



Relationship Between Hemodialysis Duration and Degree of Sensorineural Hearing Loss Based on Pure Tone Audiometry

Kathleen Monica Ayu Panjaitan¹, Cut Elvira Novita², Juliana Lina³

¹PUI Phyto-Degenerative Medicine & Lifestyle, Prima Indonesia University, Medan, Indonesia, kathleenmonica1708@gmail.com

²PUI Phyto-Degenerative Medicine & Lifestyle, Prima Indonesia University, Medan, Indonesia, cutelviranovita@gmail.com

³PUI Phyto-Degenerative Medicine & Lifestyle, Prima Indonesia University, Medan, Indonesia, julianalina@unprimdn.ac.id

Corresponding Author: kathleenmonica1708@gmail.com¹

Abstract: Sensorineural hearing loss is frequently reported in patients with chronic kidney disease undergoing hemodialysis, as recurrent physiological and biochemical changes during therapy may affect cochlear function. However, evidence on whether hemodialysis duration is related to the severity of sensorineural hearing loss remains inconsistent. This study aimed to analyze the relationship between hemodialysis duration and the severity of sensorineural hearing loss based on pure tone audiometry. This cross-sectional analytical observational study involved 30 patients with chronic kidney disease from two hospitals in North Sumatra, Indonesia, recruited through sequential sampling from May to July 2026. Pure tone audiometry assessed air and bone conduction at frequencies of 250–8000 Hz, and the Spearman correlation test was used for analysis. Sensorineural hearing loss was the most common type, affecting 46.7% of right ears and 36.7% of left ears, with the mild degree predominating (57.1% right; 54.5% left). Hemodialysis duration was not significantly correlated with severity in the right ear ($\rho=0.020$; $p=0.946$) or the left ear ($\rho=0.025$; $p=0.941$). The novelty of this study lies in analyzing hemodialysis duration as a factor in hearing loss severity; the findings suggest that hearing loss in this population is likely multifactorial and that regular audiometric monitoring remains relevant.

Keywords: Chronic Kidney Disease, Hemodialysis, Duration of Hemodialysis, Pure Tone Audiometry, Sensorineural Hearing Loss

Abstrak: Gangguan pendengaran sensorineural sering dilaporkan pada pasien penyakit ginjal kronis yang menjalani hemodialisis karena perubahan fisiologis dan biokimia yang berulang selama terapi dapat memengaruhi fungsi koklea. Namun, bukti mengenai hubungan lama hemodialisis dengan derajat gangguan pendengaran sensorineural masih belum konsisten. Penelitian ini bertujuan menganalisis hubungan lama hemodialisis dengan derajat gangguan pendengaran sensorineural berdasarkan audiometri nada murni. Penelitian observasional analitik dengan pendekatan potong lintang ini melibatkan 30 pasien penyakit ginjal kronis dari dua rumah sakit di Sumatera Utara, Indonesia, yang dipilih dengan teknik

pengambilan sampel berurutan pada Mei hingga Juli 2026. Audiometri nada murni menilai hantaran udara dan hantaran tulang pada frekuensi 250–8000 Hz, dan uji korelasi Spearman digunakan untuk analisis. Gangguan pendengaran sensorineural merupakan jenis yang paling banyak ditemukan, yaitu pada 46,7% telinga kanan dan 36,7% telinga kiri, dengan derajat ringan sebagai yang terbanyak (57,1% kanan; 54,5% kiri). Lama hemodialisis tidak berkorelasi signifikan dengan derajat gangguan pada telinga kanan ($\rho=0,020$; $p=0,946$) maupun telinga kiri ($\rho=0,025$; $p=0,941$). Kebaruan penelitian ini terletak pada analisis khusus terhadap lama hemodialisis sebagai faktor derajat gangguan pendengaran; temuan ini menunjukkan bahwa gangguan pendengaran pada populasi ini kemungkinan bersifat multifaktorial sehingga pemantauan audiometri berkala tetap relevan.

Kata Kunci: Penyakit Ginjal Kronis, Hemodialisis, Lama Hemodialisis, Audiometri Nada Murni, Gangguan Pendengaran Sensorineural

INTRODUCTION

Hearing loss is a growing health problem that can negatively impact communication skills, social interactions, psychological well-being, and overall quality of life. The World Health Organization (WHO) has emphasized that hearing loss is a major global health problem and requires early identification, particularly among populations at increased risk of hearing impairment. Therefore, evaluating hearing function in vulnerable groups remains crucial to prevent progressive disability and improve patient outcomes (World Health Organization, 2021).

Chronic kidney disease (CKD) is a systemic disorder associated with an increased prevalence of hearing loss, particularly sensorineural hearing loss (SNHL). The association between kidney dysfunction and hearing loss may be explained by the physiological similarities between the cochlea and the kidney, particularly their reliance on specialized vascular structures and electrolyte regulation mechanisms. Several mechanisms have been proposed, including accumulation of uremic toxins, electrolyte imbalance, altered osmotic regulation, cochlear microvascular dysfunction, and oxidative stress, which may contribute to damage to cochlear hair cells and auditory nerve structures (Agrawal & Singh, 2023; Kohansal et al., 2024).

Patients with chronic kidney disease (CKD), particularly those receiving renal replacement therapy through hemodialysis, are reported to have a higher prevalence of hearing impairment compared to the general population. Recent evidence suggests that sensorineural hearing loss (SNHL) is the most frequently reported type of hearing loss in CKD patients, while pure-tone audiometry (PTA) remains one of the primary objective methods used for hearing evaluation in this population (Kohansal et al., 2024; Kumar et al., 2022).

Previous studies have reported variations in the prevalence and characteristics of hearing loss among patients with chronic kidney disease (CKD) receiving renal replacement therapy through hemodialysis. Sensorineural hearing loss has consistently been identified as the predominant type, although differences exist in severity and frequency distribution. Saeed et al. (2018) reported a high incidence of SNHL among patients with CKD undergoing hemodialysis. Boateng et al. (2019) and Izzattisselim and Purnami (2020) similarly found that SNHL was the most frequently observed type of hearing loss among dialysis patients.

Recent studies using audiological assessments, including pure-tone audiometry (PTA), continue to demonstrate hearing impairment in patients undergoing dialysis. PTA-based studies have reported elevated hearing thresholds, particularly at high frequencies, suggesting that auditory dysfunction may occur as part of the systemic effects of CKD and prolonged dialysis exposure (Kumar et al., 2022; Pandit et al., 2025; Şahin & Karataş, 2025).

Although hearing impairment is commonly reported in patients receiving renal replacement therapy through hemodialysis (Kohansal et al., 2024; Kumar et al., 2022), the relationship between hemodialysis duration and SNHL severity remains unclear. Some studies suggest that longer dialysis exposure may be associated with greater hearing loss, while others show no significant association between dialysis duration and hearing loss severity (Pandit et al., 2025; Primadewi et al., 2022). Differences in sample size, patient characteristics, age distribution, comorbidities, dialysis treatment duration, audiometric assessment methods, and exposure to ototoxic medications may contribute to these inconsistent findings. Understanding whether hemodialysis duration influences SNHL severity remains clinically important because hemodialysis is a long-term treatment modality for patients with advanced CKD.

Objective hearing assessment can facilitate early identification of hearing loss and support appropriate monitoring and rehabilitation strategies. However, current evidence regarding the relationship between dialysis duration and SNHL severity is limited, particularly in regional and environmental populations with different patient characteristics (Kohansal et al., 2024; Ozmen et al., 2024).

The uniqueness of this study lies in evaluating the relationship between hemodialysis duration and SNHL severity using pure-tone audiometry among CKD patients undergoing regular hemodialysis at two hospitals in North Sumatra. Unlike previous studies that have largely focused on the prevalence or general characteristics of hearing loss, this study specifically analyzes whether the duration of hemodialysis exposure is associated with the severity of SNHL. These findings may provide additional evidence regarding the role of hemodialysis duration as a potential factor associated with hearing loss among CKD patients.

This study aimed to assess the characteristics of hearing loss and analyze the relationship between hemodialysis duration and SNHL severity, based on pure tone audiometry, in CKD patients undergoing hemodialysis at two hospitals in North Sumatra.

METHODS

This study used an observational analytical design with a cross-sectional approach. Data collection was conducted from May to July 2026 in the hemodialysis and health checkup units of two participating hospitals in North Sumatra, Indonesia. The study population included patients with chronic kidney disease (CKD) who received renal replacement therapy through hemodialysis. A total of 30 eligible subjects were enrolled using sequential sampling.

The study sample size was determined based on the number of patients assessed for eligibility during the study period. A total of 36 patients with chronic kidney disease (CKD) undergoing regular hemodialysis were initially assessed for eligibility. Of these, 6 patients were excluded because they did not meet the predetermined eligibility criteria, including 1 patient with a history of chronic noise exposure, 1 patient using non-dialysis ototoxic medications, 1 patient with active otitis media, 1 patient with anatomical ear abnormalities, 1 patient with a history of severe head trauma or hearing-related neurological disorders, and 1 patient who declined audiological examination or refused consent for the use of medical data. Consequently, 30 eligible participants who met all inclusion criteria, agreed to participate, provided informed consent, and completed the audiological examination were included in the final analysis. The inclusion criteria were CKD patients undergoing regular hemodialysis for at least one month, aged 18–75 years, able to undergo audiometric testing, and willing to sign the informed consent form.

Hearing assessment was performed using a pure-tone audiometer that complies with ANSI S3.6/ISO 389 standards and was calibrated periodically. Air conduction (AC) and bone conduction (BC) thresholds were measured at frequencies ranging from 250 to 8000 Hz. The type of hearing loss was determined based on the AC, BC, and air-bone gap patterns, while the degree of hearing loss was classified according to hearing threshold criteria. Univariate

analysis was performed to provide a descriptive overview of the characteristics of age, gender, duration of hemodialysis, and type and severity of hearing loss. The Shapiro–Wilk test was performed to evaluate the distribution of the data. Because the duration of hemodialysis in patients with sensorineural hearing loss (SNHL) is not normally distributed, the relationship between the duration of hemodialysis and the severity of SNHL was analyzed using the Spearman correlation test. A p value <0.05 was considered statistically significant.

The research was conducted in accordance with ethical standards applicable to research involving human participants. Ethical approval was obtained from the Health Research Ethics Committee (KEPK) of Universitas Prima Indonesia, with ethical clearance number 066/KEPK/UNPRI/III/2026, issued on March 13, 2026, and the study was declared ethically appropriate in accordance with the WHO 2011 Standards and the 2016 CIOMS Guidelines. Before data collection began, each participant was given an explanation of the research and asked to provide written consent. The researcher guaranteed the confidentiality of all data and the identities of participants, and the information obtained was used solely for research purposes.

RESULTS AND DISCUSSION

Results

A total of 30 patients were analyzed. Demographic and clinical characteristics of the study subjects, including gender, age distribution, and duration of hemodialysis, are presented in Table 1. There were 16 male respondents (53.3%) and 14 female respondents (46.7%). Twenty-two subjects (73.3%) were aged ≤ 60 years. The most common duration of hemodialysis was ≤ 12 months (63.3%). The mean age was 54.80 ± 10.91 years (range: 34–80 years), and the mean duration of hemodialysis was 15.00 ± 15.89 months (range: 1–72 months).

Table 1. Characteristics of Research Subjects (n=30)

Characteristics	Category	n	%
Gender	Male	16	53.3
	Female	14	46.7
Age	≤ 60 years	22	73.3
	> 60 years	8	26.7
Hemodialysis duration	≤ 12 months	19	63.3
	12–36 months	8	26.7
	> 36 months	3	10.0

Source: Primary data (2026)

Based on audiometric examination, the distribution of hearing loss types is presented in Table 2. The sensorineural type was the most common, affecting 14 right ears (46.7%) and 11 left ears (36.7%). For the right ear, mild hearing loss was the most common level of hearing loss (43.3%), while the normal category was the most common finding in the left ear (40.0%).

Table 2. Distribution of Types of Hearing Loss

Type	Right ear (n)	Right ear (%)	Left ear (n)	Left ear (%)
Normal	7	23.3	12	40.0
Conductive	5	16.7	3	10.0
Sensorineural	14	46.7	11	36.7
Mixed	4	13.3	4	13.3

Source: Primary data (2026). Types were classified based on air conduction, bone conduction, and air-bone gap patterns.

The correlation analysis between the duration of hemodialysis and the severity of SNHL is presented in Table 3. Spearman correlation analysis showed no significant relationship

between the duration of hemodialysis and the severity of SNHL in either the right ear ($\rho=0.020$; $p=0.946$) or the left ear ($\rho=0.025$; $p=0.941$).

Table 3. Correlation Between Hemodialysis Duration and SNHL Degree

Variables	n	rho	p
Hemodialysis duration – degree of SNHL in the right ear	14	0.020	0.946
Hemodialysis duration – degree of SNHL in the left ear	11	0.025	0.941

Source: Primary data (2026). Spearman correlation test; $p<0.05$ was considered significant.

The p-value for both ears was greater than 0.05, indicating that the relationship between hemodialysis duration and SNHL severity was not statistically significant. The correlation coefficient for both ears was positive but very weak, indicating that no clinically meaningful relationship could be identified from these data.

Discussion

The main finding of this study is a higher prevalence of sensorineural hearing loss (SNHL) among patients with chronic kidney disease (CKD) receiving renal replacement therapy through hemodialysis. This finding is consistent with previous studies showing that SNHL is the most frequently reported type of hearing loss among dialysis patients. Previous investigations by Saeed et al. (2018), Boateng et al. (2019), Izzattisselim and Purnami (2020), and Kohansal et al. (2024) reported similar findings, suggesting that cochlear and auditory nerve involvement are important manifestations of hearing dysfunction in patients with chronic kidney disease. The prevalence of SNHL may be related to physiological similarities between the kidney and cochlea, particularly their reliance on specialized vascular systems and electrolyte regulatory mechanisms. Chronic kidney dysfunction may contribute to cochlear injury through metabolic disturbances, oxidative stress, and microvascular changes, which may affect cochlear hair cells and auditory structures (Agrawal & Singh, 2023; Kohansal et al., 2024).

The most common level of SNHL observed in this study was mild hearing loss in both ears. Similar findings have been reported in previous studies using pure-tone audiometry, where mild hearing loss was frequently identified among CKD patients undergoing hemodialysis. Pathak et al. (2020) also demonstrated that pure-tone audiometry can identify hearing abnormalities among patients with chronic kidney disease, supporting the role of objective audiological assessment in detecting early hearing changes. The predominance of mild hearing loss in this study may indicate that hearing loss in hemodialysis patients may develop gradually and may initially present with subtle threshold changes before progressing to more severe impairment. Therefore, routine hearing evaluation may be beneficial for early identification and appropriate management of hearing dysfunction.

Although sensorineural hearing loss (SNHL) was predominant, conductive and mixed hearing loss were also identified in this study. These findings suggest that hearing loss in patients with chronic kidney disease (CKD) may not be caused by a single pathological mechanism, but rather by the interaction of multiple factors. In addition to cochlear dysfunction associated with kidney disease, factors such as middle ear abnormalities, age-related auditory degeneration, vascular changes, metabolic abnormalities, electrolyte disturbances, and systemic complications of CKD may contribute to variations in audiometric findings (Agrawal & Singh, 2023; Bedrabettu et al., 2024). These findings emphasize that hearing loss in hemodialysis patients should be evaluated comprehensively and not solely attributed to kidney dysfunction or dialysis treatment.

This study found no significant association between hemodialysis duration and the severity of SNHL in either ear. This finding differs from Primadewi et al. (2022), who reported a positive correlation between dialysis duration and SNHL severity. The differences between studies may be explained by variations in sample size, duration of dialysis exposure,

patient characteristics, hearing classification methods, and audiometric assessment procedures. Furthermore, the lack of a significant association in this study suggests that hemodialysis duration alone may not be sufficient to predict the severity of hearing loss. Previous studies have also shown that hearing changes in CKD patients are influenced by many clinical factors, not just dialysis duration alone (Azria et al., 2025; Bedrabettu et al., 2024).

The lack of a significant correlation between hemodialysis duration and SNHL severity may also be related to the relatively small number of subjects included in the correlation analysis. In this study, only 14 right and 11 left ears with SNHL were analyzed, which may have reduced statistical power to detect weak associations. Furthermore, most participants had a relatively short duration of hemodialysis, potentially limiting the ability to observe long-term hearing changes associated with prolonged dialysis exposure.

In addition, hearing loss in CKD patients may be influenced by several factors other than hemodialysis duration, including uremic status before dialysis, dialysis adequacy, diabetes mellitus, hypertension, age-related auditory degeneration, and exposure to potentially ototoxic medications (Azria et al., 2025; Caldas et al., 2025). Because this study did not include a non-CKD or non-hemodialysis comparison group, the observed hearing loss cannot be attributed specifically to CKD or hemodialysis exposure. These clinical factors may interact with renal dysfunction and dialysis-related physiological changes and may contribute to individual differences in hearing outcomes.

The novelty of this study lies in its specific analysis of whether the duration of hemodialysis exposure is associated with the severity of SNHL, assessed objectively using pure-tone audiometry among CKD patients undergoing regular hemodialysis at two hospitals in North Sumatra, whereas previous studies have largely focused on the prevalence or general characteristics of hearing loss. The finding that hemodialysis duration was not significantly correlated with SNHL severity in either ear indicates that dialysis duration alone may not be sufficient to predict the severity of hearing loss and supports the view that hearing loss in this population is multifactorial.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

Sensorineural hearing loss (SNHL) is the most common type of hearing loss among chronic kidney disease patients receiving renal replacement therapy through hemodialysis, with mild hearing loss being the most frequently observed level of impairment. This study found that the duration of hemodialysis was not significantly associated with the severity of SNHL in either the right or left ear. These findings suggest that dialysis duration alone may not be sufficient to explain variations in hearing loss among hemodialysis patients.

Limitations

This study has several limitations. First, the sample size was relatively small, and the correlation analysis included only 14 right ears and 11 left ears with SNHL, which may have reduced the statistical power to detect weak associations. Second, most participants had a relatively short duration of hemodialysis, which may have limited the ability to observe hearing changes associated with prolonged dialysis exposure. Third, the cross-sectional design and the absence of a non-CKD or non-hemodialysis comparison group mean that the observed hearing loss cannot be attributed specifically to CKD or hemodialysis exposure. Fourth, potential confounders such as diabetes mellitus, hypertension, age-related auditory degeneration, dialysis adequacy, and exposure to ototoxic medications were not adjusted for in the analysis. The findings should therefore be interpreted within the scope of this study.

Recommendations

Periodic hearing evaluation using pure-tone audiometry may be considered to facilitate early detection and monitoring of hearing dysfunction in CKD patients undergoing hemodialysis. Future studies should include larger samples, longitudinal follow-up, an appropriate comparison group, and adjustment for potential confounders, and should evaluate the influence of other potential factors, including kidney function parameters, dialysis adequacy, comorbidities, and exposure to ototoxic medications, to clarify the independent contribution of dialysis duration to hearing loss.

Author Contributions

Kathleen Monica Ayu Panjaitan: conceptualization, methodology, data collection, formal analysis, and writing—original draft. Cut Elvira Novita: data analysis, interpretation of results, writing—review and editing, and revision of the manuscript. Juliana Lina: supervision, validation, methodological guidance, and critical revision of the manuscript. All authors have reviewed and approved the final draft of the manuscript and declare their willingness to be accountable for every aspect of the research implementation.

AI Disclosure Statement

While drafting this manuscript, the authors used for language editing and to improve the clarity of the English language. The authors have thoroughly reviewed, verified, and edited the content and take full responsibility for the accuracy of the data, the interpretation of the findings, the conclusions presented, and the entire content of this publication.

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