sessions of haemodialysis.<sup>16</sup> They however, suggested that the use of ototoxic medications during dialysis and the changes in the fluids and electrolytes composition of the endolymph may be responsible for the SNHL in the CKD patients they studied. However, Thodi in their study of hearing in

renal failure patients concluded that even though the method of treatment of CKD may influence the effect of the disease on hearing, the duration of treatment with haemodialysis does not seem to have a significant impact on hearing.<sup>9</sup> Other studies have also shown that duration of haemodialysis did not appear to affect the degree of hearing loss in patients with CKD.<sup>5,8</sup>

In this study, 73.3% and 41.7% of the subjects (CKD patients on dialysis) and controls (CKD patients not on dialysis) respectively had hearing loss and majority (95.5%) of the subjects and all the controls (100%) had sensorineural HL. These findings were similar to other studies conducted in Nigeria, Egypt, India, Iraq and Albania.<sup>5,16,19-21</sup> Electrolyte disturbance and effect of haemodialysis are known to affect the cochlear function in CKD patients and these may partially explain the sensorineural HL in this group of patients.<sup>5</sup>

This study showed worsening of hearing thresholds with increasing duration of diagnosis of CKD. This present study revealed that 18 ears out of the total 26 ears (18/26, 69.2%) of subjects with duration of CKD less than one year had hearing loss while 26 ears out of the total 34 ears (26/34, 76.5%) with duration of CKD of one year and above had HL. All the controls (CKD patients not on dialysis) had duration of CKD less than one year and only 25 ears (25/60, 41.7%) had hearing loss. This finding was similar to what was reported in other studies that showed that HL increases with longer the duration of CKD.<sup>10,19,22</sup> However, Reddy et al, Sharma et al and Sam et al all in India and Henrich et al in USA, Boateng et al in Ghana all found no significant correlation between hearing loss and duration of CKD.<sup>8,17,23-25</sup> The reason for not finding correlation between hearing threshold and duration of CKD in these studies and the current study may be due to the difference in the methodology used. For instant, Reddy et al used a larger sample size and included much younger age group (15-55 years).<sup>8</sup> They also grouped the duration of diagnosis of CKD into  $< 5$  years and  $\geq 5$  years (this present study used  $< 1$  year and  $\geq 1$  year); furthermore they studied all the 5 stages of kidney disease (stage I-V) and not limiting to only those with CKD (stage III-V). These may have resulted in not finding correlation between hearing threshold and duration of CKD in their study.

This study showed that hearing loss increases with advancing stage of CKD in both subjects (CKD patients on dialysis) and controls (CKD patients not on dialysis). Those in stage 5 had worse hearing than those in stage 4 and stage 3. This finding was similar to that reported by Rahman et al in Bangladesh who showed worsening of hearing with advancing stage of CKD.<sup>26</sup> Other studies from India and Nigeria also reported worsening of hearing loss with advancing stage of CKD.<sup>27-29</sup> This finding may suggest that the possibly worst injurious insults to the inner ear may be associated with the last stages of the disease.

This present study revealed that increased number of dialysis sessions was associated with increased frequency of hearing loss ( $\chi^2=10.705$ ,  $p=0.001$ ). Lasisi et al in Ibadan, Nigeria and Adekwu et al in Jos, Nigeria all reported worsening in hearing thresholds of CKD patients following haemodialysis, hence in agreement with the findings of this study.<sup>10,16</sup> Sreedharan et al in their study also found a positive correlation between hearing loss and increasing number of haemodialysis sessions.<sup>30</sup> It is however noteworthy that virtually all those on haemodialysis are in stage 5 CKD and this group of subjects tend to have other factors that may independently contribute to hearing loss, these may include longer duration of disease and poorer renal and biochemical parameters.

However, Nikolopoulos found no significant changes in the audiometric findings before haemodialysis and immediately after a single session of haemodialysis in patients with pre-end stage and end stage renal disease.<sup>31</sup> Similarly, Reddy et al and Sam et al also found no correlation between hearing loss and haemodialysis sessions.<sup>8,23</sup> In their study, Reddy enrolled all patients with renal disease (stage 1-5) and not limiting to only CKD (stage 3-5); further, they grouped them into those that had dialysis for less than three years and those that had dialysis for three years or more.<sup>8</sup> This may have resulted in the failure to find correlation between hearing loss and haemodialysis. Furthermore, that study included younger age group (15 years and above). However, the effect of haemodialysis and the number of dialysis sessions on sensorineural hearing loss is largely unclear in most reported series.<sup>30,32-34</sup>

### Limitation

The limitation of the study was that the hearing test was not carried out in a sound proof booth. Background noise may have affected the hearing thresholds.

### CONCLUSION

This study found that hearing thresholds of CKD patients on haemodialysis was higher than those not on dialysis. The hearing thresholds of the subjects worsen with increasing sessions of haemodialysis. Haemodialysis significantly affects the hearing thresholds of CKD patients.

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