Analysis of Auditory Function before and after a Single Session of Hemodialysis in Patients with Chronic Kidney Disease

Érica Alessandra Caldas[1] Patrick Rademaker Burke[2] Aline Gomes Bittencourt[2]
Patricia Andréia Caldas[3] Eduardo Henrique Costa Rodrigues[4,5] Natalino Salgado Filho[6]

[1] Programa de Ciências da Saúde, Universidade Federal do Maranhão (UFMA), São Luis, MA, Brazil
[2] Universidade Federal do Maranhão (UFMA), São Luís, MA, Brazil
[3] Department of Speech Therapy, Universidade Estadual Paulista (UNESP), Marília, SP, Brazil
[4] Department of Environmental Sciences, Universidade Estadual Paulista Júlio de Mesquita Filho (UNESP), São Paulo, SP, Brazil
[5] Universidade Ceuma (UNICEUMA), São Luís, MA, Brazil
[6] Hospital Universitário da Universidade Federal do Maranhão (HUUFMA), São Luís, MA, Brazil

Address for correspondence Érica Alessandra Caldas, Universidade Ceuma (UNICEUMA), Rua Josué Montello, 1. Renascença II. São Luís, (A 65075-120, Brazil (e-mail: ericaacaldas@hotmail.com).

Int Arch Otorhinolaryngol 2025;29(2):s00441789196.

Abstract

Introduction Hearing is a complex process that involves mechanical, chemical, and neurophysiological components. Changes in hearing can be caused by congenital or acquired etiological factors. Chronic kidney disease (CKD) is one of the causes of hearing loss.

Objective To compare auditory findings before and after a single session of hemodialysis in patients with chronic kidney disease.

Methods A clinical cross-sectional research was conducted with a sample of 23 individuals between 24 to 57 years of age with a diagnosis of CKD undergoing hemodialysis. Distortion product otoacoustic emission (DPOAE) and transient otoacoustic emission (TOAE) tests were performed before and after a session of hemodialysis.

Results The DPOAE test revealed that 26% of the participants had failure in both ears prior to dialysis and 30.4% had failure after dialysis. Comparing the DPOAE and TOAE tests before and after hemodialysis, a slight decrease was found in patients with "fail" results from the predialysis test to the postdialysis test, but the difference did not achieve statistical significance.

Conclusions No significant hearing changes assessed through otoacoustic emissions occurred after a single session of hemodialysis in the sample analyzed.

Keywords
- hemodialysis
- hearing tests
- hearing loss

Introduction

Hearing is a complex process that involves mechanical, chemical, and neurophysiological components. Changes in hearing can be caused by congenital or acquired etiological factors, with various degrees and types of hearing loss. One possible cause is chronic kidney disease (CKD). Studies report that the prevalence of neurosensory hearing loss among patients with CKD ranges from 28 to 77%,[1,2] which is considerably higher than the rate found in the general population.

received
April 9, 2024
accepted
June 30, 2024

DOI https://doi.org/10.1055/s-0044-1789196.
ISSN 1809-9777.

Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Although the association between CKD and hearing loss has been reported, the physiopathological mechanics of this condition have not been investigated.[3–5] The kidneys and cochlea are similar in regard to both structure and physiological mechanisms, involving the transport of fluids and electrolytes, which may explain hearing loss in individuals with CKD.[6,7]

Other causes of hearing loss in this population have been considered, such as factors related to the severity and duration of CKD, electrolyte disorders, the use of ototoxic drugs, advanced age, comorbidities (diabetes mellitus and hypertension), and hemodialysis.[1,8,9]

The systematic frequency of hemodialysis sessions can induce electrolytic, biochemical, immunological, osmotic, and vascular changes that can alter the functioning of the inner ear.[10] Therefore, the aim of the present study was to compare the auditory findings of patients diagnosed with CKD before and after a single session of hemodialysis.

Methods

The present clinical cross-sectional study received approval from the Human Research Ethics Committee (approval number: 123.444) and was conducted in compliance with Resolution 466/2012 of the National Board of Health. All volunteers agreed to participate by signing a statement of informed consent.

Data collection took place between June 2022 and March 2023. Auditory findings were obtained before and after a single session of hemodialysis in patients with a diagnosis of CKD using distortion product otoacoustic emission (DPOAE) and transient otoacoustic emission (TOAE) tests with the aid of the Ero-Scan Pro (MAICO Diagnostics, Eden Prairie, MN, USA), duly calibrated following the ANSI S3.6 standard.

Twenty-three adults with CKD undergoing hemodialysis, irrespective of the time elapsed since diagnosis, were included. The exclusion criteria were age older than 60 years, individuals with altered hearing prior to the diagnosis of CKD, a history of exposure to noises of strong intensity, a family history of deafness, history of infection by rubella, cytomegalovirus, syphilis, herpes, hepatitis B, hepatitis C, or human immunodeficiency virus (HIV), individuals having undergone or currently undergoing treatment for cancer, and individuals having received a kidney transplant.

The otoacoustic emission (OAE) tests were performed by the same speech therapist in a silent room prior to and immediately after the end of the hemodialysis session. The following procedures were employed:

- Test in QuickScreen mode (rapid format with 12 milliseconds analysis window).
- Global analysis of responses for both TOAE and DPOAE, using the pass/fail protocol.
- Transient otoacoustic emission measured at frequencies of 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0 KHz through 83 dB NPS click stimulus (duration $\sim$ 64 seconds). To be considered present, the signal/noise ratio (SNR) needed to be $\geq$ 6 dB at frequences between 1.0 and 4.0 KHz, and responses for at least 3 frequencies were required.
- Distortion product otoacoustic emission measured using 2 simultaneous pure tones with different frequencies at intensities P1 = 65 dB NPS and P2 = 55 dB NPS at frequencies of 2.0, 3.0, 4.0, and 5.0 KHz. Distortion product otoacoustic emission analyses were performed per frequency with the following criteria: amplitude (SD) greater than -5 dB and SNR higher than 6 dB.

The data were expressed as absolute and relative (%) frequencies. The Student *t*-test for paired samples was used to determine differences in the results before and after hemodialysis. The Chi-squared test was used to test possible associations with a 95% confidence interval (CI). The significance level was set at 5% ($p < 0.05$). All analyses were performed with the aid of the SPSS Statistics for Windows, version 13.0 (SPSS Inc., Chicago, IL, USA).

Results

A total of 30 patients were recruited, three of whom met one or more exclusion criteria and four who did not return for the follow-up exam after hemodialysis. Thus, the final sample comprised 23 individuals—12 women (52.1%) and 11 men (47.8%). Patient's ages ranged from 24 to 57 years, with a mean and standard deviation of 41 $\pm$ 9.82 years. The average duration of hemodialysis was 9.17 years (range: 1–36 years). With regards to comorbidities, 4 patients (17.3%) had diabetes mellitus and 17 (73.9%) had arterial hypertension. All patients had 3-weekly sessions of hemodialysis, with an average of four hours per session (►**Table 1**).

There were 7 patients (30.4%) with complaints of tinnitus, 6 of whom (26.0%) described the frequency of the symptom as sporadic, occurring mainly at the end of the hemodialysis session and characterized as mild. Also, 5 patients (21.7%) reported hearing loss, and 100% had no knowledge of hearing impairment being linked to kidney disease.

Furthermore, 6 patients (26.0%) failed in both ears during the predialysis DPOAE test, and 5 (21.7%) failed during the postdialysis test. There were 7 patients (30.4%) who failed during the predialysis TOAE test, and 7 (30.4%) failed during the postdialysis test (►**Table 2**). In the analysis of patients who "passed" or "failed" in both ears on the DPOAE and TOAE tests, no associations were found with age group or duration of hemodialysis.

A greater number of failures were found for TOAE in both the right and left ears compared with DPOAE. Failures were predominantly in the left ear for DPOAE in the postdialysis test and in the left ear for TOAE in both the pre and postdialysis tests.

In the analysis of the frequencies tested, a greater number of patients failed at the highest frequencies (4.0 and 5.0 KHz) on both the pre and postdialysis tests (►**Table 3**). A discrete reduction was found in the number of patients who failed at all frequencies in the right ear between the pre and postdialysis tests. In contrast, an increase was found in the number of patients who failed at all frequencies in the left

Table 1 Demographic and clinical characteristics of sample ($n = 23$)

Variables	Female n (%)	Male n (%)	Total n (%)
Demographic			
Age group (years)			
24–30	3 (13.0)	1 (4.34)	4 (17.3)
31–40	4 (17.3)	3 (13.0)	7 (30.4)
41–50	5 (21.7)	3 (13.0)	8 (34.7)
51–57	0 (0.0)	4 (17.3)	4 (17.3)
Clinical			
Duration of dialysis (years)			
1–10	9 (39.1)	7 (30.4)	16 (69.5)
11–20	1 (4.34)	2 (8.6)	3 (13.0)
21–30	1 (4.34)	2 (8.6)	3 (13.0)
31–40	1 (4.34)	0 (0.0)	1 (4.34)
Diabetes			
Yes	3 (13.0)	1 (4.34)	4 (17.3)
No	9 (39.1)	10 (43.4)	19 (82.6)
Hypertension			
Yes	10 (43.4)	7 (30.4)	17
No	2 (8.6)	4 (17.3)	6
Auditory symptoms			
Tinnitus	3 (13.0)	4 (17.3)	7 (30.4)
Hearing loss	2 (8.6)	3 (13.0)	5 (21.7)
Total	12 (52.1)	11 (47.8)	23 (100)

Source: Author, 2023.

Table 2 General responses on pre and postdialysis OAE tests using pass/fail system

	GENERAL OAE RESPONSES							
	DPOAE $n = 23$				TOAE $n = 23$			
Side	Pre-dialysis		Post-dialysis		Pre-dialysis		Post-dialysis	
	Pass n %	Fail n %	Pass n %	Fail n %	Pass n %	Fail n %	Pass n %	Fail n %
BEs	13 (56.5)	6 (26.0)	12 (52.1)	5 (21.7)	10 (43.4)	7 (30.4)	13 (56.5)	7 (30.4)
RE	14 (60.8)	9 (39.1)	16 (69.5)	7 (30.4)	13 (56.5)	10 (43.4)	16 (69.5)	7 (30.4)
LE	17 (73.9)	6 (26.0)	14 (60.8)	9 (39.1)	13 (56.5)	10 (43.4)	13 (56.5)	10 (43.4)

Abbreviations: BEs, both ears; DPOAE, distortion product otoacoustic emission; LE, left ear; RE, right ear; TOAE, transient otoacoustic emission; OAE, otoacoustic emission.

ear between the pre and postdialysis tests. However, the Student *t*-test revealed that the differences did not achieve statistical significance ($p > 0.05$).

The results of the TOAE analysis for the number of patients who failed at each frequency are displayed in ►**Table 4**. A greater number of patients failed at frequencies of 3.0, 3.5, and 4.0 KHz for both the right and left ears. In the comparison of the pre and postdialysis tests, an increase was found in the number of patients who failed at frequencies of 1.5 and 4.0 KHz for the right ear and frequencies of 2.5 and 3.5 KHz for the left ear. The results also show a reduction in the number of patients who failed on the postdialysis tests at frequencies of 2.0, 3.0, 3.5, and 4.0 KHz for the right ear and frequencies of 1.5, 2.0, and 4.0 KHz for the left ear. However, no statistically

Table 3 Distribution of pre and postdialysis results (pass/fail) of DPOAE by ear ($n = 23$)

Frequency (KHz)	Fail RE		Fail LE	
	Pre (%)	Post (%)	Pre (%)	Post (%)
2.0	5 (21.7)	4 (17.3)	1 (4.34)	5 (21.7)
3.0	6 (26.0)	4 (17.3)	7 (30.4)	8 (34.7)
4.0	10 (43.4)	9 (39.1)	9 (39.1)	10 (43.4)
5.0	10 (43.4)	9 (39.1)	6 (26.0)	7 (30.4)

Abbreviations: DPOAE, distortion product otoacoustic emission; LE, left ear; RE, right ear.
Note: Student *t*-test $p > 0.05$.

Table 4 Distribution of pre and postdialysis results (pass/fail) of TOAE by ear ($n = 23$)

Frequency (KHz)	Fail RE		Fail LE	
	Pre (%)	Post (%)	Pre (%)	Post (%)
1.5	8 (34.7)	10 (43.4)	11 (47.8)	7 (30.4)
2.0	10 (43.4)	8 (34.7)	10 (43.4)	8 (34.7)
2.5	11 (47.8)	11 (47.8)	12 (52.1)	14 (60.8)
3.0	16 (69.5)	13 (56.5)	15 (65.2)	15 (65.2)
3.5	15 (65.2)	13 (56.5)	16 (69.5)	19 (82.6)
4.0	19 (82.6)	12 (52.1)	12 (52.1)	10 (43.4)

Abbreviations: LE, left ear; RE, right ear; TOAE, transient otoacoustic emission.
Note: Student *t*-test $p > 0.05$.

Table 5 Mean signal/noise ratios of DPOAE ($n = 23$)

S/N ratio	2.0		3.0		4.0		5.0	
RE	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean	12.2	16	15.8	16	15.4	16.1	16.7	17.2
SD	10	8.7	8.7	8.2	9.5	9.0	11.1	9.3
Minimum	−10.3	−3	−2.9	−3	0	0.1	−6	−1
Maximum	30.2	30.5	31.7	29.3	32.2	31.2	32.9	31
LE								
Mean	15	13	16	16.2	17.3	15	18.8	17
SD	8.7	8.7	9.3	7.2	10	10.2	9.3	9.2
Minimum	2	0	−1	0	−4	−1	−1.1	−1
Maximum	34.2	30.6	30.1	26.3	30.2	29.6	27	28.3

Abbreviations: DPOAE, distortion product otoacoustic emission; LE, left ear; RE, right ear; SD, standard deviation.
Source: Author, 2023.

significant differences were found in the comparison of the pre and postdialysis tests ($p > 0.05$).

An increase was found in the responses of the mean S/N ratio at all frequencies tested for the right ear and a frequency of 3.0 KHz for the left ear between the pre and postdialysis DPOAE tests (►**Table 5**).

In the analysis of mean SNR for pre and postdialysis TOAE, an increase in values was found at frequencies of 2.5, 3.0, and 3.5 KHz for the right ear and frequencies of 1.5, 2.0, 2.5, and 3.0 KHz for the left ear (►**Table 6**).

Discussion

The hearing of patients with CKD has been widely studied in different countries in recent years, with important results demonstrating the risk of hearing loss in this population.[11–16] The most common finding is bilateral neurosensory hearing loss, with higher frequencies affected more and a notch at 6 KHz.[17]

Similar results were found in the present study, as a larger number of patients failed at the frequencies of 4.0 and 5.0

Table 6 Mean signal/noise ratios of TOAE ($n = 12$)

S/N ratio	1.5		2.0		2.5		3.0		3.5		4.0	
RE	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean	12.4	5	9.6	5	−5.4	5	−1.4	4.6	1.1	4	4.4	3
SD	7.5	6.3	4.8	4.2	6.7	4.9	5.6	5.5	3.2	5.1	2.9	4.5
Minimum	−7	−3	−2	−2.1	−6	−3.3	−10	−48	−5	−8.1	−4	−3.8
Maximum	15.8	19.8	13.6	13.6	13	14.7	15	15	11.5	12	7	13.2
LE												
Mean	4.9	7	4	5	2.4	6	3.8	4	3.9	2	6	5.7
SD	4.9	4	4.6	4.6	5.8	4.8	3.8	4.5	4.3	3.9	4.9	4.9
Minimum	−3	−1	−3	−3	−6	−3	−12	−6	−5	3.5	−4.6	−3.5
Maximum	19.6	16.1	15.4	15.4	14.5	16.4	12.7	12.7	12.2	12.2	13	13

Abbreviations: LE, left ear; RE, right ear; SD, standard deviation; TOAE, transient otoacoustic emission.
Source: Author, 2023.

KHz for DPOAE and frequencies of 3.0, 3.5, and 4.0 KHz for TOAE. The sample was composed of 12 women and 11 men, and no significant associations were found with sex, age group, or duration of hemodialysis.

The authors of a case-control study also identified neurosensory hearing loss in a sample of 50 patients with CKD and found no associations between hearing loss and disease duration or age.[14] However, Wu et al.[18] found that the risk of hearing loss increased considerably with the duration of the disease.

The type of treatment and its relationship to hearing loss is another point widely discussed in the literature. Patients on hemodialysis have better hearing results compared with those undergoing conservative treatment (medicinal therapy).[12]

Although no statistically significant differences were found between the OETs conducted before and after hemodialysis, a discrete reduction was found in the number of patients who failed on the postdialysis tests. In 2001, Şerbetçioğlu et al.[19] studied 19 adults submitted to the high-frequency tonal audiometric test 1 hour before and 2 hours after hemodialysis and found no significant effect on hearing after a single session.

It is noteworthy that OAE tests have greater specificity for the assessment of cochlear function than other exams. These tests enable identifying cochlear disfunction prior to the change in audiometry.[20–22] Ozturan and Lam[23] also used OAE tests before and after a single session of hemodialysis and found no effect on hearing.

The reduction in the number of patients who failed the postdialysis test in the present investigation has been reported in previous studies.[24] Hemodialysis corrects a large part of hydroelectrical and metabolic changes of the endolymph induced by CKD and promotes the stabilization and correction of metabolic changes caused by the disease, leading to an increase in neural conduction and restoring the function of ciliated cells.[1,25] According to Gafter et al.,[26] dialysis may be beneficial to hearing, but the effect is temporary.

Although numerous studies have associated hearing loss and CKD, few investigated the symptom of tinnitus. This symptom is defined as consciously perceptible sound in the absence of an external auditory stimulus.[27] Like hearing loss, tinnitus has a negative impact on quality of life.[28] In a retrospective cohort study involving 185,430 patients with CKD, Shih et al.[29] concluded that the disease constitutes a significant, independent risk factor for tinnitus and that patients with terminal kidney disease on dialysis are at greater risk of tinnitus than patients with CKD not undergoing dialysis.

In the present study, 30.4% of the patients reported tinnitus as an auditory symptom. The etiology of tinnitus can be considered multifactorial. Patients with arterial hypertension, diabetes mellitus, heart failure, and liver cirrhosis are at greater risk of tinnitus, and many of these factors are commonly found in individuals with CKD.

Conclusions

No statistically significant auditory changes were found after a single session of hemodialysis in the sample analyzed. However, the number of patients who failed on the DPOAE and TOAE responses diminished following hemodialysis, characterizing an improvement in hearing.

Funding

Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Saeed HK, Al-Abbasi AM, Al-Maliki SK, Al-Asadi JN. Sensorineural hearing loss in patients with chronic renal failure on hemodialysis in Basrah, Iraq. Tzu-Chi Med J 2018;30(04):216–220
2 Kim S, Lee DK, Kim HR, Park JM, Kim SB, Yu H. Treatment outcomes for idiopathic sudden sensorineural hearing loss in dialysis patients. Sci Rep 2024;14(01):360

3 Gatland D, Tucker B, Chalstrey S, Keene M, Baker L. Hearing loss in chronic renal failure-hearing threshold changes following haemodialysis. J R Soc Med 1991;84(10):587–589
4 Pirodda A, Ferri GG, Raimondi MC, Borghi C. Kidney disease and inner ear sufferance of non-familial origin: A review of the literature and a proposal of explanation. Vol. 8. J Int Adv Otol 2012
5 Kumar KA, Hishamudin ADB, Krishnan DA, et al. The effect of hemodialysis on hearing in chronic kidney disease patients – A systematic review. Indian J Med Sci 2022;74(01):32–39
6 Fufore MB, Kirfi AM, Salisu AD, Samdi TM, Abubakar AB, Onakoya PA. Stage of chronic kidney disease and cochlear function: A cross-sectional survey. Niger Postgrad Med J 2020;27(02):122–126
7 Liu W, Meng Q, Wang Y, et al. The association between reduced kidney function and hearing loss: a cross-sectional study. BMC Nephrol 2020;21(01):145
8 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):2378–2383
9 Greenberg D, Rosenblum ND, Tonelli M. The multifaceted links between hearing loss and chronic kidney disease. Nat Rev Nephrol 2024;20(05):295–312
10 Reddy EK, Surya Prakash DR, Rama Krishna MGKD. Proportion of hearing loss in chronic renal failure: Our experience. Indian Journal of Otology. 2016;22(01):
11 Peyvandi A, Roozbahany NA. Hearing loss in chronic renal failure patient undergoing hemodialysis. Indian J Otolaryngol Head Neck Surg 2013;65(Suppl 3):537–540
12 Sam SKT. Hearing impairment in patients with Chronic Renal Failure. Journal of Medical Science And Clinical Research. 2014;2(02):
13 Seo YJ, Ko SB, Ha TH, et al. Association of hearing impairment with chronic kidney disease: a cross-sectional study of the Korean general population. BMC Nephrol 2015;16(01):154
14 Boateng JO, Boafo N, Osafo C, Anim-Sampong S. Hearing impairment among chronic kidney disease patients on haemodialysis at a tertiary hospital in Ghana. Ghana Med J 2019;53(03):197–203
15 Gupta S, Curhan SG, Cruickshanks KJ, Klein BEK, Klein R, Curhan GC. Chronic kidney disease and the risk of incident hearing loss. Laryngoscope 2020;130(04):E213–E219
16 Fadel FI, Yamamah GAN, Hasanin RM, et al. Hearing assessment in Egyptian children with chronic renal failure on regular hemodialysis and renal transplantation children. Ther Apher Dial 2022;26(05):960–968
17 Agrawal M, Singh CV. Sensorineural Hearing Loss in Patients With Chronic Kidney Disease: A Comprehensive Review. Cureus 2023;15(11):e48244
18 Wu KL, Shih CP, Chan JS, et al. Investigation of the relationship between sensorineural hearing loss and associated comorbidities in patients with chronic kidney disease: A nationwide, population-based cohort study. PLoS One 2020;15(09):e0238913
19 Serbetçioğlu MB, Erdoğan S, Sifil A. Effects of a single session of hemodialysis on hearing abilities. Acta Otolaryngol 2001;121(07):836–838
20 Yilmaz S, Öktem F, Karaman E. Detection of cisplatin-induced ototoxicity with transient evoked otoacoustic emission test before pure tone audiometer. Eur Arch Otorhinolaryngol 2010;267(07):1041–1044
21 Sharifian MR, Kamandi S, Sima HR, Zaringhalam MA, Bakhshaee M. INF- α and ototoxicity. BioMed Res Int 2013;2013:295327
22 Corvaro C, Lagreca LCC, Munhoz MSL, de Azevedo MF. Emissões otoacústicas evocadas na doença de Ménière. Audiol Commun Res 2022;•••:27
23 Ozturan O, Lam S. The effect of hemodialysis on hearing using pure-tone audiometry and distortion-product otoacoustic emissions. ORL J Otorhinolaryngol Relat Spec 1998;60(06):306–313
24 Aspris AK, Thodi CD, Balatsouras DG, Thodis ED, Vargemezis V, Danielides V. Auditory brainstem responses in patients under treatment of hemodialysis. Ren Fail 2008;30(04):383–390
25 Ghasemi MM, Bakhshaei M, Jamei AS. Medical Joumal of the Islamic Republic of Iran HEARING LOSS IN HEMODIALYSIS PATIENTS. Vol. 17. MJIRI; 2004
26 Gafter U, Shvili Y, Levi J, Talmi Y, Zohar Y. Brainstem auditory evoked responses in chronic renal failure and the effect of hemodialysis. Nephron J 1989;53(01):2–5
27 Saeed S, Khan QU. The Pathological Mechanisms and Treatments of Tinnitus. Discoveries (Craiova) 2021;9(03):e137
28 Hung SH, Xirasagar S, Cheng YF, Kuo NW, Lin HC. Association of Chronic Kidney Disease with Prior Tinnitus: A Case-Control Study. J Clin Med 2022;11(24):7524
29 Shih CP, Lin HC, Chung CH, et al. Increased risk of tinnitus in patients with chronic kidney disease: A nationwide, population-based cohort study. PLoS One 2017;12(08):e0183192