**Original Article**

# Hearing Assessment in Pediatric Patients with Chronic Kidney Diseases.

**Sawsan Moselhy[1], Ghada Moharram[2], Mostafa Yahia[1], Dina E. Sallam[1]**

**1-** Department of Pediatrics, Faculty of Medicine, Ain Shams University, Egypt.

**2-** Department of Otolaryngology, Faculty of Medicine, Ain Shams University, Egypt.

**Abstract**

**Introduction:** Many similarities exist between the nephron & ear infrastructures, making them vulnerable to same risk factors. Idiopathic sensory neural hearing loss is frequent in pediatric patients with chronic kidney disease (CKD).

**Aim of the study**: Determine the prevalence, type, & degree of hearing impairment in pediatric CKD patients.

**Methods**: This cross-sectional study was carried out at pediatric dialysis & nephrology unit at Children's hospital & Audiology unit, Faculty of Medicine Ain Shams University, included 45 CKD patients' stage 2-4, 45 CKD patients' stage 5 on hemodialysis, & 90 children as controls. Detailed history, physical, otological examinations & audiological assessment by standard pure tone audiometry, speech audiometry & tympanometry, also some laboratory investigations were done for all.

**Results**: pure tone audiometry showed 16.6% of CKD patients with hearing loss mainly sensory neural hearing loss (SNHL); (53.3%), which was significantly higher compared to the control group ($p < 0.001$). A mild degree of high-frequency hearing loss was frequently reported. These findings weren't significantly different between dialysis & non-dialysis patients. Regarding speech discrimination scores, controls had a higher significant change compared to CKD patients. Regarding Tympanometry test results, most of CKD patients & the controls had normal middle ear pressure.

**Conclusion & recommendations**: High-frequency SNHL is not uncommon in CKD pediatric patients. It's recommended to do a routine audiological evaluation & follow up for early diagnosis & intervention.

**Key words:** CKD, pure tone audiometry, speech audiometry, SNHL, tympanometry

**Running Title:** Hearing Assessment in Pediatric Patients with Chronic Kidney Diseases.

**Corresponding author: Dina Ebrahem Sallam**

Department of Pediatrics, Pediatric Nephrology, Faculty of Medicine, Ain Shams University, Cairo, Egypt.

**Email:** dinaebrahim2008@gmail.com, dinaebrahim2008@med.asu.edu.eg

**Phone:** 01115132098

## INTRODUCTION

Chronic kidney disease (CKD) is a major risk factor for many morbidities, including stunted growth, electrolyte disturbances, renal osteodystrophy, cardiovascular disease, & hence cardiovascular mortality in addition to renal replacement therapy related complications [1, 2]. Many anatomical, physiological, pharmacological, & pathological similarities exist between the nephron & stria vascularis of the cochlea, both contain epithelial structures in close contact with their vascular supply. In addition to this basement membrane-lined, intercellular channels exist both in the glomerulus &the stria vascularis [3].

As CKD progresses, the formation & accumulation of uremic toxins will lead to adverse biological effects by inflammation, immune dysfunction, vascular disease, & platelet dysfunction which all increase the risk of cognitive impairment by 65% & is related to hearing impairment [2]. Also, factors such as the osmotic alterations caused by hemodialysis, similarities in antigenicity between the labyrinth &the kidney, uremic neuropathy &ototoxins contribute to process of hearing impairment in CKD patients [4, 5].

Idiopathic sensory neural hearing loss (ISNHL) frequently occurs in patients with CKD, which not only influences the child's health, but also have long term impact on life, so screening & prompt treatment of hearing abnormalities is mandatory in CKD patients [6].

**Aim of the study:** to determine the prevalence, type & degree of hearing impairment in pediatric patients with CKD & to evaluate the relationships of various possible etiological factors with hearing impairment.

## METHODS

A cross-sectional analytical study was carried out at pediatric dialysis, nephrology unit children's hospital and Audiology unit, otolaryngology department faculty of medicine, Ain Shams University, during the period between January 2020 till January 2022. This study included 90 CKD pediatric patients following up regularly at our unit & 90 apparently healthy age & gender-matched controls. CKD patients were divided into two groups: Group 1: forty-five CKD patients not on dialysis (CKD 2 to 4) & Group 2: forty-five CKD patients on regular hemodialysis (CKD 5d).

Our inclusion criteria were compliant patients between 4 to 18 years old, with non-syndromic CKD stage 2 to 5, while exclusion criteria were patients known with history of previous hearing problem, chronic ear infection, family history of hearing loss, or primary renal diseases with anatomical abnormalities in the ear or hearing affection as Alport's syndrome, diabetes mellitus, in addition to who underwent kidney transplantation, were excluded from the start. All patients were subjected to the following: detailed history taking focusing on demographic data of the patients, primary pathology, duration of renal disease & dialysis, type of dialysis & medication history. Physical examination was done included vital data, anthropometric measures & complete otological examination were done for all study groups to exclude abnormalities.

All subjects underwent basic Audiological assessment in the form of

(after dialysis session for patients with CKD 5 on regular hemodialysis):

**1.** Pure tone audiometry: to determine the type, degree, and configuration of hearing loss by conventional or play techniques according to the age. This includes both air conduction thresholds (250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, 8000 Hz) and bone conduction thresholds (500 Hz, 1000 Hz, 2000 Hz, 4000 Hz) [7].

**2.** Speech audiometry: it comprised speech reception threshold (SRT) using Arabic bisyllabic words for children [8] and speech discrimination score using Arabic Phonetically Balanced words for children [9].

**3.** Tympanometry: to measure middle ear pressure and to diagnose middle ear pathology.

**Laboratory investigations were done including** hemoglobin level, iron, lipid, metabolic bone profile, sodium, and potassium. Ethical consideration: Oral & informed consent was taken from the patients & caregivers; the work was approved by the Research Ethics Committee with approval number MS 58 / 2020.

### Statistical Analysis

The collected data was revised, coded, tabulated, &introduced to a PC using the Statistical Package for Social Science (SPSS 25). Data was presented &suitable analysis was done according to the type of data obtained for each parameter. Numerical data were summarized as means & standard deviations (SD). While qualitative data were described as frequencies &percentages. Comparison between two groups for numerical variables was done using Student's t-test. The relation between qualitative data was done using the Chi-square test. Stepwise logistic regression was applied to the significant variables within the univariate analysis using the forward likelihood ratio method. The odds ratio (OR) &its 95% confidence intervals (CIs) were calculated to estimate the risk. Probability (p-value) equal to or less than 0.05 is considered significant.

## RESULTS

The median age of our patients was 8 (4 - 17), where 46 (51.2%) were males, & 44 (44.4%) were females, with mean disease duration of.91±1.74 & 4.51±2.48 years, for pre-dialysis & dialysis groups respectively. The mean duration of hemodialysis was 2.93±1.99 years in the CKD5d group. The control group had 49 males (54.4%) & 41 females (45.6%) with a median age of 9 (5- 17) years with no significant difference compared with the patients **(Tables 1& 2)**.

The most common etiology of CKD among our patients was congenital anomalies of Kidney & urinary tract (CAKUT); (30 patients, 33.33%), followed by chronic glomerulonephritis (17 patients, 18.8%), ciliopathy (16 patients, 17.7%), Podocytopathy (16 patients, 17.7%), chronic tubulointerstitial nephritis (4 patients, 4.4%), global glomerulosclerosis (3 patients, 3.3%), thrombotic micro-angiopathic anemia (3 patients, 3.3%) and post Wilms' tumor (1 patient, 1.1%). %). The commonly used medications were anti-hypertensive medications in the form of angiotensin converting enzyme inhibitors, angiotensin receptor blockers & calcium channel blockers, also vitamin D, calcium, phosphate binding agents, iron & erythropoietin were used, with no statistically significant difference between

all of them regarding the currently used medications (p=0.87). There were no obtained history of ototoxic medications uses. The baseline weight, height, & body mass index (BMI) standard deviation scores of the patients' groups were significantly ($p < 0.001$) lower than the control group. Both systolic (SBP) & diastolic blood pressures (DBP) were significantly higher among patients in comparison to the control group ($p< 0.001$); **(Table 3).**

**Table 1:** Demographic characters of the studied groups.

| Variables | | Patient group (n = 90) | | Control group (n = 90) | | p-value |
|---|---|---|---|---|---|---|
| | | No. | % | No. | % | |
| Age | Median (Range) | 8 (4 - 17) | | 9 (5- 17) | | 0.56 |
| Gender | Male | 46 | 51.1% | 49 | 54.4% | 0.654 |
| | Female | 44 | 48.9% | 41 | 45.6% | |

**Table 2 :** Demographic characters of the CKD patients

| Variables | | Group 1 (non-dialysis) (n=45) | Group 2 (On dialysis) (n=45) | P-value |
|---|---|---|---|---|
| **CKD duration (Year)** | **Mean± SD** | **2.91±1.74** | **4.51±2.48** | **<0.001** |
| **Hemodialysis duration (Year)** | **Mean± SD** | **0** | **2.93±1.99** | **------** |
| **Age (year)** | **Median (Range)** | 8 (4 - 16) | 8 (5 – 17) | 0.468 |
| **CKD stage** | **Stage 2** | 19 | 0 | **<0.00** |
| | **Stage 3** | 13 | 0 | |
| | **Stage 4** | 13 | 0 | |
| | **Stage 5** | 0 | 45 | |
| **Diagnosis** | **CAKUT (n=30, 33.3%)** | **13** | **17** | **0.346** |
| | **Chronic glomerulonephritis (n= 17, 18.9%)** | 11 | 6 | |
| | **Ciliopathy (n= 16, 17.8%)** | **9** | **7** | |
| | **Podocytopathy (n= 15, 16.7%)** | **8** | **8** | |
| | **Chronic tubulo-interstitial nephritis (n= 4, 4.4%)** | **2** | **2** | |
| | **Global glomerulosclerosis (n= 3, 3.3%)** | **1** | **2** | |
| | **Thrombotic micro-angiopathic anemia (n= 3, 3.3%)** | **0** | **3** | |
| | **Post Wilms' tumor (n= 1, 1.1%)** | **1** | **0** | |

P value< 0.05 is significant, SD: Standard deviation

**Table (3):** Anthropometric measures & blood pressure parameters of patients & control groups.

| Variables | | Patients (n=90) | Controls (n=90) | P-value |
|---|---|---|---|---|
| **Weight by SD score** | **Mean± SD** | -1.30± 0.89 | 0.01± 0.57 | **<0.001** |
| **Height by SD score** | **Mean± SD** | -1.04± 1.08 | 0.14± 0.93 | **<0.001** |
| **BMI in SD score** | **Mean± SD** | -1.26±.04 | 0.09± 0.25 | **<0.001** |
| **SBP%** | **Mean± SD** | 96.18± 3.88 | 69.56± 10.0 | **<0.001** |
| **DBP%** | **Mean± SD** | 95.93± 3.94 | 71.17± 9.11 | **<0.001** |

BMI: body mass index, DBP: diastolic blood pressure, SBP: systolic blood pressure, SD: Standard deviation

**Auditory findings:** Pure tone audiometry test revealed that 15 CKD patients (16.6%) had hearing loss, {where CAKUT were 4 (4.4%), 2 (2.2%) chronic glomerulonephritis, 3 (3.3%) ciliopathies in the form of 1(1.1%) ARPKD & 2 (2.2%) nephronophthisis, 2 (2.2%) post-TMA & 2 (2.2%) podocytopathy-focal segmental glomerulosclerosis (FSGS)}, while only one (1.1 %) child at the controls had mild unilateral conductive hearing loss (CHL), with statistical significance between patients and controls ($p<0.001$). Sensory neural hearing loss (SNHL) accounted for most of the cases (8 patients, 53.3%), while 5 patients (33.3%) had CHL & the remaining two had mixed results **(Table 4)**. As regards the configuration of hearing loss, 10 cases (66.7%) had high-frequency hearing loss, low frequency in 4 cases (26.7%), while only one patient had a flat curve **(Table 4)**. Degree of hearing loss was significantly different between patients & controls at both ears **(Table 5)**; ($p <0.001$, <0.001 respectively), while no difference between both CKD patients' groups at both ears (p 0.529 & 0.535 respectively); **(Table 6).** These auditory findings were of no significant differences between the dialysis & non-dialysis CKD patients **(Table 7)**.

**Regarding speech audiometry**, the Control group had a higher speech audiometry level than CKD patients bilaterally (right-sided means 94.6 versus 91.1 & left-sided means 95.8 versus 91.74) with a significant difference between both of them ($p =0.014$ in the right ear and $p=0.004$ in the left ear). There was no significant difference between dialysis and predialysis groups in the right ear ($p=0.137$) while there was a significant difference in the left ear ($p=0.043$); **(Tables 8 & 9)**.

**Regarding the tympanometry test**, all CKD patients & control group had normal middle ear pressure, apart from 2 patients (2.2%), who had tympanogram type AS at right ears, whereas it was seen in only one child in the control group unilaterally, which indicated a status of resolving otitis media after correlation with history, clinical examination, and audiological assessment. with no significant difference between them ($p=1$); **(Table 8).**

Laboratory tests including estimated glomerular filtration rate (eGFR), hemoglobin level, serum iron, ferritin, total cholesterol, triglycerides, LDL & HDL cholesterols, serum calcium, phosphorus &alkaline phosphatase, sodium, potassium were not significantly different between CKD patients with or without hearing impairment ($p = 0.51$, 0.76, 0.68, 0.45, 0.58, 0.23, 0.79, 0.70, 0.18, 0.18, 0.24, 0.53, 0.65 respectively); **(Table 10)**.

On trying to study the correlation of hearing impairment with gender, age, durations of CKD & hemodialysis, BMI SDS, both systolic & diastolic blood pressure percentiles, CKD stage & primary disease diagnosis, there were no significant differences between the two groups, with or without hearing loss ($p=0.70,0.79,0.78,0.83,0.50,0.81,077$, 0.46,0.66 respectively); **(Table 11).**

**Table 4 :** Auditory findings in patients & control groups

| Variables | | Patients (n=90) | | Controls (n=90) | | P-Value |
|---|---|---|---|---|---|---|
| | | No. | % | No. | % | |
| Hearing assessment | Normal | 75 | 83.3% | 89 | 98.9% | *< 0.001* |
| | Impaired | 15 | 16.7% | 1 | 1.1% | |
| Type of hearing loss | SNHL | 8 | 53.3% | 0 | 0% | *0.049* |
| | CHL | 5 | 33.3% | 1 | 100% | |
| | Mixed | 2 | 13.3% | 0 | 0% | |
| Configuration of hearing loss | Flat | 1 | 6.7% | 0 | 0% | 0.080 |
| | Low | 4 | 26.7% | 1 | 100% | |
| | High | 10 | 66.7% | 0 | 0% | |

P value< 0.05 is significant. SNHL = Sensory neural hearing loss, CHL= Conductive hearing loss

**Table 5 :** Comparison between CKD groups regarding Pure Tone Audiometry (PTA)

| PTA | | | Group1 (non-dialysis) (n=45) | | Group 2 (On dialysis) (n=45) | | P-value |
|---|---|---|---|---|---|---|---|
| | | | No. | % | No. | % | |
| Rt Ear | Normal peripheral hearing | | 39 | 86.7% | 37 | 82.2% | 0.529 |
| | Impaired | Mild | 5 | 11.1% | 5 | 11.4% | |
| | | Moderate | 0 | 0.0% | 1 | 2.3% | |
| | | Severe | 1 | 2.2% | 2 | 4.5% | |
| Lt Ear | Normal peripheral hearing | | 40 | 88.9% | 39 | 86.7% | 0.535 |
| | Impaired | Mild | 3 | 6.7% | 3 | 6.8% | |
| | | Moderate | 2 | 4.4% | 2 | 4.5% | |
| | | Severe | 0 | 0.0% | 1 | 2.3% | |

**P value< 0.05 is significant.**

**Table 6 :** Degree of hearing loss in all studied groups using Pure Tone Audiometry (PTA)

| PTA | | | Patients (n=90) | | Controls (n=90) | | P-value |
|---|---|---|---|---|---|---|---|
| | | | No. | % | No. | % | |
| Rt Ear | Normal peripheral hearing | | 75 | 83.3% | 89 | 98.9% | *<0.001* |
| | Impaired | Mild | 10 | 11.1% | 1 | 1.1% | |
| | | Moderate | 1 | 1.1% | 0 | 0% | |
| | | Severe | 4 | 4.4% | 0 | 0% | |
| Lt Ear | Normal peripheral hearing | | 78 | 86.7% | 90 | 100% | *<0.001* |
| | Impaired | Mild | 6 | 6.7% | 0 | 0% | |
| | | Moderate | 3 | 3.3% | 0 | 0% | |
| | | Severe | 3 | 3.3% | 0 | 0% | |

**Table 7:** Comparison between CKD groups regarding auditory findings

| Variables | | Group1 (non-dialysis) (n=45) | | Group 2 (On dialysis) (n=45) | | P-value |
|---|---|---|---|---|---|---|
| | | No. | % | No. | % | |
| Hearing assessment | Normal | 39 | 86.7% | 36 | 80.0% | 0.396 |
| | Impaired | 6 | 13.3% | 9 | 20.0% | |
| Type of the hearing loss | SNHL | 3 | 50.0% | 5 | 55.6% | 0.949 |
| | CHL | 2 | 33.3% | 3 | 33.3% | |
| | Mixed | 1 | 16.7% | 1 | 11.1% | |
| Configuration of hearing loss | Flat | 0 | 0.0% | 1 | 11.1% | 0.659 |
| | Low | 2 | 33.3% | 2 | 22.2% | |
| | High | 4 | 66.7% | 6 | 66.7% | |

**Table 8 :** Comparison between the studied groups regarding speech discrimination test score & Tympanogram

| Variables | | | Patients (N=90) | | Controls (N=90) | | P-value |
|---|---|---|---|---|---|---|---|
| | | | No. | % | No. | % | |
| Speech Discrimination test | Right Ear | Mean± SD | 91.1± 11.8 | | 94.6± 5.5 | | ***0.014*** |
| | Left Ear | Mean± SD | 91.7± 12.2 | | 95.83± 5.26 | | ***0.004*** |
| Tympanogram | Right ear | Normal | 88 | 97.8% | 89 | 98.9% | 1.000 |
| | | Type AS | 2 | 2.2% | 1 | 1.1% | |
| | Left ear | Normal | 90 | 100% | 90 | 100% | 1.000 |
| | | Type AS | 0 | 0% | 0 | 0% | |

P value < 0.05 is significant

**Table 9:** Comparison between CKD groups regarding speech discrimination test & Tympanogram.

| Variables | | | Group 1 (non-dialysis) (n=45) | | Group 2 (On dialysis) (n=45) | | P-value |
|---|---|---|---|---|---|---|---|
| | | | No. | % | No. | % | |
| Speech Discrimination test | Right ear | Mean± SD | 93 ± 7.8 | | 89.3 ± 14.8 | | 0.137 |
| | Left ear | Mean± SD | 94.3 ± 8.16 | | 89.1 ± 14.9 | | ***0.043*** |
| Tympanogram | Right ear | Normal | 44 | 97.8% | 44 | 97.8% | 1.00 |
| | | Type AS | 1 | 2.2% | 1 | 2.2% | |
| | Left ear | Normal | 45 | 100% | 45 | 100% | 1.00 |
| | | Type AS | 0 | 0.0% | 0 | 0.0% | |

P value < 0.05 is significant

**Table 10 :** Relation between auditory impairment and laboratory data.

| Variables | Normal (n=75) | | | Impaired (n=15) | | | P-value |
|---|---|---|---|---|---|---|---|
| | Mean | ± SD | Median | Mean | ± SD | Median | |
| **eGFR** | 32.62 | 26.93 | 18.00 | 26.09 | 22.12 | 14.10 | 0.519 |
| **Hb (g %)** | 9.45 | 0.87 | 9.40 | 9.49 | 0.86 | 9.10 | 0.765 |
| **Serum iron** | 80.04 | 22.58 | 83.00 | 81.40 | 22.52 | 87.00 | 0.681 |
| **Ferritin** | 325.65 | 76.62 | 350.00 | 343.87 | 68.57 | 348.00 | 0.452 |
| **Cholesterol (mg %)** | 189.05 | 17.35 | 189.00 | 192.27 | 17.04 | 189.00 | 0.588 |
| **TG** | 106.87 | 58.13 | 71.00 | 129.93 | 66.77 | 162.00 | 0.234 |
| **LDL** | 48.73 | 4.33 | 49.50 | 49.25 | 4.22 | 49.00 | 0.799 |
| **HDL** | 33.34 | 7.31 | 35.30 | 31.83 | 6.92 | 29.70 | 0.709 |
| **Calcium (mg %)** | 8.60 | 1.00 | 8.50 | 8.22 | .98 | 8.00 | 0.181 |
| **Phosphorus (mg %)** | 5.21 | 0.71 | 5.10 | 4.87 | .88 | 5.00 | 0.189 |
| **ALP** | 378.94 | 215.62 | 345.00 | 304.87 | 158.90 | 315.00 | 0.247 |
| **Sodium (mEq/L)** | 132.29 | 6.74 | 133.00 | 133.80 | 5.28 | 135.00 | 0.533 |
| **Potassium (mEq/L)** | 5.04 | 1.29 | 5.00 | 4.65 | 1.44 | 4.50 | 0.654 |

ALP: alkaline phosphatase, eGFR: estimated glomerular filtration rate, Hb: hemoglobin, HDL-cholesterol: high-density lipoprotein, LDL: low-density lipoprotein, SD: Standard deviation, TG: triglycerides

**Table 11 :** Relation between auditory impairment and other clinico-demographic data:

| Variables | | Normal (n=75) | | Impaired (n=15) | | P-value |
|---|---|---|---|---|---|---|
| | | No. | % | No. | % | |
| **Gender** | **Male** | 39 | 52% | 7 | 46.7% | 0.706 |
| | **Female** | 36 | 48% | 8 | 53.3% | |
| **Age (Years)** | | 8.81 | 3.47 | 8.30 | 3.22 | 0.794 |
| **Disease Duration (Years)** | | 3.75 | 2.31 | 3.53 | 2.20 | 0.788 |
| **HD duration (Years)** | | 2.94 | 1.97 | 2.89 | 2.20 | 0.834 |
| **BMI by SD score** | | 15.18 | 2.04 | 14.84 | 1.92 | 0.509 |
| **SBP%** | | 96.09 | 3.90 | 96.60 | 3.85 | 0.810 |
| **DBP %** | | 95.77 | 4.17 | 96.73 | 2.40 | 0779 |
| **CKD stage** | **2** | 18 | 24% | 1 | 6.7% | 0.468 |
| | **3** | 10 | 13.3% | 3 | 20% | |
| | **4** | 11 | 14.7% | 2 | 13.3% | |
| | **5** | 36 | 48% | 9 | 60% | |
| **Diagnosis** | **CAKUT** | 26 | 34.6% | 4 | 26.6% | 0.663 |
| | **Ciliopathy** | 13 | 17.3% | 3 | 20% | |
| | **Podocytopathy** | 13 | 17.3% | 3 | 20% | |
| | **CGN** | 15 | 20% | 2 | 13.3% | |
| | **Post-TMA** | 1 | 1.3% | 2 | 13.3% | |
| | **Global glomerulo sclerosis** | 2 | 2.6% | 1 | 6.7% | |
| | **Wilms' tumor** | 1 | 1.3% | 0 | 0.0% | |
| | **Chronic TIN** | 4 | 5.3% | 0 | 0.0% | |
| **Medications** | **ACEI** | **4** | **5.3%** | **1** | **6.7%** | **0.87** |
| | **ARBS** | 1 | 1.3% | 3 | 20% | |
| | **CCB** | 2 | 2.6% | 0 | 0.0% | |
| | **Vitamin D** | 1 | 1.3% | 0 | 0.0% | |
| | **Calcium** | 1 | 1.3% | 0 | 0.0% | |
| | **Phosphate binder** | 4 | 5.3% | 0 | 0.0% | |
| | **ACEI, vitamin D + calcium + phosphate binder + Iron, Erythropoietin** | 20 | 26.6% | 5 | 33.3% | |
| | **CCB, vitamin D + calcium+ phosphate binder + Iron, Erythropoietin** | 22 | 29.3% | 4 | 26.6 | |
| | **ARBS + vitamin D + calcium + phosphate binder, Iron, Erythropoietin** | 20 | 26.6% | 2 | 13.3% | |

ACEI = angiotensin-converting enzyme inhibitor; ARB = angiotensin receptor blocker, BMI: body mass index, CCB: calcium channel blocker, DBP: diastolic blood pressure, HD: hemodialysis, SBP: systolic blood pressure, SD: Standard deviation

## DISCUSSION

Auditory dysfunction is one of the complications in CKD patients. Studies have suggested the possible link between the linings of the kidney & the inner ear due to similarity in the collagen membranes that aid in maintaining the chemical balance of the fluids of the inner ear &the kidney. These similarities make them vulnerable to the same risk factors, like hypertension, diabetes, electrolyte derangement, the use of nephrotoxic &ototoxic drugs, & hemodialysis [10].

Our studied CKD patients had stunted growth &low BMI in comparison to the healthy control group, which is multifactorial due to disturbances in growth hormone (GH) metabolism &insulin-like growth factor-I (IGF-I), electrolyte abnormalities, nutritional deficiency, metabolic acidosis, uremia, anemia, &inflammation [11].

Elevated systolic & diastolic blood pressures were noted in our studied CKD patients in comparison to the control group. While hypertension in children is rare, with a prevalence of 3%–9%; in children with CKD, the prevalence rises to 50% **[12, 13].** It is multifactorial, where the kidneys are unable to excrete the volume needed to maintain normal BP, addition to the sympathetic nervous system plays a critical role in the progression &persistence of pediatric hypertension **[14].**

The most common etiology of CKD among our patients was congenital anomalies of kidney &urinary tract (CAKUT); (33.3%) followed by chronic glomerulonephritis (18.88%), ciliopathy (17.77%), and Podocytopathy (17.77%).

In accordance with our results, the epidemiological study of Kim et al., 2020 **[15]** reported that the underlying causes of CKD in their population were CAKUT (43.7%), followed by glomerulonephritis (24.9%), cystic kidney disease (9.3%), perinatal problems (6.9%), & others (15.2%).

The overall prevalence of hearing loss in the current study was 16.6% of all CKD patients. This prevalence is somewhat lower than old previous studies, 29%–40% **[16, 17],** but much higher than that in the general population **[18]**. Electrolyte disturbances, water imbalance, hypertension, Vitamin D deficiency, elevated serum urea levels, alterations in the peripheral and central nervous system, uremic neuropathy, all are proposed mechanisms for the prevalent hearing impairment in patients with CKD. The lower prevalence of HL in the current study could be explained using aluminum free water in hemodialysis, owing to its routine surveillance, in addition to the use of aluminum free phosphate binders for all the patients, all of these exclude the possibility of additive risks of dialysis procedure & medication, rather than the primary diagnosis itself in the process of haring loss.

SNHL represent most hearing-impaired cases (8 patients, 53.3%), followed by conductive hearing loss (CHL); (5 patients, 33.3%) and the minority had mixed results (2 patients, 13.3%). These results were in accordance with the studies **[4], [19], [20] & [21],** where hearing loss was common in CKD adult patients, in which SNHL accounted for most cases, On the other hand, studies on CHL in children with CKD are hard to find. We assume that the prevalence of otitis media with effusion might be high in CKD children with lower rate of spontaneous resolution than normal population, especially in those with ESRD, because of the higher susceptibility to infection. However, further investigations are required to identify causes of conductive and mixed hearing loss. Besides otitis media with effusion, cholesteatoma, ossicular anomalies and other syndromes such as: branchio-oto-renal (BOR) syndrome, Fraser syndrome, and CHARGE syndrome may explain the association between conductive or mixed HL and renal impairment.

There were no significant differences between dialysis & non-dialysis groups as regards auditory findings in the current study. The hemodialysis effect on hearing function is still controversial. However, the pathogenesis of hearing loss in CKD patients might be due to either alteration in the electrolyte &fluid composition of endolymph, or excessive amyloid materials accumulation in inner ear

structures. Aluminum toxicity accompanied with chronic dialysis may have a role in hearing loss.

In contrast to our findings, Ghasemi et al., 2004 [22]& Aspris et al. 2008[23] reported that hearing was improved by hemodialysis & explained it by the improvement in neural auditory function following hemodialysis, the plausible explanation of hearing improvement particularly in low-frequency hearing loss is that hemodialysis promotes normalization &stabilization of hydroelectric &metabolic changes in the endolymph that were induced by CKD, leading to enhancement of neural conduction &restore hair cell function. Meanwhile Pandey et al., 2011 [24] illustrated that auditory functions were not affected by hemodialysis.

On assessing the pattern of hearing loss, we found that mild degree of high frequency sensorineural hearing loss is quite the most common pattern in CKD patients. However, hearing loss in CKD patients does not follow any specific pattern and prevails at any degree with high and low frequencies. These results are in accordance with El-Anwar et al., 2013 [25] and Fufore et al., 2019 [21].

In a trial to study factors affecting hearing status in CKD patients, some clinico-demographic data & laboratory tests were analysis & showed no significance changes between CKD pediatric patients with normal & and with those who had impaired hearing (tables 10 & 11), however, the lack of a significant relationship between HL & these data preclude a detailed description of the mechanisms causing HL in CKD, where the link might be due to structural & functional similarities between tissues in the inner ear & the kidney, &the fact that the kidney disease & hearing loss share common risk factors [26, 10].

In accordance with our findings, previous studies [27], [28] & [15] reported that age, gender, prematurity, age at start CKD, & disease duration did not increase the risk of hearing loss. However, other studies [29], [30], [27] & [31] found a significant correlation between duration of disease &degree of hearing loss, where they stated that the link between CKD & hearing loss are still unclear, however it had been ascribed to uremic neuropathy & to fluid & electrolyte abnormalities. Meanwhile, Kim et al., 2020 [15] showed that the stage of CKD was the most important determinant factor affecting the hearing, where hearing loss was higher in patients with advanced CKD stage than earlier ones.

Such differences might reflect the variations in the study population, emphasizing the differences between CKD patients &the general population, or the characteristics of this study of young subjects. In addition to advanced CKD stage, an underlying disease of glomerulopathy was a risk factor of HL, especially SNHL, which could be attributed to the fact that genetic & syndromic diseases accompanying SNHL were more common in CKD patients [15].

Though our work is showing that a significant number of pediatric CKD patients are suffering from hearing loss, **the limitation of the study** is being representing only one pediatric nephrology center with relatively small sample size and with no follow up of the hearing status over a period. Also, there are no clear data about the previous exposure to ototoxic drugs prior to the kidney disease and before referral to our center.

## CONCLUSIONS & RECOMMENDATIONS

Hearing loss especially high frequency SNHL is not uncommon in CKD pediatric patients. The early diagnosis of hearing impairment can prevent further progression of hearing loss by reducing exposure to ototoxic agents wherever possible and achieving a better quality of life.

## REFERENCES


1. KDIGO: Clinical Practice Guideline for the Evaluation & Management of Chronic Kidney Disease. Kidney Int Suppl. (2012). 3:1-*150.*
2. Webster, A. C., Nagler, E. v., Morton, R. L., & Masson, P. Chronic Kidney Disease. The Lancet, (2017). 389 (10075), 1238–52.
3. Vilayur E, Gopinath B, Harris DC, Burlutsky G, McMahon CM, Mitchell P. The association between reduced GFR and hearing loss: a cross-sectional population-based study. Am J Kidney Dis. (2010). 56(4):661-9.
4. Lasisi OA, Salako BL, Kadiri S, Arije A, Oko-Jaja R, Ipadeola A, Olatoke F. Sudden sensorineural hearing loss and hemodialysis. Ear Nose Throat J. (2006). 85(12):819-21.
5. Seo YJ, Ko SB, Ha TH, Gong TH, Bong JP, Park DJ, Park SY.: Association of hearing impairment with chronic kidney disease: a cross-sectional study of the Korean general population. BMC Nephrol. (2015). 16; 16:154.
6. Lin C, Hsu HT, Lin YS, Weng SF. Increased risk of getting sudden sensorineural hearing loss in patients with chronic kidney disease: a population-based cohort study. Laryngoscope. (2013). 123(3):767-73.
7. ASHA (2005): Guidelines for Manual Pure-Tone Threshold Audiometry.
8. Soliman, S. & El-Mahalawi, T. Simple speech test as a predictor for speech reception threshold (SRT) in preschool children. Master thesis, faculty of medicine, Ain Shams University. (1984).
9. Soliman, S. Speech discrimination audiometry using Arabic phonetically balanced words. Ain Shams Medical Journal (1976): 27: 27-30.
10. Rahman, R., Akhtar, N., Khanam, A., Medical, M. A.-A. J. Prevalence and patterns of hearing loss among chronic kidney disease of various stages in Bangladeshi patients. Citeseer, (2016). 4(3), 53–8
11. Rashid R, Neill E, Maxwell H, Ahmed SF. Growth and body composition in children with chronic kidney disease. Br J Nutr. (2007). 97(2):232-8.
12. Flynn JT, Mitsnefes M, Pierce C, Cole SR, Parekh RS, Furth SL, Warady BA. Chronic Kidney Disease in Children Study Group. Blood pressure in children with chronic kidney disease: a report from the Chronic Kidney Disease in Children study. Hypertension. (2008).52(4):631-7.
13. Samuels J, Ng D, Flynn JT, Mitsnefes M, Poffenbarger T, Warady BA, Furth S. Chronic Kidney Disease in Children Study Group. Ambulatory blood pressure patterns in children with chronic kidney disease. Hypertension. (2012). 60(1):43-50.
14. Horowitz B, Miskulin D, Zager P. Epidemiology of hypertension in CKD. Adv Chronic Kidney Dis. (2015). 22(2):88-95.
15. Kim JH, Lee DH, Lee B, Lim SH, Ahn YH, Kang HG, Ha IS, Cheong HI. Renal Syndromic Hearing Loss Is Common in Childhood-onset Chronic Kidney Disease. J Korean Med Sci. (2020). 16;35(44): e364
16. Klinger Vagner Teixeira da Costaa, Sonia Maria Soares Ferreiraa, Pedro de Lemos Menezes. Hearing handicap in patients with chronic kidney disease: a study of the different classifications of the degree of hearing loss, Braz J Otorhinolaryngol. 2017; 83(5):580-4.
17. Jishana Jamaldeen1, Aneesh Basheer2, Akhil Chandra Sarma1, Ravichandran Kandasamy. Prevalence and patterns of

hearing loss among chronic kidney disease patients undergoing haemodialysis, AMJ 2015; 8 (2):41–6.

**18.** Liu W, Meng Q, Wang Y, Yang C, Liu L, Wang H, Su Z, Kong G, Zhao Y, Zhang L. The association between reduced kidney function and hearing loss: a cross-sectional study. BMC Nephrol. (2020). 22; 21(1):145.

**19.** Aloubaide RA, Alsaedi AJ, Saker R, Jamil NS, Mohammed FA. Sensorineural Deafness among Patients with Chronic Renal Failure in Al-kindi Teaching Hospital. Al-Kindy Col. Med. J. (2011). 30 7(2):137-41.

**20.** Somashekara, K., Gowda, B., Smitha, S., & Amrita, S. Etiological evaluation of hearing loss in chronic renal failure. Indian J Basic Appl Med Res. (2015). 4:194–9.

**21.** Fufore MB, Kirfi AM, Salisu AD, Samdi TM, Abubakar AB, Onakoya PA. Prevalence and pattern of hearing loss in patients with chronic kidney disease in Kaduna, Northwestern Nigeria. Indian Journal of Otology. (2019). 1; 25(4):201.

**22.** Ghasemi MM, Bakhshaei M, Saheb Jamei A. Hearing loss in hemodialysis patients. Medical Journal of the Islamic Republic Of Iran. (2004). 10; 17(4):293-6.

**23.** Aspris AK, Thodi CD, Balatsouras DG, Thodis ED, Vargemezis V, Danielides V. Auditory brainstem responses in patients under treatment of hemodialysis. Renal failure. (2008). 1; 30(4):383-90.

**24.** Pandey S, Gore G, Valame D, Mehta K. Audiometric profile in patients with chronic renal failure. J Otolaryngol Head Neck Surg. (2011). 40(2):131-6.

**25.** El-Anwar MW, Elsayed H, Khater A, Nada E. Audiological findings in children with chronic renal failure on regular hemodialysis. The Egyptian Journal of Otolaryngology. (2013). 29(3):182-8.

**26.** Wachukwu CM, Emem-Chioma PC, Wokoma FS, Oko-Jaja RI. Prevalence of risk factors for chronic kidney disease among adults in a university community in southern Nigeria. Pan African Medical Journal, (2015). 21(1).

**27.** Saeed, H. K., Al-Abbasi, A. M., Al-Maliki, S. K., & Al-Asadi, J. N. Sensorineural hearing loss in patients with chronic renal failure on hemodialysis in Basrah, Iraq. Tzu-Chi Medical Journal, (2018). 30(4):216.

**28.** Stevens G, Flaxman S, Brunskill E, Mascarenhas M, Mathers CD, Finucane M. Global Burden of Disease Hearing Loss Expert Group. Global and regional hearing impairment prevalence: an analysis of 42 studies in 29 countries. Eur J Public Health, (2013). 23(1):146-52

**29.** Renda R, Renda L, Selçuk ÖT, Eyigör H, Yılmaz MD, Osma Ü. Cochlear sensitivity in children with chronic kidney disease and end-stage renal disease undergoing hemodialysis. Int J Pediatr Otorhinolaryngol, (2015). 79(12):2378-83.

**30.** Reddy E., Surya Prakash DR & Rama Krishna MG. Proportion of hearing loss in chronic renal failure: our experience. Indian J Otol. (2016). 1; 22 (1):4.

**31.** Fadel FI, Yamamah GAN, Hasanin RM, Mostafa EA, Abdalgeleel SA, Salah MM, Galal REE, Abdel Mawla MA. Hearing assessment in Egyptian children with chronic renal failure on regular hemodialysis and renal transplantation children. Ther Apher Dial. (2021). 24.

## AUTHORS' CONTRIBUTIONS

The submitted manuscript is the work of the author & co-authors.

All authors have contributed to authorship, have read and approved the manuscript.

**Conception and design of study:** All authors

**Acquisition of data:** All authors

**Analysis and/or interpretation of data:** All authors

**Drafting the manuscript:** All authors

**Revising the manuscript critically for important intellectual content:** All authors

**Approval of the version of the manuscript to be published:** All authors

## STATEMENTS

**Ethics approval and consent to participate**

This study protocol and the consents were approved and deemed sufficient by the Ethical Committee of Faculty of Medicine, Ain Shams University, Egypt and informed written consent

was obtained in every case from their legal guardians.

**Consent for publication**

"Not applicable"

**Availability of data and material**

"Available on request, anytime"

**Conflict of interest**

The authors declare no conflict of interest.

**Funding**

The authors declare that this research work did not revise any fund.

**Acknowledgements**

Authors would like to thank all patients and their family members for their valuable contributions to the study.

**Submitted : 17/03/2022**
**Accepted : 05/04/2022**
**Published : 30/06/2022**