

## Hearing impairment among chronic kidney disease patients on haemodialysis at a tertiary hospital in Ghana

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### SUMMARY

**Background:** Chronic kidney disease is a major public health challenge, globally. Inadequate excretion of metabolic waste products by the kidneys results in circulation of these toxic materials in the body. This can cause damage to tissues and organ systems including the auditory system which can lead to hearing loss.

**Aim:** The study was aimed at determining the prevalence, degrees and types of hearing impairment among Chronic kidney disease patients on haemodialysis in Ghana.

**Methods:** A case-control study involving 50 Chronic Kidney disease patients and 50 age and gender-matched control group was carried out at the Korle Bu Teaching Hospital (KBTH). A structured questionnaire was administered to obtain basic socio-demographic data and case history of the participants. Audiological assessment was performed using a test battery comprising otoscopy, tympanometry and pure tone audiometry in a soundproof booth.

**Results:** Higher hearing thresholds were recorded across all the frequencies tested among the case group than the control group ( $p < 0.05$ ) in both ears. Only sensorineural hearing loss was identified among the cases. The prevalence of hearing loss was 32% among the case group and 12% among the control group. No significant association was observed between hearing loss and duration of Chronic kidney disease ( $p = 0.16$ ), gender of Chronic kidney disease patient and hearing loss ( $p = 0.88$ ), and duration of Chronic kidney disease and degree of hearing loss ( $p=0.31$ ).

**Conclusion:** Our study showed that Chronic Kidney disease patients on haemodialysis are at higher risk of experiencing hearing loss.

**Keywords:** Hearing loss, chronic kidney disease, prevalence, haemodialysis, hearing threshold

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### INTRODUCTION

Each kidney comprises about a million functional nephrons responsible for filtering blood plasma. About 1200 ml of blood enters the kidneys every minute and materials such as wastes, drugs, excess water and ions are filtered out.<sup>1</sup> Through this process of urine formation, the kidneys regulate the blood's pH by excreting  $H^+$  and conserving  $HCO_3^-$ , as well as the levels of ions like sodium, potassium, calcium, chloride and phosphate. The kidneys also maintain blood volume by either conserving or eliminating water. Disruption in the kidneys' function therefore leads to disarray of electrolytes and accumulation of these waste substances in the blood. This subsequently causes damage to tissues and organ systems.

Chronic kidney disease (CKD) refers to a gradual and usually irreversible reduction of glomerular filtration rate (GFR) which can be caused by trauma, genetic disorders, infections and effect of drugs that are toxic to the kidneys.<sup>1</sup> Other disease conditions such as diabetes and hypertension increase the risk of an individual developing kidney failure.<sup>2</sup> About 10% of the world's population is affected by various forms of kidney disease making it a global public health challenge.<sup>3</sup>

The disease accounts for 8% to 10% of medical admissions in Nigeria.<sup>4,5</sup> In Ghana, CKD constitutes 10% of all medical admissions<sup>6</sup> with a prevalence of 46.9% recorded among patients with hypertension.<sup>7</sup> The most affected are males between 20 and 50 years old.

There is a projected rise in the prevalence of CKD in sub-Saharan Africa due to rise in conditions such as diabetes and hypertension. Comparatively, hearing loss has been found to be more prevalent among CKD patients than the general population in different parts of the world. Prevalence rates ranging from 28% to 67% have been recorded in similar studies.<sup>8,9,10</sup> At the time of this study, no work had investigated the burden of hearing impairment among CKD patients in Ghana.

### METHODS

A case-control research design was adopted for the study. Purposive sampling was used to recruit a population of 50 CKD stage 5 (End Stage Renal Disease, ESRD) patients aged 18 to 50 years on hemodialysis, and a control group of 50 age and gender-matched healthy individuals. The study was conducted at the largest haemodialysis centre in Ghana located in a referral hospital due to the heterogeneity of patients presenting for this treatment. The study site also has the largest hearing assessment centre in Ghana. Only Ghanaian patients aged 18 to 50 years, diagnosed with ESRD and on maintenance haemodialysis were included in the case study group. In particular, age was limited to 50 years for purposes of excluding possibility of presbycusis. Age and gender-matched individuals without any history of ototoxic medications within the last three months, as well as those with no chronic diseases such as diabetes, hypertension, renal impairment and rheumatoid diseases constituted the control group.

For both case and control groups, patients and individuals who refused participation, those considered too ill to undergo hearing assessment, and those with family histories of hearing loss, prolonged noise exposure, ear diseases and ear surgery were excluded.

Ethical clearance and approval were respectively obtained from the Scientific and Technical Committee/Institutional Review Board (KBTH-STC/IRB/0004/2016) and the Renal Unit of the referral hospital. The purpose of the study and procedure for data collection were explained to all participants and informed consent forms were signed. Anonymity and confidentiality of participants' information were ensured.

Otoscopy was carried out using a Welch Allyn otoscope to identify structural abnormalities, impacted wax or foreign bodies, ear discharge and perforations. The GSI TymStar version 2 Middle-Ear Analyzer was used for assessing middle ear function. In this study, ear canal volumes between 0.4 and 1.5 cm<sup>3</sup>, middle ear compliance of 0.2 and 1.6 cm<sup>3</sup> and middle ear pressure between -100

and +100 daPa were considered to be normal in accordance with the standards of the British Society of Audiology.<sup>11</sup>

Pure tone audiometry was performed to determine the hearing acuity of the participants by presenting tones via both air and bone conduction using a calibrated Interacoustics AD229e audiometer in a sound-treated booth (ambient noise  $\leq$  30 dBA). Hearing thresholds were established at 250Hz, 500Hz, 1000Hz, 2000Hz, 3000Hz, 4000Hz, 6000Hz and 8000Hz for air conduction and 500Hz, 1000Hz, 2000Hz, 3000Hz and 4000Hz for bone conduction. Air and bone conduction thresholds were compared to identify the type and degree of hearing loss.<sup>12</sup> Instructions to participants in languages of their understanding included:

- *This is a test to determine the lowest intensity at which you can perceive each frequency*
- *Sit down quietly and listen attentively*
- *Do not fidget with the headphone or bone vibrator*
- *Anytime you hear the tone, indicate by pressing the response button no matter how faint it sounds*

Sound frequencies between 250 and 500 Hz were considered low, while 1000 Hz and 2000 Hz, and 4000 to 8000Hz were defined as mid and high respectively. The threshold for each frequency was established using the Hughson-Westlake method. Tones were presented between 1 to 2 seconds and in this order; 1000Hz, 2000Hz, 3000Hz, 4000Hz, 6000Hz, 8000Hz, 1000Hz, 500Hz and 250Hz for air conduction tests, and 500Hz, 1000Hz, 2000Hz, 3000Hz and 4000Hz for bone conduction tests. The initial presentations of the tones were done at intensities higher than the expected threshold.

The intensity was decreased by 10 dB anytime a participant responded positively and then increased in 5 dB steps until another positive response was obtained. Thresholds for frequencies were obtained when the participants responded to two out of three presentations at a particular intensity level.<sup>12</sup> Masking was done when air conduction threshold for individual frequencies differed by 40 dB or more between the right and left ear and when air-bone gaps of more than 10 dB was identified. This involved introduction of noise in the non-test ear (NTE) to prevent it from hearing tones intended for the test ear.<sup>13</sup>

The initial intensity level of the masking noise was calculated by adding 5 dB to the air conduction threshold of the NTE. Also, an occlusion effect of 10 dB was added during masking of low frequencies.<sup>13</sup> Narrow band noise was used. Participants were instructed to respond upon hearing the tones and not the steady rushing noise in the NTE (BSA, 2011).<sup>11</sup> Masked thresholds were obtained using the plateau method.

This implies that the participants had to respond to the pure tone at a particular intensity even when the narrow band noise was increased in three 10 dB steps.<sup>12</sup>

A structured questionnaire was used to access participant's demography, etiology and duration of the CKD and current medications. The insert ear tips of the tympanometer probe were discarded after testing each participant. The TDH 49 headphones of the Interacoustics AD 229e audiometer were disinfected with germ-X sanitizing wipes after every test. To ensure consistency, validity and reliability of tests, data collection was done by the same person. The same set of equipment was used to assess each participant. All equipment were calibrated to American National Standards Institute (ANSI S3.6) standards prior to testing.

The data was analyzed with the Statistical Package for Social Sciences (SPSS) version 20 software. Mean hearing thresholds of CKD patients and controls were compared and independent *t*-test was used to determine significance of the difference. Test of associations between duration of CKD, gender of CKD patients and hearing loss were conducted using Pearson's chi-square while Spearman's correlation test was used to ascertain the correlation between duration of CKD and degree of hearing loss. All analyses were done at 95% confidence level.

**RESULTS**

Majority (64% and 60%) of the participants in both case and control groups were males. The mean ages of the case and control groups were 33.18 ± 8.32 years and 31.90 ± 6.86 years respectively. However, there was no significant difference between the mean ages of the two groups [*t*<sub>(100)</sub> = 0.839, *p* = 0.40].

**Etiology and Duration of CKD**

Table 1 shows the causes of CKD among the patients. Hypertension was the most prevalent (50.0%) cause while obstructive uropathy was the least cause of CKD (4%). The CKD patients were grouped into two based on the duration of disease. Most (60%) of them had suffered CKD for more than 5 years.

**Table 1** Etiology, duration of CKD and medications

Variable	Causes	n (%)
Etiology	Obstructive uropathy	2 (4.0)
	Hypertension	25 (50.0)
	Chronic glomerulonephritis	10 (20.0)
	Hypertension and Type 2 diabetes melitus	13 (26.0)
Duration of CKD	Less than 5 years	20 (40.0)
	5 years and above	30 (60.0)
Medications	Supplements	50 (100.0)
	Anti-diabetics drugs	12 (24.0)
	Anti-hypertensives	38 (76.0)

Unknown ototoxic drugs such as anti-hypertensives, anti-diabetic, iron and bicarbonate supplements were mostly used by the patients.

**Tympanometry and Pure Tone audiometry results**

All the participants presented with normal tympanograms (type A) in both ears indicative of normal middle ear function. Generally, the mean thresholds of the CKD patients across the different frequencies tested in both ears were higher than the non-CKD individuals (Tables 2 and 3).

There was a significant difference between the hearing thresholds of the cases and controls at each tested frequency with *p*-values ranging from 0.00 to 0.04 at 95% confidence level.

**Table 2** Mean air conduction thresholds  
*Mean air conduction thresholds (dBHL)*

Frequency (Hz)	Ears	Cases	Controls
		Mean ± s.d	Mean ± s.d
250	Right	27.60 ± 10.61	16.30 ± 7.48
	Left	25.70 ± 7.83	14.60 ± 6.46
500	Right	24.80 ± 7.21	16.90 ± 5.79
	Left	24.10 ± 7.84	14.40 ± 7.32
1000	Right	22.20 ± 6.86	16.90 ± 6.84
	Left	20.90 ± 6.75	16.20 ± 5.94
2000	Right	20.95 ± 7.74	16.10 ± 6.49
	Left	22.80 ± 9.04	15.10 ± 6.02
3000	Right	26.10 ± 10.07	14.50 ± 6.80
	Left	26.80 ± 10.29	18.20 ± 8.07
4000	Right	29.00 ± 11.65	18.60 ± 6.39
	Left	28.20 ± 11.83	17.30 ± 7.43
6000	Right	33.60 ± 11.02	19.80 ± 6.39
	Left	32.90 ± 16.04	18.70 ± 8.38
8000	Right	37.50 ± 16.17	22.30 ± 7.51
	Left	38.10 ± 17.46	23.44 ± 7.23

**Table 3** Mean bone conduction thresholds  
*Mean bone conduction thresholds (dBHL)*

Frequency (Hz)	Ears	Cases	Controls
		Mean ± s.d	Mean ± s.d
500	Right	7.20 ± 8.93	2.90 ± 4.29
	Left	7.80 ± 10.41	3.40 ± 4.09
1000	Right	7.70 ± 7.37	3.30 ± 4.90
	Left	7.80 ± 6.93	2.90 ± 3.79
2000	Right	9.10 ± 8.61	3.80 ± 5.58
	Left	7.70 ± 6.93	2.90 ± 3.79
3000	Right	10.90 ± 13.04	3.40 ± 4.20
	Left	10.70 ± 11.87	3.60 ± 4.29
4000	Right	14.00 ± 14.64	3.60 ± 5.10
	Left	14.50 ± 14.37	3.80 ± 4.80

The mean air conduction thresholds of the various frequencies among the CKD patients were used to plot an audiogram to ascertain the configuration of the hearing loss. A dome or tent-shaped configuration was observed in both ears (Figure 1).

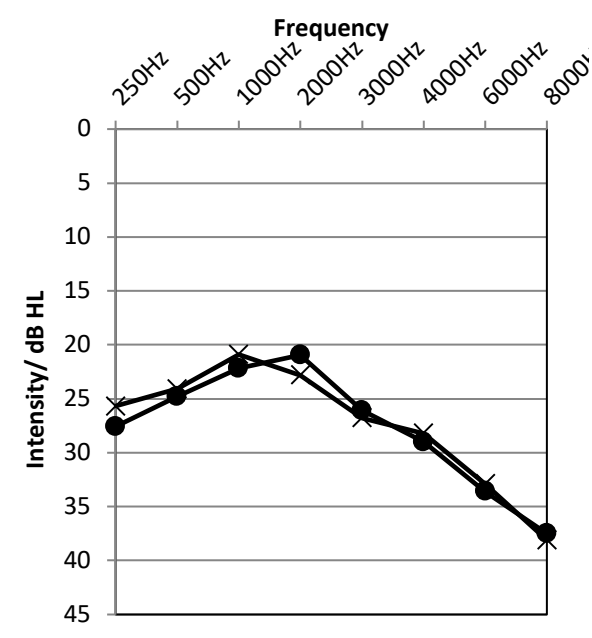


Figure 1 Configuration of hearing loss

Hearing impairment was identified in 16 (32%) of the cases and 6 (12%) of the controls. The impairment was present in both ears among 10 of the cases and 4 of the controls, while the remaining had unilateral losses respectively. The only type of hearing loss present in this study population was SNHL. This was characterized by the presence of normal tympanogram and absence of air-bone gap across all the frequencies tested. The degree of hearing loss ranged from mild to moderately severe among the cases whilst only mild hearing loss was recorded among the controls (Table 4).

Association between duration of CKD and hearing loss was tested using chi-square at 95% CI. Statistically, there was no significant association between duration of CKD and hearing loss among this study population [ $\chi^2(1, N = 50) = 0.035, p > 0.05$ ], as shown in Table 5.

Also, statistical analysis of the data gathered using Spearman's correlation test indicated no significant correlation between the duration of CKD and degree of hearing loss ( $R_s = 0.21, n = 26, p > 0.05$ ). Although more male CKD patients ( $n = 10$ ) than females ( $n = 6$ ) presented with hearing loss, the statistical analysis showed no significant association [ $\chi^2(1, N = 50) = 0.02, p > 0.05$ ] between gender and hearing loss among the study population.

Table 4 Types and degrees of hearing loss

Variable	Cases	Control
	n (Ears) (%)	n (Ears) (%)
Normal hearing	74 (74.0)	90 (90.0)
Conductive	-	-
Sensorineural	26 (26.0)	10 (10.0)
Mixed	-	-
Total	100 (100.0)	100 (100.0)
Normal hearing	74 (74.0)	90 (90.0)
Mild	20 (20.0)	9 (9.0)
Moderate	4 (4.0)	1 (1.0)
Moderately severe	2 (2.0)	-
Total	100 (100.0)	100 (100.0)

Table 5 CKD duration, hearing loss and degree of hearing loss

CKD Duration	Number of ears		p-value	Degree of hearing loss				p-value
	Normal	Hearing loss		Mild	Moderate	Moderately severe	Total	
< 5 years	30	10	0.85	8	2	0	10	0.31
5 years and above	44	16		10	14	2	16	

More self-reported hearing losses were recorded than those diagnosed using pure tone audiometry. Majority of the patients indicated that the onset of hearing loss was gradual while the rest reported it was sudden. More than half of the patients complained of tinnitus (60%) and the presence of vertigo (56%), usually after dialysis.

## DISCUSSION

CKD is associated with several complications. This study evaluated the hearing function of 50 CKD patients and 50 age and gender-matched controls. It was postulated that there will be a significant difference between hearing thresholds of CKD patients and the non-CKD control group. Several studies have reported significant difference in hearing thresholds between CKD patients and non-CKD individuals. In this study, higher hearing thresholds were recorded across all test frequencies among the case group than the control group.

Statistical analyses using unpaired *t*-test indicated that this difference was significant ( $0.00 < p < 0.038$ ) at 95% confidence level in both ears. The difference could have been caused by the impact of electrolyte imbalance due to CKD or haemodialysis on the inner ear.<sup>14,8</sup> The prevalence of hearing loss recorded in this study was 32.0% among the case group and 12.0% among the controls. This rate is low albeit, consistent with the literature where prevalence in the range of 46.0% to 77.0% has been reported among CKD patients.<sup>15,16,17,18,9</sup>

The difference in prevalence rates can be attributed to difference in sample size, inclusion and exclusion criteria, test protocols and hearing loss criterion. For instance, the addition of distortion product otoacoustic emission (DPOAE) test to pure tone audiometry raised the percentage of detected hearing loss in one study but the exact difference was not stated.<sup>20</sup> However, DPOAE was not measured during this study. This may account for the relatively low prevalence recorded.

The degree of hearing loss observed among the cases ranged from mild to moderately severe. Mild hearing loss was most prevalent at 76.9%. This is similar to the findings of another study where 50% of the patients presented with mild hearing loss, 13% had moderate hearing loss and 0.5% had moderately severe hearing loss.<sup>19</sup> On the contrary, others found only moderately severe to severe hearing loss among their study population.<sup>20</sup>

The mean hearing thresholds in this study suggest that the low and high frequencies were more affected than the mid frequencies. The worse thresholds were recorded at high frequencies. This produced a dome-shaped audiogram (Figure 1) for both ears. This is consistent with findings in the literature.<sup>21,22,23</sup>

A study attributed the low frequency SNHL to excessive build-up of endolymph in the inner ear since they recorded an improvement in the thresholds of the low frequencies (125Hz and 250Hz) after dialysis suggesting a reversal of the fluid build-up.<sup>21</sup> Our study did not involve pre and post-dialysis hearing assessment. The finding of this work contradicts the results of other authors who identified hearing loss only in the high frequencies (4000 – 8000 Hz).<sup>17,19,24</sup>

It was hypothesized that there will be a significant association between the duration of CKD and hearing loss. The cases were divided into two groups based on duration of CKD. Group one comprised patients who had suffered CKD for less than 5 years while those who suffered CKD for 5 years and above formed the second group. Statistically, no significant association between hearing loss and duration of CKD [ $\chi^2(2, N = 50) = 1.974, p = 0.16$ ] was found. Hence, this hypothesis was not supported. This is contrary to findings reported in the literature where significant correlations between duration of CKD and hearing loss were observed.<sup>8,25,19</sup> However, Zeigelboim and colleagues<sup>18</sup> observed that hearing loss progressed significantly in older CKD patients (40 – 59 years old) but not in the younger ones (30 – 39 years old). The CKD patients involved in this study were relatively young; hence the reason for no association between CKD duration and hearing loss.

It is also important to note that increases in CKD durations imply increases in the patients' age. In a study involving 200 CKD patients in India, a significant correlation between duration of CKD and degree of hearing loss was recorded.<sup>19</sup> Another author<sup>8</sup> observed a relation between the two variables among 50 CKD patients but test for statistical significance was not stated. The results from the current study showed a weak positive correlation which was not significant at 95% confidence level.

Generally, men are more likely to suffer hearing loss than women. Odds of hearing loss was reported to be 5.5 times higher in men compared to women among the American population.<sup>26</sup> This phenomenon has been attributed to lifestyle, nature of occupation and health-seeking behaviour of men. Among CKD patients, this study as well as other authors observed no correlation between gender and hearing loss.<sup>25,27</sup> This implies that CKD equally affects the auditory function of both men and women.

Less than half of the population (48%) of CKD patients reported that they perceived reductions in their hearing level. However, hearing thresholds obtained were within normal in some cases. This may be attributed to limitations with respect to the test battery or response bias on the part of the patient. Most patients (60.0%) reported that the onset of the hearing loss was gradual, while the rest indicated reported it was sudden.

More than half (56% and 60%) of the patients complained of fluctuating tinnitus and vertigo usually after dialysis. The tinnitus may be caused by hypertension since some of them described it to be pulsating. It can also be associated with the noisy environment of the dialysis unit. Equally, another study recorded dizziness among 50.0% of CKD patients which supports the findings of this study.<sup>28</sup>

Based on the study outcomes, it is recommended that routine hearing assessments should be included in the protocol for managing patients with CKD. This will allow early detection of hearing loss for prompt intervention. Other studies to compare the hearing function of CKD patients before and after haemodialysis and also with those on other treatment regimens are also recommended.

### Limitations

The study was limited by the absence of other test batteries such as otoacoustic emissions and ultra-high frequency pure tone audiometry in the determination of hearing loss among CKD patients. Also, the criteria used in selecting the samples did not exclude CKD patients with conditions like hypertension and diabetes.



## CONCLUSION

Our study showed a significant difference in hearing thresholds in CKD patients and the control group across all tested frequencies. However, vast differences occurred in the high frequencies. This study therefore has concluded that CKD patients are at higher risk of experiencing hearing loss than non-CKD individuals. There was no significant association between duration of CKD, gender and hearing loss.

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