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Analysis Between Kidney Function and Hearing Loss Using Hemodynamic and Physical Characteristics: A Large Cross-Sectional Cohort Study With Health Screening Test

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혈역학적, 신체적 지표를 사용한 신장 기능과 청력 손실 간의 분석: 대규모 건강검진 결과를 통한 단면 코호트 연구

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Background and Objectives A large-scale community-based study of the general population has not been conducted. There have been no studies on the relationship between decreased renal function and the degree of hearing loss. Thus, the purpose was to evaluate the relationship between hearing loss and impaired renal function with a large number of populations.
Subjects and Method We performed a cross-sectional population-based cohort study by enrolling 470718 adults, 18 to 80 years old with pure tone audiometry tests who had regular health screening between 2013 and 2018. Hearing loss was defined as a pure-tone average of thresholds at 500, 1000, and 2000 Hz in both right and left ears. Kidney function was evaluated based on eGFR. Chronic kidney disease (CKD) was diagnosed as an eGFR<60 mL/min/1.73 m². Other predictor variables including noise and age that can affect hearing were also used to evaluate correlation factors.
Results Of Participants with CKD, 14.2% had any hearing loss (>25 dB) and 5.0% had above moderate hearing loss (>40 dB). But those with normal kidney function, 2.0% either had any hearing loss and 0.4% had above moderate hearing loss. The odds ratio (OR) of above moderate hearing loss for participants with CKD was 1.51 (95% confidence interval [CI]: 1.15−2.00, *p*=0.003) but the OR of mild hearing loss for participants with CKD was 0.82 (95% CI: 0.67−1.02, *p*=0.073). The result suggested that CKD and above moderate hearing loss were related even after correcting for potential confounders, but had no statistical significance with mild hearing loss.
Conclusion Decreased kidney function is associated with above moderate hearing loss.
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Keywords Chronic kidney insufficiency; Glomerular filtration rate; Hearing loss; Kidney.

Introduction

Hearing impairment is one of the most frequent chronic conditions. From 1995 to 2004, the number of people suffering from the hearing loss was significantly increased from 120 million to 275 million.[1] The World Health Organization reported that about one-third of people over the age of 65 suffer from hearing loss in 2018.[2,3] The increase in the number of hearing impairment is emerging as a social problem due to the increase in an aging society. Hearing impairment is closely related to physical, emotional and cognitive impairments, which can seriously impair quality of life and social communication.[4]

Factors that can cause hearing loss are very diverse, including genetic factors, aging, problems during pregnancy, chronic ear infections and exposure to excessive noise.[5,6] Recently, some studies have proposed that additional factors such as diabetes, hypertension (HTN), smoking, and decreased estimated glomerular filtration rate (eGFR) are risks of developing a hearing impairment.[1,4,7] For a long time, questions have been raised about the relationship between hearing and kidney function.[8-11] Although cross-sectional studies have been conducted before, there are no large population-based studies because they are relatively small studies with thousands of subjects, and there are no studies on what level of kidney damage can exacerbate which level of hearing loss.

Thus, the purpose was to evaluate the effect of kidney impairment level on hearing loss level in large general population-based study.

Subjects and Methods

Study population

Baseline examination was conducted for 470718 adults aged 18 to 80 years old who had hearing tests in Kangbuk Samsung Hospital Health Screening Center in Seoul and Suwon between 2013 and 2018. In South Korea, the Industrial Safety and Health Law requires all employees to undergo a medical examination annually or every two years. So, more than 70% of the participants belonged to a various corporation or government institution and performed health checkups in accordance with the law, and the rest of the participants were those who voluntarily received health checkups.

We excluded participants who had a history of stroke (n=2890). Participants whose hearing level in both ears did not belong to one group were also excluded (n=15389). For example, participants with a hearing of 31 dB in the right ear and 21 dB in the left ear, which corresponded to a mild hearing loss in the right ear, were excluded because the hearing in the left ear was normal. This type of participants is a group of patients with asymmetric hearing with a high possibility of hearing loss due to other diseases. We also further excluded participants with missing covariates including blood urea nitrogen, uric acid, albumin, sodium, potassium, phosphorous, glucose, hemoglobin A1c (HbA1c) (n=13860). Thus, the final sample had 438579 participants (Fig. 1).

Data collection

At health checkup, participants were asked including smoking, consumed alcohol and medical history through self-questionnaires. Smoking status was described by pack-years of smoking derived from smoking amount (cigarettes/days) and smoking duration (years). Alcohol intake was divided into none, moderate intake, and high intake. The moderate intake was defined as ≤30 g/day in men and ≤20 g/day in women. HTN was diagnosed when systolic blood pressure (SBP) ≥140 mm Hg with diastolic blood pressure (DBP) ≥90 mm Hg, or recent taking of anti-HTN medications. A BMI of 25 or higher was diagnosed as obesity.[12] We determined the reference level of HbA1c <6.0% because The Expert Committee proposed the use of HbA1c values between 6.0% and 6.4% to identify prediabetic status.

Laboratory methods

Blood samples from subjects were taken after fasting for at

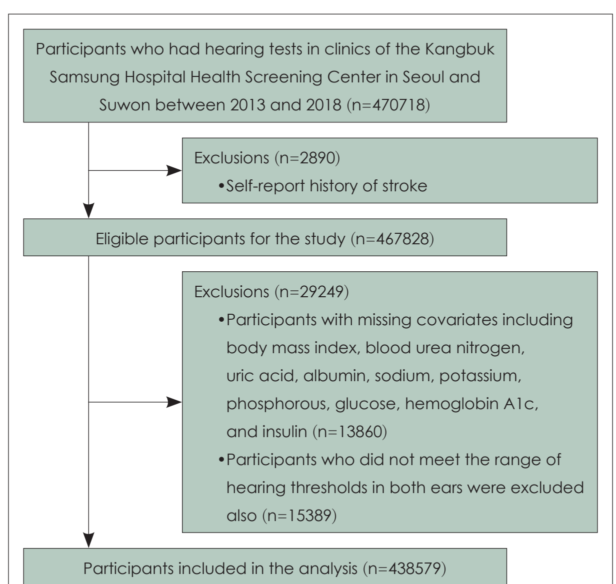

Fig. 1. Flow chart of study design.

least 8 hours. Baseline biochemistry tests including uric acid, electrolytes, total cholesterol, high-density lipoprotein (HDL) cholesterol, and triglycerides (TG) and HbA1c level were used to evaluate correlation factors.

Assessment of kidney function

We evaluated kidney function with eGFR which is one of the current criteria used to diagnose chronic kidney disease (CKD) in adults. Generally, eGFR is classified into five groups: normal=CKD Stage 1 (eGFR ≥90 mL/min per 1.73 m^2), mild loss=CKD Stage 2 (eGFR=60−89 mL/min per 1.73 m^2), mild to moderate loss of kidney function=CKD Stage 3a (eGFR= 45−59 mL/min per 1.73 m^2), moderate to severe loss of kidney function=CKD stage 3b (eGFR=30−44 mL/min per 1.73 m^2), severe=CKD stage 4 (eGFR=30−44 mL/min per 1.73 m^2), and Kidney failure=CKD stage 5 (eGFR <15 mL/min per 1.73 m^2). This classification was based on the current CKD Stage defined by the Kidney disease: Improving Global Outcomes guideline 2012. Reduced kidney function is usually indicated by eGFR <60 mL/min per 1.73 m^2.[13] Thus, eGFR ≥60 mL/min per 1.73 m^2 was used as a reference group. GFR was estimated using the Modification of Diet in Renal Disease Study equation: GFR (mL/min/1.73 m^2)=186×(serum creatinine)$^{-1.154}$×(age)$^{-0.203}$ (if female, ×0.742).[14]

Audiometric measure

Pure tone audiometry was performed by well-trained audiologist using in a soundproof booth. Air conduction hearing thresholds were measured for both the right and left ears and were assessed in dB hearing level at 500, 1000, and 2000 Hz. We divided the hearing loss into 3 groups so that each of the right and left hearing levels satisfies the category (normal hearing: both <25 dB; mild hearing loss: both = 25−40 dB; above moderate hearing loss: both >40 dB). Participants who do not correspond to this were excluded. In accordance with the Korea Occupational Safety and Health Act, employees exposed to more than 8 hours a day in a workplace with a noise of 85 dB or more were required to undergo an annual hearing test for additional frequencies of 3000 and 4000 Hz. In our study, participants who were tested at 3000 and 4000 Hz were considered to have a history of exposure to noise.

Statistical analysis

STATA statistical software was used for statistical analyses including multinomial logistic regression analysis. Multinomial logistic regression analysis was used to calculate adjusted odds ratio (OR) and 95% confidence interval (CI) for associations between hearing loss and kidney function.

For all analyses, we used three models after adjusting for potential confounding factors. For the first model, age, sex, and study center were adjusted. For the second model, total cholesterol, TG, HDL cholesterol, smoking, history of noise at work, BMI, HTN, alcohol intake and exercise were additionally adjusted. The third model was additionally adjusted for HbA1c.

Results

Total characteristics of participants were stratified by hearing loss group (Table 1). Their mean age was 41.43 years. Among the participants, 52.17% were male and 47.83% were female. There were significant difference in age, sex, BMI, smoking, SBP, DBP, uric acid, sodium, potassium, glucose, HbA1c, eGFR, noise exposure, study centre, total cholesterol, HDL, TG, and alcohol (p<0.001) among hearing loss groups. Of the total participants, 0.44% had CKD. The mean eGFR level for the group with CKD was 49.72 mL/min/1.73 m^2, and the mean eGFR level for the group without CKD was 100.43 mL/min/1.73 m^2. The prevalence of any hearing loss (>25 dB) was 2.09% in all participants. The prevalence of above moderate hearing loss (>40 dB) was 0.43% in all study participants. Of Participants with CKD, 14.2% had any hearing loss (>25 dB) and 5.0% had above moderate hearing loss (>40 dB). But those without CKD, 2.0% either had any hearing loss and 0.4% had above moderate hearing loss.

Association between CKD and hearing threshold

Compared to participants without CKD, the CKD group was associated with above moderate hearing loss (adjusted OR [aOR]: 1.51; 95% CI: 1.15−2.00, p=0.003) after adjusting for age, sex, smoking, BMI, noise exposure, HTN, study centre, TG, HDL, total cholesterol, alcohol, and HbA1c (Table 2). In male, CKD was statistically significant with above moderate hearing loss (aOR: 1.46; 95% CI: 1.09−1.96, p=0.012) after adjusting for age and sex. In female, CKD was statistically significant with above moderate hearing loss (aOR: 1.64; 95% CI: 1.06−2.55, p=0.027) which was adjusted for age, sex, smoking, BMI, noise exposure, HTN, study centre, TG, HDL, total cholesterol, alcohol, and HbA1c.

Interaction between age and CKD on hearing loss

Participants were classified by age to consider the effect of

Table 1. Baseline characteristics of study participants

Characteristics	Overall	Hearing loss			*p*-value
		Normal	Mild	Moderate/severe	
Number	438579	429383 (97.90)	7283 (1.66)	1913 (0.44)	
Age (years)	41.43±9.71	41.05±9.32	58.18±10.78	61.64±13.32	<0.001
Sex					0.001
Male	228824 (52.17)	223858 (52.13)	3913 (53.73)	1053 (55.04)	
Female	209755 (47.83)	205525 (47.87)	3370 (46.27)	860 (44.96)	
BMI (kg/m^2)	23.59±3.49	23.57±3.5	24.31±3.14	24.11±3.16	<0.001
BMI category (kg/m^2)					<0.001
<18.5	21083 (4.81)	20846 (4.85)	182 (2.5)	55 (2.88)	
18.5–23	182734 (41.67)	179779 (41.87)	2306 (31.66)	649 (33.93)	
23–25	98225 (22.4)	95750 (22.3)	1959 (26.9)	516 (26.97)	
>25	136537 (31.13)	133008 (30.98)	2836 (38.94)	693 (36.23)	
Smoking (pack-years)	4.2±8.3	4.1±8.1	9.2±14.6	9.6±15.9	<0.001
SBP (mm Hg)	109.92±13.01	109.78±12.95	116.2±14.14	117.47±14.29	<0.001
DBP (mm Hg)	70.75±9.94	70.7±9.94	73.5±9.84	72.42±9.46	<0.001
Urica (mg/dL)					<0.001
<3.4/2.4	4792 (1.09)	4629 (1.08)	122 (1.68)	41 (2.14)	
Normal	372026 (84.83)	364137 (84.8)	6270 (86.09)	1619 (84.63)	
>7/6.0	61761 (14.08)	60617 (14.12)	891 (12.23)	253 (13.23)	
Sodium (mmol/L)	141.42±1.96	141.4±1.96	142.15±2.05	142.13±2.15	<0.001
Potassium (mmol/L)	4.44±0.35	4.44±0.35	4.45±0.37	4.45±0.37	0.009
Potassium category (mmol/L)					<0.001
<3.5	283 (0.06)	258 (0.06)	22 (0.3)	3 (0.16)	
3.5–5.5	437430 (99.74)	428286 (99.74)	7240 (99.41)	1904 (99.53)	
>5.5	866 (0.2)	839 (0.2)	21 (0.29)	6 (0.31)	
Calcium (mg/dL)	9.48±0.35	9.48±0.35	9.47±0.36	9.45±0.36	<0.001
Phosphorous (mg/dL)	3.58±0.45	3.58±0.45	3.58±0.49	3.56±0.5	0.063
Glucose (mg/dL)	94 (89–100)	94 (89–100)	98 (92–109)	98 (92–108)	<0.001
HbA1c (%)	5.53±0.56	5.52±0.55	5.9±0.86	5.91±0.83	<0.001
HbA1c category (%)					<0.001
<6.0	398416 (90.84)	391886 (91.27)	5196 (71.34)	1334 (69.73)	
6.0–6.5	24791 (5.65)	23315 (5.43)	1147 (15.75)	329 (17.2)	
6.5–7.5	9571 (2.18)	8825 (2.06)	589 (8.09)	157 (8.21)	
7.5–8.5	2882 (0.66)	2646 (0.62)	185 (2.54)	51 (2.67)	
>8.5	2919 (0.67)	2711 (0.63)	166 (2.28)	42 (2.2)	
eGFR (mL/min/1.73 m^2)	100.21±18.73	100.4±18.69	91.68±18.17	90.3±19.77	<0.001
≤60	49.72±12.53	49.65±12.77	50.29±11.04	49.79±10.94	0.811
>60	100.43±18.45	100.6±18.44	92.7±17.09	92.46±17.69	<0.001
eGFR category (mL/min/1.73 m^2)					<0.001
≤60	1921 (0.44)	1649 (0.38)	175 (2.4)	97 (5.07)	
>60	436658 (99.56)	427734 (99.62)	7108 (97.6)	1816 (94.93)	
Noise exposure	59347 (13.53)	59047 (13.75)	230 (3.16)	70 (3.66)	<0.001
Center					<0.001
Seoul	245178 (55.9)	238597 (55.57)	5278 (72.47)	1303 (68.11)	
Suwon	193401 (44.1)	190786 (44.43)	2005 (27.53)	610 (31.89)	
Total cholesterol (mg/dL)	191.27±34.3	191.27±34.2	191.98±38.37	187.74±39.1	<0.001
HDL cholesterol (mg/dL)	60.61±16.61	60.7±16.61	56.93±16.03	55.92±15.55	<0.001
TG (mg/dL)	94 (66–140)	94 (66–140)	105 (75–152)	104 (73–148)	<0.001
Alcohol intake					<0.001
None	65627 (14.96)	63212 (14.72)	1849 (25.39)	566 (29.59)	
Moderate	284536 (64.88)	280325 (65.29)	3391 (46.56)	820 (42.86)	
High intake	54479 (12.42)	53294 (12.41)	971 (13.33)	214 (11.19)	

Data are presented as number (%), mean±standard deviation or mean±95% CI. BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, hemoglobin A1c; eGFR, estimated glomerular filtration rate; HDL, high density lipoprotein; TG, triglycerides

Table 2. aOR (95% CI) between chronic kidney disease and hearing threshold using multivariable logistic regression analysis

eGFR category	Normal (<25 dB)	Model 1				Model 2				Model 3			
		Mild (25–40 dB)		Above moderate (>40 dB)		Mild (25–40 dB)		Above moderate (>40 dB)		Mild (25–40 dB)		Above moderate (>40 dB)	
		aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value
Total			0.363		0.001		0.109		0.003		0.073		0.003
≤60	1 (reference)	0.92 (0.77–1.1)		1.51 (1.19–1.9)		0.84 (0.68–1.04)		1.53 (1.16–2.02)		0.82 (0.67–1.02)		1.51 (1.15–2.00)	
>60	1 (reference)	1 (reference)		1 (reference)		1 (reference)		1 (reference)		1 (reference)		1 (reference)	
Male			0.724		0.012		0.648		0.053		0.526		0.064
≤60	1 (reference)	0.96 (0.77–1.20)		1.46 (1.09–1.96)		0.94 (0.73–1.21)		1.43 (0.996–2.05)		0.92 (0.72–1.19)		1.41 (0.98–2.02)	
>60	1 (reference)	1 (reference)		1 (reference)		1 (reference)		1 (reference)		1 (reference)		1 (reference)	
Female			0.357		0.016		0.048		0.024		0.039		0.027
≤60	1 (reference)	0.87 (0.64–1.17)		1.59 (1.09–2.32)		0.68 (0.46–0.997)		1.66 (1.07–2.58)		0.67 (0.46–0.98)		1.64 (1.06–2.55)	
>60	1 (reference)	1 (reference)		1 (reference)		1 (reference)		1 (reference)		1 (reference)		1 (reference)	

Model 1: age, sex and centre. Model 2: age, sex, centre, smoking, noise exposure, BMI, study centre, HTN, alcohol and vigorous exercise, total cholesterol, HDL and TG. Model 3: age, sex and centre, smoking, noise exposure, BMI, study centre, HTN, alcohol and vigorous exercise, total cholesterol, HDL, TG and HbA1c. aOR, adjusted odds ratio; CI, confidence interval; eGFR, estimated glomerular filtration rate; BMI, body mass index; HTN, hypertension; HDL, high density lipoprotein; TG, triglycerides; HbA1c, hemoglobin A1c

age on hearing loss after adjusting for sex, smoking, BMI, noise exposure, HTN, study centre, TG, HDL, total cholesterol, alcohol, and HbA1c (Table 3) : young age group (age <40), middle age group (40≤age<60), old age group (age >60). In young age group, the number of participants with CKD was only 139, and none of them had the above moderate hearing loss. In middle age group, CKD was statistically significant with above moderate hearing loss (aOR: 2.42; 95% CI: 1.07–5.47, p=0.034). In old age group, CKD also was statistically significant with above moderate hearing loss (aOR: 2.01; 95% CI: 1.51–2.67, p<0.001). As a result, when the participants were classified by age, there was no significant difference with the OR of the previous age-adjusted results in the above moderate hearing loss in the presence of CKD (Table 2). Also, relationship between the eGFR level and the hearing threshold was not different according to the age category (interaction p=0.764).

Discussion

Our large cross-sectional study is consistent with previously published studies reporting the association between kidney function and hearing loss. Antonelli, et al.[15] have used auditory brainstem response (ABR) and found that 39% of patients with CKD in their study have abnormal ABR results compared to 24% in the control group. Vilayur, et al.[11] suggested that those with moderate CKD are associated with any hearing loss (>25 dB) compared with those without CKD. They also investigated the association between the severity of hearing loss and eGFR. Similarly, Seo, et al.[16] suggested that eGFR <60 mL/min/1.73 m^2 have a significant effect on above moderate (>40 dB) hearing loss of adults. They set the hearing loss threshold at 40 dB because the threshold of serviceable hearing is within 40 dB and if it exceeds, it is disabling hearing impairment.[16] However, they did not study the association with mild hearing loss and eGFR.

Mechanisms involved between decreased kidney function and hearing loss are not clear, although electrolyte imbalance and uremic neuropathy have been proposed as possible mechanisms. Cochlea and kidney have physiological, ultrastructural, and antigenic similarities. Thus, physiological mechanisms involved in electrolyte transport in cochlear and renal glomerulus might explain the relationship between hearing loss and decreased eGFR.[6] They also share a number of similar microstructures such as ion channels and transporters involved in depolarization, potassium recycling, and endolym-

Table 3. aOR and 95% CIs for hearing threshold by age category

eGFR category	Multivariable model				
	Normal (<25 dB)	Mild (25–40 dB)		Above moderate (>40 dB)	
	aOR (95% CI)	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value
Young age (age <40) (n=205960)			0.203		-
>60 (n=205821)	1 (reference)	3.61 (0.5–26.12)		N/A	
≤60 (n=139)	1 (reference)	1 (reference)		1 (reference)	
Middle age (age 40–60) (n=210657)			0.55		0.034
>60 (n=209662)	1 (reference)	0.86 (0.52–1.42)		2.42 (1.07–5.47)	
≤60 (n=995)	1 (reference)	1 (reference)		1 (reference)	
Old age (age >60) (n=21962)			0.206		<0.001
>60 (n=21175)	1 (reference)	1.16 (0.92–1.45)		2.01 (1.51–2.67)	
≤60 (n=787)	1 (reference)	1 (reference)		1 (reference)	

Adjusted for sex and centre, smoking, noise exposure, body mass index, study centre, hypertension, alcohol and vigorous exercise, total cholesterol, high density lipoprotein, triglycerides and hemoglobin A1c. aOR, adjusted odds ratio; CI, confidence interval

phatic ion circulation.[6,17,18] Therefore, other pathological factors related to renal dysfunction might cause auditory dysfunction. Yassin, et al.[19] suggested that the degree of hearing loss is related to the degree of hyponatremia, and that correcting renal insufficiency and serum sodium levels could improve cochlear function. Gatland, et al.[5] have suggested that changes in fluid and electrolyte composition of endolymph can induce recovery of the hearing threshold of low frequencies. Govender, et al.[20] have suggested that elevated electrolyte, urea, and creatinine levels may affect cochlear function in CKD patients. Also, some previous studies have suggested that nerve conduction problems may affect auditory response in patients with end-stage renal disease.[21-23] Changes in central and peripheral nervous systems have been previously observed in uremic patients, indirectly demonstrating the presence of uremic neuropathy.[24] Serum uric acid is commonly elevated in subjects with CKD. Di Paolo, et al.[21] have observed abnormal nervous conduction in patients with CKD. They confirmed that the nerve conduction velocity was decreased with a uremic neural injury. Other studies also suggest that CKD patients have disturbance of auditory nerve and pathway.[6,15,23,25]

In this large cross-sectional population-based cohort study, participants with CKD showed a high prevalence of above moderate hearing loss. Their association was evident even after adjusting for covariates. In the CKD group, the prevalence of mild hearing loss was 9%. The prevalence of above moderate hearing loss was about 5%, higher than that in the group without CKD. The association between CKD and mild hearing loss was not statistically significant after adjustment. However, the association with the above moderate hearing loss was statistically significant even after adjustment. CKD is a chronic condition whose presence and extent is determined by the level of eGFR. Thus, the presence of CKD means that kidney function is below a certain level and suggests that there is cochlear dysfunction above a certain level. Considering the physiological, ultrastructural, and antigenic similarities of cochlea and kidney that have been previously proposed,[6,26,27] our study suggests that the decreased kidney function and above moderate hearing loss have association because the kidney and cochlear are similar. In addition, it was thought that as the kidney function decreased below a certain level, uremic neuropathy or electronic imbalance to the extent of causing a hearing loss of 40 dB or more had progressed. However, more specific research is needed on these.

Our study have some limitations. First, high-frequencies hearing impairment (>2000 Hz) could not be assessed because of the lack of data. Second, we did not obtain data on the presence of otologic diseases, daily noise exposure, or the use of ototoxic drugs. However, some otologic diseases were filtered out by excluding hearing asymmetry in the grouping process. Also, noise exposure primarily causes hearing loss in the high frequency range of 3000 Hz.[28]

Third, our study is a cross-sectional study so causal inferences about whether CKD is a predictor of hearing loss are lacking. However, strengths of our study included the quantification of hearing threshold based on a standardized pure-tone audiometry test, standardized baseline laboratory data, and a large sample size for the general population. And we also studied the level of hearing loss related to CKD by analyzing mild hearing loss as well as above moderate hearing loss.

In conclusion, this large cross-sectional cohort study found that CKD was associated with moderate or greater hearing loss more than with a mild hearing loss. Our study suggests that nephrologists might need to encourage CKD patients to have their screen hearing function evaluated as hearing loss of 40 dB or more can occur in CKD patients, thereby avoiding social isolation.

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None

Author Contribution

Conceptualization: Sang Hyun Kim, Sang Hyuk Lee, Min-Beom Kim. Data curation: Sang Hyun Kim, Mi Yeon Lee, Joon Pyo Hong. Formal analysis: Sang Hyun Kim, Tae Hwan Kim, Jung Yeop Lee. Funding acquisition: Sang Hyun Kim, Sun O Chang. Investigation: Sang Hyun Kim, Sun O Chang. Methodology: Sang Hyun Kim, Tae Hwan Kim, Min-Beom Kim. Project administration: Tae Hwan Kim. Resources: Sang Hyun Kim, Tae Hwan Kim. Software: Mi Yeon Lee. Supervision: Sang Hyuk Lee, Min-Beom Kim. Validation: Sang Hyun Kim, Tae Hwan Kim, Sang Hyuk Lee. Visualization: Sang Hyun Kim. Writing—original drift: Sang Hyun Kim, Tae Hwan Kim. Writing—review & editing: Sang Hyun Kim, Tae Hwan Kim, Sang Hyuk Lee.

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