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Original Article

Audiological and Vestibular Measurements in Chronic Renal Failure Patients Receiving Hemodialysis Treatment

Ahmet Ozmen[1], Fulya Ozer[2], Dilek Torun[3], Hatice Seyra Erbek[2], Selim Sermed Erbek[2], Levent Naci Ozluoglu[2]

[1]Department of Audiology, Başkent University, Faculty of Medicine, Ankara, Turkey
[2]Department of Otorhinolaryngology, Başkent University, Faculty of Medicine, Ankara, Turkey
[3]Department of Nephrology, Başkent University, Faculty of Medicine Adana Hospital, Adana, Turkey

ORCID iDs of the authors: O.A. 0000-0002-9775-3900, F.O. 0000-0001-5381-6861, D.T. 0000-0002-6267-3695, H.S.E. 0000-0002-8453-6069, S.S.E. 0000-0003-4825-3499, L.N.O. 0000-0002-2150-0237.

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BACKGROUND: The aim was to evaluate the changes in the audiovestibular system in adult patients with the diagnosis of chronic renal failure who were treated with hemodialysis.

METHODS: Thirty-five patients diagnosed with chronic renal failure and receiving hemodialysis treatment 3 days a week and 35 healthy individuals were tested with pure tone audiometry, video head impulse test, and post-head shake nystagmus test. Dizziness Handicap Inventory was applied to all participants.

RESULTS: The Dizziness Handicap Inventory scores of the patient groups are higher than the control groups ($P = .001$). In the video head impulse test, there is no statistically significant difference between the patient and control groups in terms of gain asymmetry. 17.1% of the patients had both left and right lateral saccades ($P = .03$). A statistically significant difference was also found after the post-head shake test ($P = .025$). In the patient group, an inverse relationship between the presence of left anterior right posterior saccades and blood urea nitrogen–creatinine ratio and a direct relationship between the presence of right anterior left posterior saccades and creatinine elevation were determined. The presence of saccades in the video head impulse test increased significantly as the disease duration of hemodialysis patients increased.

CONCLUSION: It was determined that the overt and covert saccades in the video head impulse test increased significantly as the creatinine increased and the duration of the disease increased in the patients with chronic renal failure. The common clinical usage of video head impulse test in monitoring the vestibular side effects of creatinine elevation and disease duration in chronic renal failure patients may be possible with future studies.

KEYWORDS: Chronic renal failure, video head impulse test (vHIT), Dizziness Handicap Inventory, post-head shake nystagmus

INTRODUCTION

Chronic kidney disease (CKD) is defined as a chronic disease (≥ 3 months) that can occur due to various causes and with different chronic diseases, and may result in irreversible nephron loss.[1] Glomerular filtration rate (GFR) is the best indicator of the kidneys' ability to clean the blood, and a decrease below 60 mL/min/1.73 m^2 is considered one of the most important criteria of CKD.[2] With the progression of the disease, end-stage chronic renal failure (CRF) may be happened with the GFR value falling below 15 mL/min and/or nephron loss and pathological damage to the kidney.[1,2] In this case, the most preferred renal replacement therapy method is hemodialysis for the treatment of patients with CRF[3]

In CRF, hearing loss may occur due to the toxicity of nitric components, electrolyte disturbances, and easy penetration of ototoxic drugs.[4] The incidence of sensorineural hearing loss in renal failure varies between 20% and 87%.[5]

Corresponding author: Fulya Ozer, e-mail: fdeveci06@hotmail.com
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In the literature, the involvement of the vestibular system in patients with CRF and receiving hemodialysis treatment has not been studied as much as the involvement of the cochlea and hearing. Mineral bone disorder, electrolyte imbalance, anemia-related symptoms, metabolic acidosis, multiple drug use, malnutrition, muscle atrophies and fatigue, intradialytic hypotension and dialysis-related arrhythmias, peripheral and autonomic neuropathies can be seen in CRF patients.[6,7] It is also known that CRF patients are older, and the disease generally develops with various multisystemic diseases in advanced age.[8] Therefore, the vestibular system can be expected to be affected in CRF patients.

In 2 studies in which posturography was used to evaluate balance in hemodialysis patients, no difference was found in dialysis patients compared to the control group. However, these studies showed that the risk of falling after dialysis increased significantly when predialysis and postdialysis posturography test results were compared.[9,10] In another study, patients treated with hemodialysis were examined with the ocular vestibular evoked myogenic potential (oVEMP) test, and no difference was found compared to the control group.[11]

The vestibulo-ocular reflex (VOR) ensures that the gaze remains fixed and maintained during head movement, and that the image remains fixed on the retina, thus maintaining correct vision.[11] Testing of the vestibular system is often based on revealing this reflex. The video head impulse test (vHIT) is a diagnostic method that evaluates VOR functions. In this test, 3 semicircular canals in the vestibular system, as well as the superior and inferior branches of the vestibular nerve are evaluated.[12] It is a fast-scanning tool that provides high-frequency information about the vestibular system.[13]

The aim of this study is to examine the audiovestibular system in adult patients who received hemodialysis treatment due to the diagnosis of CRF with vHIT as well as pure tone audiogram test, post-head shake nystagmus test, and dizziness disability questionnaire.

MATERIAL AND METHODS

This study was approved by Başkent University Institutional Review Board and Ethics Committee (Approval No: 21/311) and supported by Başkent University Research Fund. Informed consent forms were received from the participants' parents and the participants were informed about the tests to be applied.

Study Design

This descriptive, comparative, case–control, and nonexperimental study was conducted at the Department of Otorhinolaryngology, Audiology and the Department of Nephrology of our hospital which is tertiary referral center. Thirty-five patients treated in the Dialysis Unit of the Nephrology Department and 35 volunteer personnel working in the same hospital, who were compatible with the patient group in terms of age and gender, and who did not have any systemic disease, were included.

The criteria for inclusion in the study group are listed as follows:

- Over the age of 18 years and diagnosed with CKD and undergoing hemodialysis treatment for at least 3 months,
- Having normal ear examinations,
- Not having any ear disease (vestibular neuritis, benign paroxysmal positional vertigo, chronic otitis media, otosclerosis, vestibular ototoxicity, labyrinthitis) that may cause dizziness
- Not having metabolic or cardiac diseases such as anemia, hypothyroidism, hyperthyroidism, diabetes mellitus, and hypertension that may cause dizziness, and not using chemotherapeutic drugs,
- Not having any known neurological disease (skull fracture, multiple sclerosis, meningitis).

Data Collection

Dizziness Handicap Inventory: Dizziness Handicap Inventory (DHI) was applied face-to-face to all of 70 participants by an expert audiologist. It consists of 25 statements answered by the patient in the format of "yes" (4 points), "sometimes" (2 points), "no" (0 points). Thus, a score of 100 represents the maximum feeling of discomfort, and a score of 0 represents the minimum of discomfort.

Pure tone audiometry (Interacoustics AC 40 ®, Denmark): The patients have been pure tone audiometry in the quiet rooms with the standard of Industrial Acoustic Company (IAC). As a rule, the mean frequency of speech frequency was between 0 and 20 dB, and a speech discrimination score of 92% and above was accepted as corresponding to normal hearing.

vHIT (GN Otometrics, ICS Impulse, Denmark): The participant was seated in a chair 1 meter away from the wall and a circle was drawn on the wall at eye level, large enough for the patient to see. The glasses of the device were firmly attached to the patient and the movement of the glasses was prevented. The vHIT glasses used in the study have a curved, bendable frame; a head-mounted structure with a rubber band; and a weight of 40 g.[14] There is a monocular camera and an inertial measurement unit (IMU) with 6 degrees of freedom on the glasses. The glasses are connected to the computer with a USB 2.0 cable that provides data transfer.

By adjusting the position of the movable camera on the glasses, the eye was centered on the screen and the calibration phase was started. While performing the calibration, the volunteer was asked to look at 5 laser light points reflected on the wall without moving his head. The point to be looked at was told to the participant aloud by watching on the computer screen. According to the commands given by the device, this process for the calibration of eye movements was completed in about 24 seconds. The calibration process was repeated for each participant before each test.

During the test, the participant's head was held by the audiologist to be grasped by the chin and quickly pushed to the right, left, forward,

MAIN POINTS

- The video head impulse test (vHIT) is an important test that can be easily used in the evaluation of the vestibular system in chronic renal failure (CRF) patients receiving hemodialysis treatment.
- The overt and covert saccades in the vHIT increased significantly as the creatinine increased and the duration of the disease increased.
- Future studies would help expand the clinical use of vHIT in monitoring the vestibular side effects of creatinine elevation and disease duration in CRF patients.

or back at an angle of about 15° while the participant was asked to free his head. The participant was asked also to try not to look away from the circle. The test was completed by making at least 10 head thrusts for each channel. During the lateral semicircular canal measurements, the participant's head was tilted forward about 30° and it was checked on the computer screen that it was in the correct plane. For the lateral canals, random rapid head thrusts were applied to the right and left by the practitioner standing behind. Since the measurements of the vertical semicircular canals were in the same plane, the right anterior (RA) and left posterior (LP) semicircular canals [right anterior left posterior (RALP)] and left anterior (LA) and right posterior (RP) semicircular canals [left anterior right posterior (LARP)] were tested together.

Normal limits for VOR gain are accepted as ≥0.8 seconds for the left lateral semicircular canal (left lateral, LL) and right lateral semicircular canal (right lateral, RL); ≥0.7 seconds for RALP and LARP.[15,16] In this way, whether there is a decrease in VOR gain in all individuals and the presence of overt/covert saccade were investigated and recorded.

Post-head shake test (Micromedial Visual Eyes, Micromedial Technologies USA): In this test, the participant was in a sitting position, with his head tilted forward 30 degrees, at a rate of 2 times per second (frequency of 2 Hz) and for 20 seconds in a horizontal plane. It was ensured that there was no visual fixation while shaking the head, and that the patient's eyes were closed or Frenzel glasses were worn. A few beats of nystagmus, which may occur within 1-2 seconds after head shaking, was considered normal. If the nystagmus exceeded this time, post-head-shake nystagmus was considered pathological and was examined in terms of direction/direction change.

Blood parameters: Calcium (CA), parathyroid hormone (PTH), creatinine, blood urea nitrogen (BUN), and BUN–creatinine ratio were recorded in blood samples taken before dialysis in 35 hemodialysis patients. The correlation between these values and the presence of saccades in the vHIT was examined.

Statistical Analysis

For the statistical analysis IBM Statistical Package for the Social Sciences, version 25.0 (IBM SPSS Corp.; Armonk, NY, USA) program was used. First, it was determined whether the data collection tools comply with the normal distribution hypothesis by looking at the skewness and kurtosis coefficients, the data set outliers were checked and nonparametric test methods were preferred. Afterward, descriptive statistics are given. Finally, a hypothesis evaluation was made.

In comparisons between groups, the normal distribution of continuous variables was determined by Kolmogorov–Smirnov normality test. "Independent sample *t*-test" was used for normal distributions, "Mann-Whitney *U*-test" for nonnormal distributions, and "chi-square tests" for categorical variables. "Pearson's correlation analysis" was performed for comparisons of continuous variables. The results were evaluated at 95% significance level and statistical significance was accepted as $P < .05$.

RESULTS

Of the hemodialysis group, 16 (45.5%) were male and 19 (51.4%) were female. In the control group, 17 men (51.5%) and 18 women (48.6%) were included. There was no statistically significant difference between the groups in terms of gender ($P = .811$). The mean age of the patient group included in the study was 33.09 ± 6.8 (range between 24 and 46). The mean age of the control group was 33.77 ± 6.85 (range between 23 and 46). There was no statistically significant difference between the patient and control groups in terms of age ($P = .68$).

Pure tone audiometry test results were compared between control and study groups. The pure tone average (PTA) of thresholds measured at the frequencies 0.5, 1, and 2 kHz was calculated as speech frequency average, and the PTA of thresholds measured at the frequencies 4 and 6,8 kHz was calculated as the high frequency average. In the patient group, it was determined that PTA was statistically significantly higher in both high frequencies and speech frequencies in both ears, and the hearing was worse in the patient group ($P < .05$) (Table 1).

Dizziness Handicap Inventory was applied to all the participants in both groups and the scores were compared and showed a statistically significant difference between the groups ($P = .001$). The mean DHI score of the patient group was 5.2 (SD ± 8.6), which was higher than the mean DHI score of the control group (mean: 0).

Video Head Impulse Test and Post-Head Shake Test Results

Both groups were compared in terms of gain asymmetry in both ears with the vHIT, and no statistically significant difference was found ($P > .05$) (Table 2).

The presence of saccades in the left and right lateral canals between the study and control groups were examined separately by the chi-square test, and a statistically significant difference was found ($\chi^2 = 6.56$, $P = .03$). While 17.1% of the patients had both left and right lateral saccades, in the control group saccades were not observed in the lateral canals. The presence of left and right anterior canal saccades between the study and control groups was evaluated with the chi-square test, and no statistically significant difference was found

Table 1. Comparison of the Audiometer Results of Patients with CRF Disease and Normal Individuals

	Group	N	Mean	SD	*P*
Speech frequencies					
R (dB)	CRF disease	35	30.46	21.157	**.00***
	Normal	35	7.34	7.696	
L (dB)	CRF disease	35	23.4	16.085	.00*
	Normal	35	6.51	5.777	
High frequencies					
R (dB)	CRF disease	35	17.89	16.273	**.00***
	Normal	35	5.31	5.063	
L (dB)	CRF disease	35	12.83	9.06	**0.001***
	Normal	35–	5.06	3.933	

Speech frequencies involved 500, 1000, and 2000 Hz; high frequencies involved 4000, 6000, and 8000 Hz.
CRF, chronic renal failre L, left ear; R, right ear.
*Mann–Whitney *U*-test; $P < .05$.

Table 2. Descriptive Statistics and Analysis of the vHIT Results

	Group	N	Mean	SD	*P*
Left lateral gain	CRF disease	35	0.99	0.13	.798
	Normal	35	0.99	0.13	
Right lateral gain	CRF disease	35	0.97	0.09	.325
	Normal	35	3.60	15.56	
Left anterior gain	CRF disease	35	0.99	0.12	.589
	Normal	35	0.97	0.10	
Right anterior gain	CRF disease	35	0.94	0.09	.634
	Normal	35	0.95	0.08	
Left posterior gain	CRF disease	35	0.96	0.08	.286
	Normal	35	0.98	0.09	
Right posterior gain	CRF disease	35	0.96	0.10	.725
	Normal	35	0.97	0.07	

CRF, chronic renal failure; vHIT, video head impulse test.
*P: Mann–Whitney *U*-test, <.05.

for either side. ($\chi^2 = 1.06$, $P = .61$ for the left anterior canal; $\chi^2 = 2.06$, $P = .49$ for the right anterior canal).

A statistically significant difference was found in the chi-square test results of the patient and control groups in terms of the presence of nystagmus after the post-head shake test ($\chi^2 = 6.56$, $P = .03$). While 17.1% of hemodialysis patients had nystagmus after post-head shake test, in the control group nystagmus was not observed.

The relationship between the change in blood parameters of hemodialysis patients and the presence of saccade in the lateral channels was investigated and there was no significant difference ($P > .05$).

The relationship between the change in blood parameters of hemodialysis patients and the presence of saccade in LARP canals was investigated and it was found that only the BUN–creatinine ratio differed significantly with presence of LARP saccade ($t = 2.52$; $P = .02$). Patients with no LARP saccade had a higher BUN–creatinine ratio than patients with a LARP saccade.

The relationship between the change in blood parameters of hemodialysis patients and the presence of saccade in RALP canals was investigated and it was found that that only the mean creatinine value differed significantly with presence of RALP saccade ($t = -2.09$, $P = .04$). Patients with RALP saccade had a higher creatinine ratio than patients without RALP saccade (Tables 3 and 4).

According to the results of the correlation analysis, it was determined that there was a statistically positive low–strong significant relationship at 99% confidence level between dialysis time and left lateral saccade formation ($r = 0.34$, $P = .005$, $P < .01$). It was also determined that there was a statistically positive low–strong significant relationship between dialysis time and right posterior saccade formation at 95% confidence level ($r = 0.29$, $P = .015$,).

DISCUSSION

Chronic Renal failure is a multisystemic disease in which many organs are affected due to the functions of the kidneys in the body. Especially neurological findings significantly affect the quality of life of patients. Uremic toxins, metabolic and hemodynamic disorders, oxidative stress, inflammation, and impaired blood–brain barrier are the main causes of neurological findings in CRF.[17] Both the peripheral and central nervous systems can be affected. Peripheral neurological findings occur mostly due to somatic and cranial peripheral neuropathies.[17,18] Cranial neuropathies are observed more in olfactory, visual, and auditory nerves.[18]

Table 3. Comparison of Blood Parameters with Left Anterior Saccade Presence

	Left Anterior Saccade	N	Mean	SD	*t*	*df*	*P*
CA	Saccade (–)	32	8.39	0.78	–0,152	33	.88
	Saccade (+)	3	8.47	1.34			
PTH	Saccade (–)	32	603.32	603.95	–1,39	33	.174
	Saccade (+)	3	1106.03	518.58			
Cr	Saccade (–)	32	10.85	2.32	–1,491	33	.145
	Saccade (+)	3	12.95	2.41			
BUN	Saccade (–)	32	73.47	15.77	1.449	33	.157
	Saccade (+)	3	60.00	7.21			
BUN/Cr	Saccade (–)	32	6.93	1.53	2.518	33	**.017***
	Saccade (+)	3	4.67	0.29			
Vit-D	Saccade (–)	3	15.37	8.27			
	Saccade (+)	0	.	.	.		

$t = 2.52$; $P = .02$; $P < .05$.
cBUN, blood urea nitrogen; BUN/Cr, blood urea nitrogen-to-creatinine ratio; CA, calcium; Cr, creatinine; PTH, parathyroid hormone; *t*, independent samples *t*-test; Vit-D, 25-hydroxyvitamin D.only the BUN–creatinine ratio differed significantly with presence of LARP saccade ($t = 2.52$; $P = .02$)

Table 4. Comparison of Blood Parameters with Left Posterior Saccade Presence

	Left Posterior Saccade	N	Mean	SD	*t*	*df*	*P*
CA	Saccade (–)	34	8.42	0.81	1.122	33	.27
	Saccade (+)	1	7.50	.	.	.	.
PTH	Saccade (–)	34	615.35	587.50	–1.824	33	.077
	Saccade (+)	1	1702.60	.	.	.	.
Cr	Saccade (–)	34	10,90	2.26	–2.094	33	**.044***
	Saccade (+)	1	15.69	.	.	.	.
BUN	Saccade (–)	34	72.44	15.85	0.276	33	.784
	Saccade (+)	1	68.00	.	.	.	.
BUN/Cr	Saccade (–)	34	6.80	1.57	1.556	33	.129
	Saccade (+)	1	4.33	.	.		
Vit – D	Saccade (–)	3	15.37	8.27			
	Saccade (+)	0	.	.	.		

$t = 2.52$; $P = .02$; $P < .05$.
BUN, blood urea nitrogen; BUN/Cr, blood urea nitrogen-to-creatinine ratio; CA, calcium; Cr, creatinine; PTH, parathyroid hormone; *t*, independent samples *t*-test; Vit-D, 25-hydroxyvitamin D.*only the mean creatinine value differed significantly with presence of RALP saccade ($t = -2.09$, $P = .04$).

In a study which investigated hearing before and after hemodialysis with PTA, it was found that a 10% loss occurred in low frequencies after dialysis, but there was no significant change in other frequencies.[19] Antonelli et al[7] detected a prolongation in the I-III interpeak latency value in auditory brainstem response (ABR) recordings in adult patients with CRF and claimed that the cochlear nerve could be affected and a slowdown in nerve conduction might be occurred due to uremic neuropathy in kidney failure. Samir et al[20] found the positive response at low percentage in the transitory evoked otoacoustic emission (TEOAE) test in children receiving hemodialysis treatment compared to the control group. In these studies, all of the authors claimed that uremia-induced physiopathological and neuropathic changes in the cochlear and/or auditory nerves are responsible for the hearing loss. We could not perform ABR and TEOAE tests in our study, but the PTA results of our study revealed worse hearing in both speech frequencies and high frequencies in patients receiving hemodialysis treatment, and support the above studies. In our study, the confounding effect of age was eliminated by not including participants over the age of 50 years who may have age-related high-frequency hearing loss.

In CRF patients, their balance may be impaired due to decreased physical activity, myopathy, neuropathy, and even drug-related complications.[21] Erken et al[10] evaluated 53 adult hemodialysis patients and found that the fall risk index scores evaluated with the Tetrax posturography device were significantly higher after dialysis compared to the control group and before dialysis. In a study in which cochleovestibular symptoms were analyzed in CRF patients, it was observed that 32 patients had sudden hearing loss.[22] Vertigo complaints were reported in 56.3% of these evaluated patients. In histopathology studies conducted in 10 patients with CRF, degeneration in the organ of Corti, cochlear hydrops, fibrosis in the perilymph, deterioration of the tectorial membrane, and calcification in the stria vascularis were observed.[23] These findings speculated that uremic neurotoxicity inhibits the Na/K adenosine triphosphatase pump and that this might cause endolymphatic hydrops.[22] Another cause of inner ear damage in CRF may be rapid and pronounced fluctuations in blood pressure during hemodialysis. These sudden and massive changes in blood pressure can affect the vascularity of the inner ear, leading to cochleovestibular dysfunction. In addition, diseases that disrupt microcirculation such as diabetes mellitus and hypertension, which can be seen together in some of the CRF patients, can also cause vertigo by forming microemboli.[23]

Sazgar et al[24] investigated vestibular functions of hemodialysis patients and performed the cervical vestibular evoked myogenic potential (cVEMP) test, which is the test of the saccule and associated neural pathways. A group of CRF patients treated with hemodialysis had less response to this test than the control group and this result was statistically significant. A significant correlation was found between the presence and absence of VEMP wave and creatinine levels in the dialysis group. Wrobel et al[25] examined 45 patients with CRF (25 treated with hemodialysis and 20 not requiring dialysis) for vestibular organ function. They reported vestibular organ damage in 84.4% of the patients and revealed that there was a statistically significant increase in parathormone serum concentration in patients with central type damage. However, they did not mention the type of vestibular test and the type of vestibular function. Varhagese et al[11] evaluated otolith functions by applying o/c VEMP test in CRF patients and found a decrease in amplitudes. In the literature, no study using the vHIT has been found in the evaluation of vestibular functions in CRF patients receiving hemodialysis treatment.

In the present study, CRF patients scored significantly higher in DHI compared to the control group. Dizziness Handicap Inventory is used safely in many studies as an important marker that subjectively shows the vestibular system being affected.[26] In this study, obtaining a high questionnaire score in the patient group was evaluated as a possible vestibular involvement. Dizziness Handicap Inventory can also be used to assess patients' risk of falling. Huang et al[27] performed logistic regression analysis and found that 283 patients with vestibular pathology had a high risk of falling in patients with high DHI. For this reason, even if CRF patients receiving hemodialysis cannot be evaluated with effective vestibular diagnostic methods to decide the status of balance, it is recommended to apply DHI for early recognition of the involvement of the vestibular system and determination of the risk of falling.

The post-head shake test is recommended in the literature as an easy and bedside test for the diagnosis of vestibular dysfunction.[26,28,29] Teggi et al[28] determined that 15% of the patient population of 511 adults with a definite diagnosis of Meniere's disease showed abnormal vHIT findings and the post-head shake test was positive in 23% with a correlation with vHIT. Ertugrul et al[26] found that the post-head shake test and vHIT results were affected in accordance with each other in Behçet's disease patients. Our study also supports these studies with the significant correlation between the presence of post-head shake nystagmus and the presence of positive saccades in the vHIT in the patient group.

High creatinine is considered more reliable than all other values in showing the estimated GFR level and therefore the functioning of the kidneys.[2] Elevated creatinine may lead to inadequate clearance of the drugs used and the formation of neurotoxicity with possible increased blood–brain barrier penetrance, as well as affecting peripheral nerve conduction. This situation may affect many other systems as well as the vestibular system.[18] Sazgar et al[24] compared serum creatinine level and VEMP test results in 20 hemodialysis patients and observed that there were no VEMP waves as creatinine increased. Tekkarışmaz et al[9] found that the fall index scores in posturography were higher in kidney transplant patients, especially in patients with high creatinine levels. In our study, the presence of overt and covert saccades was found to be significantly more common in dialysis patients. When the relationship between blood values and vHIT results was examined, an inverse correlation between the presence of LARP saccades and BUN–creatinine ratio and a direct correlation between the presence of RALP saccades and creatinine elevation were determined. In summary, saccades were found to be increased in the vHIT in the presence of high creatinine and therefore low BUN–creatinine ratio.

In this study, it was observed that the presence of saccades in the vHIT increased significantly as the duration of the disease in hemodialysis patients increased. Varhagese et al[11] also found that test results of o/c VEMP were affected with renal failure disease duration. However, our vHIT results were different from those of Ertuğrul et al's[26] study that examined the vestibular system with the vHIT in Behçet's disease patients and those of Kalkan et al's[30] study that examined the vestibular system with the vHIT in diabetes mellitus patients. Ertuğrul et al[26] observed that the vHIT results were affected in the early stage before neurological symptoms appeared in Behçet's disease patients. Kalkan et al's study did not found the difference between values of vHIT between diabetes mellitus and diabetic neuropathy with long standing diabetes patients.[30] However, in the present study, the effect of the vestibular system increases significantly as the duration of the disease and therefore the duration of hemodialysis increase. Tekkarışmaz et al[9] performed posturography on the patients after kidney transplantation and found that the risk of falling in transplant patients with normal graft function was similar to healthy volunteers. Our study, along with this study, suggests that early transplantation in patients with CRF and having a functional graft after transplantation have a more protective effect on the vestibular system than hemodialysis treatment for many years. This idea should be supported by future studies.

Although our study is a prospective case–control study, it has some limitations. One of the limitations is that TEOAE could not be performed together with PTA to show cochlear involvement properly. Future studies on the influence of hemodialysis on cochlear functions may help interpret the involvement of the vestibular system. The second limitation is that videoelectronystamography (VENG) test could not be performed the with all its subtests. The most important reason for this limitation was the difficulties in the transfer of patients from the dialysis unit to audiology unit located in separate buildings of the hospital. Also, the ability of patients to tolerate all test periods at the same time might be difficult. This study should be considered a pioneering study of a comprehensive analysis of the vestibular system of dialysis patients by providing a combination of all tests such as VENG test battery, posturography, VEMP, and vHIT.

Despite all these limitations, our study is the first study in the literature to evaluate the vestibular system with the vHIT in CRF patients receiving hemodialysis treatment.

As a conclusion, the vHIT is an important test that can be easily used in the evaluation of the vestibular system in CRF patients receiving hemodialysis treatment. The vestibular system is significantly affected in patients receiving hemodialysis treatment, and it was determined that the overt and covert saccades in the vHIT increased significantly as the creatinine increased and the duration of the disease increased. Expanding the clinical use of the vHIT in monitoring the vestibular side effects of creatinine elevation and disease duration in CRF patients is possible with future studies.

Ethics Committee Approval: This study was approved by the Ethics Committee of Başkent University (Approval No: 21/311).

Informed Consent: Informed consent was obtained from the participants and their parents who agreed to take part in the study.

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