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Audiological Findings of Speech Perception in Noise Test and Speech, Spatial, and Qualities of Hearing Scale Questionnaire in Patients with Chronic Kidney Disease

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ABSTRACT

Background: The study aims to investigate the impact of chronic kidney diseases (CKD) on the auditory processing abilities of patients, including uremic neuropathy. The impairment of auditory processing may result in communication, social, and emotional problems in their lives. Accordingly, this study analyzes the communication abilities and speech perception of noise in CKD patients to identify potential auditory disorders rapidly.
Methods: In this cross-sectional-comparative study, the authors randomly selected 30 CKD patients and 29 normal adults aged 20-55, all of whom had normal peripheral hearing. The participants underwent the consonant-vowel (CV) test with five signal-to-noise ratios (SNR) and silence. Additionally, the participants completed the speech, spatial, and qualities of hearing scale questionnaire (SSQ), which consisted of three subscales. The scores of the two groups were compared using the Mann-Whitney U test.
Results: In both groups, the recognition scores for consonant-vowel decreased as the noise level increased. However, the normal group consistently outperformed the CKD patients at all noise levels. Regarding the three subscales of the SSQ, the patients obtained lower scores than the normal group, but this difference was not statistically significant.
Conclusion: Chronic renal failure appears to have a negative impact on speech perception abilities in noise, suggesting auditory neurological involvement in CKD. Although patient self-assessment did not indicate any speech processing disability, conducting regular and periodic assessments of central hearing in CKD patients is still advisable. Early diagnosis of hearing disability can help mitigate its consequences, and appropriate rehabilitation measures should be taken if a disability is detected.

Introduction

Chronic kidney disease (CKD) is characterized by irreversible kidney damage and/or diminished renal function [1]. The prevalence of CKD has been on the rise in recent decades, with approximately 2.5 million patients worldwide diagnosed with the condition in 2013. It is projected that this number will escalate to 6.5 million by the year 2030 [2]. CKD can affect various organs in the body, and the auditory system is no exception

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to potential damage. Certain diseases and syndromes, such as Alport syndrome, may simultaneously impact the kidneys and ears [3, 4]. Research findings indicate that individuals with CKD are more likely to experience hearing impairment than the general population [2, 5].

Hearing impairment can significantly impact the quality of life and restrict participation in daily activities [2]. People with hearing difficulties may experience communication challenges, leading to feelings of isolation, reduced self-confidence, and even depression [6, 7]. Auditory processing involves the central nervous system's ability to utilize auditory information and associated neurobiological activities for comprehending and interpreting auditory stimuli [8]. Auditory processing disorder refers to alterations in specific auditory abilities that affect how individuals perceive and recognize what they hear. The integration of the auditory system, whether peripheral or central, is essential for effective human communication, including spoken and written language skills [5, 9].

Speech is a fundamental aspect of human communication, and any impairment in speech processing can hinder interpersonal interactions [10]. We encounter complex acoustic signals in everyday auditory environments rather than single auditory stimuli. The auditory system must process these complex signals simultaneously to extract relevant information. For example, listening to speech in the presence of background noise requires intricate interactions between the auditory system and cognitive functions of the central nervous system to distinguish the target sound from competing noise [11]. Individuals who struggle to understand speech in noisy environments may feel distressed by background noise and often report difficulties following conversations in such settings [12].

Researchers have extensively studied the auditory system in patients with CKD, and their findings indicate that hearing impairment in these patients ranges from 20% to 80% [3, 13-17]. This significant prevalence of hearing impairment suggests damage to the auditory pathway. Several studies evaluating the auditory nerve pathway using the auditory brainstem response (ABR) in CKD patients have reported evidence of varying degrees of auditory dysfunction, with 24% to 44% of the studies showing increased latency of waves. Notably, end-stage CKD seems to lead to more pronounced hearing impairment and delays in nerve conduction along the auditory nerve pathway, surpassing the impact of old age [17, 18].

However, it is worth noting that our review did not uncover any studies that included behavioral tests on the central nervous system (CNS) in patients with CKD. D'Andrea et al. (2012) conducted one study focused on adults with transplantation. The results showed that while there were no complaints about hearing in the questionnaire responses, pure tone audiometry (PTA) was generally normal. However, the findings of the staggered spondee word (SSW) test and the random gap detection test (RGDT) in these patients differed from the control group [5].

Speech perception difficulties in noisy environments are a common hallmark of auditory processing disorders (APD). As such, it is crucial to conduct behavioral evaluations of speech perception in noise [11]. Henriques and Costa emphasized that relying solely on pure tone audiometry (PTA) thresholds and word evaluations may not be sufficient for accurately and comprehensively identifying communication skills. Instead, speech recognition tests in noise directly assess individuals' communication abilities and are valuable tools for analyzing auditory capabilities in situations akin to everyday auditory experiences [9]. The Consonant-Vowel (CV) in noise test is a suitable assessment tool with these characteristics for quantifying hearing ability in noisy conditions. This test was developed and localized into the Persian language by Lotfi et al. in 2016. It involves presenting various meaningless syllables and a sequence of monosyllabic letters without semantic or syntactic meaning in silence and at five different signal-to-noise ratios (SNRs). These phonologically correct and pronounceable syllables are not affected by cognitive factors due to the nature of the stimulus [11].

Indeed, the availability of valid and reliable tools is essential for identifying and measuring communication problems and finding appropriate methods to compensate for communication disabilities. Psychological tools like self-assessment questionnaires can assess individuals' real-life environments based on their judgments. In audiology, self-assessment questionnaires have gained significant attention as they serve various purposes, from identifying and categorizing hearing-related issues to evaluating the efficacy of different hearing rehabilitation approaches. One such questionnaire is the Speech, Spatial, and Qualities of Hearing (SSQ) scale, adapted into the Persian language, validated, and localized by Lotfi et al. in 2016 [19].

The auditory disorders associated with renal failure, such as "uremic neuropathy," have been reported in several studies, indicating changes in the central nervous system of uremic patients. Di Paolo et al. demonstrated a high incidence of nervous conduction disorders in CKD patients, and Mancini et al. suggested delayed neural transmission along the auditory pathway due to CKD [20]. However, most existing research has focused on peripheral hearing, and there is a lack of studies on speech perception in noise in CKD patients. Understanding central auditory abilities, including speech perception in noise, is crucial for the early detection of auditory sensitivity and neurological changes in CKD patients, enabling timely interventions and monitoring of disease complications. In light of the limited exploration of behavioral consequences of auditory nerve damage in CKD, this study aims to conduct the CV in noise test and apply the SSQ self-assessment questionnaire to analyze the everyday hearing, speech, and communication problems of CKD patients at Shahid Beheshti Hospital in Babol, Iran.

Materials and Methods

Participants

In this descriptive-analytical cross-sectional study, we recruited 30 patients with end-stage CKD who had been receiving hemodialysis for at least two years from the hemodialysis ward of Shahid Beheshti Hospital in Babol, Iran. Additionally, 29 normal adults between the ages of 20 and 55 were randomly selected and referred to the audiology clinic of the same hospital to serve as the control group. The sample size was determined using the appropriate sample size formula. The control group was matched with the patient group regarding age and gender. Participants with a history of inherited disease (e.g., the Alport syndrome), acquired hearing loss, auditory and vestibular diseases, excessive noise exposure, mental disability, trauma, or ear surgery were excluded from the study.

Participants' relevant information was recorded in the patient's history form after obtaining informed consent. The Edinburgh questionnaire was administered to identify and select right-handed individuals, while left-handed individuals were excluded from the study [21]. Before commencing the assessments, the test method and procedures were thoroughly explained to all participants.

Procedure

Audiological Evaluation

First, all participants underwent otoscopic examinations to assess the condition of their ear canals and eardrums. Subsequently, a series of hearing tests were conducted, including Pure Tone Audiometry (PTA), speech audiometry, 226 Hz tympanometry, and acoustic reflex tests for all patients. PTA was performed by an experienced audiologist using an audiometer (AD226, Interacoustic Company, Middelfart, Denmark) within the frequency range of 250-8000 Hz. Individuals with hearing thresholds above 25 dB were excluded from the study.

Additionally, Tympanometry was carried out using a tympanometer (MI34, Maico Company, Berlin, Germany) to assess middle ear function. Only individuals with normal middle ear function, indicated by type A tympanometry, were included in the study. Participants who met the inclusion criteria underwent the Speech, Spatial, and Qualities of Hearing Scale (SSQ) and the Consonant-Vowel in noise test (CV in noise test).

SSQ Assessment

The SSQ questionnaire used in this study comprises 47 questions covering various aspects of hearing experiences in different contexts. These questions are categorized into three subscales:

1. Speech Perception: This subscale consists of 14 questions about speech perception in different listening situations, such as comparing sounds, understanding multiple speakers, and dealing with various acoustic environments (e.g., silence, continuous noise, and acoustic reflections).

2. The direction of Sound Source: 16 questions in this subscale assess the ability to determine the spatial position, direction, distance, and movement of sound sources.

3. Hearing Quality: The third subscale includes 17 questions that evaluate sound segregation, differentiation, auditory recognition, and sound clarity.

Participants rate their responses to these questions on a scale ranging from 0 (indicating complete hearing disability) to 10 (representing complete hearing ability). Higher scores on the SSQ indicate better hearing abilities in the respective domains assessed by the questionnaire [19].

CV in Noise Measurements

The CV in noise test used in this study involves two lists of CV words (e.g., /pu/, /gha/, /da/, and /du/), with each list randomly played in each ear. The test is administered using Sound Forge version 10 on a laptop, with headphones connected to the laptop's audio output. Each list lasts 12 minutes, with a 3-second interval between each speech stimulus.

During the test, the speech stimulus is played at 30 dB above the participant's speech recognition threshold (SRT) with the addition of white noise. The test is conducted at various signal-to-noise ratios (SNRs) of 0, +6, -12, -6, and +12 dB and in silence. Each list contains 25 CV words, and participants are required to repeat the words after hearing them. Each word is worth 4 points, resulting in a total score of 100 points for each SNR condition and silence.

Several practice items are played for them before the actual test to ensure that the participants correctly perceive the CV words. The sound level is calibrated using a sound level meter in a silent environment, and the sound level is set to 60% of the laptop's output, resulting in 84 dB SPL in the headphones for all participants [11].

Statistical Analysis

The collected data were entered into a datasheet in SPSS-25 (IBM Corp.; Armonk, NY, USA) for statistical analysis. The normality of the data was assessed using the Kolmogorov-Smirnov test. The nonparametric Mann-Whitney U test was utilized to compare speech recognition in silence and at various SNRs and the SSQ questionnaire subscales between the CKD and normal groups. The results of the analysis are presented as mean and standard deviation. The significance level for all statistical tests was set at 0.05.

Ethical Consideration

This article results from a research project with the ethics code IR.MUBABOL.REC.1399.269 approved by the Student Research Committee of Babol University of Medical Sciences, Iran.

Results

The study included 59 participants below 55, divided into two groups: the normal group, with 29 individuals, and the CKD group, with 30 individuals. The proportions of men and women were similar in both groups. Among the CKD group, there were 15 women and 15 men, with a mean age of 42.97 years (SD=10.01). In the normal group, there were 16 women and 13 men, with a mean age of 43.76 years (SD=8.76). The two groups were comparable in terms of age, gender, and pure tone audiometry (PTA) thresholds, with no statistically significant differences observed (P>0.05).

Table 1 presents the CV results in the noise test for both the right and left ears in the normal and CKD groups. The analysis showed no significant difference between either group's right and left ear results (P>0.05). However, it was observed that in both groups, the CV recognition scores improved with an increase in the SNRs (signal-to-noise ratios). Nevertheless, patients with CKD had significantly lower scores in silence and noise than the normal participants (P<0.05), indicating poorer speech perception abilities in noise for the CKD group.

Table 2 displays the results of the SSQ scale for both the normal and CKD groups. The CKD patients obtained lower scores on the questionnaire than the normal group. However, the analysis revealed no statistically significant difference between the two groups regarding the spatial hearing, speech perception, and hearing quality subscales (P>0.05).

Table 3 presents the correlation analysis between the results of the CV in the noise test and the subsets of the SSQ questionnaire for both the normal and CKD groups. The correlation was calculated using the Spearman test, and the results of both the right and left ears were combined since no significant difference was found between them. In both the normal and CKD groups, no significant correlation was observed between the CV scores in the noise test and the subsets of the SSQ questionnaire.

Discussion

The main objective of this study was to assess speech perception of noise in CKD patients. For this purpose, both the CV in noise test and the SSQ questionnaire were utilized to evaluate the speech recognition abilities in both normal participants and CKD patients.

As shown in Table 1, an increase in background noise in both the normal and CKD groups resulted in a decrease in the CV recognition scores. However, it was observed that the normal group exhibited better speech perception performance at all levels of signal-to-noise ratios, as well

Table 1: Consonant vowel test score on noise and silence in chronic kidney diseases patients and normal individuals

CV in noise		**Normal**	**CKD**	P value
		mean / SD	**mean / SD**	
Silence	R	96.62 / 5.68	92.80 / 6.07	0.004
	L	96.48 / 5.33	89.20 / 8.41	0.001
SNR +12	R	95.79 / 6.19	87.47 / 9.43	0.00
	L	95.72 / 7.00	85.33 / 11.13	0.00
SNR +6	R	92.48 / 9.88	80.13 / 11.72	0.00
	L	93.17 / 9.99	78.00 / 14.27	0.00
SNR 0	R	85.86 / 12.29	70.93 / 12.60	0.00
	L	83.72 / 14.13	65.47 / 16.05	0.00
SNR -6	R	65.03/ 10.31	55.07 / 12.00	0.003
	L	66.41 / 9.73	/ 14.80 54.27	0.001
SNR -12	R	47.17 / 10.97	37.20 / 13.25	0.006
	L	46.07 / 9.06	34.87 / 13.30	0.00

Consonant-vowel in noise (CV); Signal-to-noise ratio (SNR); Chronic kidney disease (CKD)

Table 2: Score of speech, spatial, and qualities of hearing scale questionnaire in chronic kidney diseases patients and normal individuals

SSQ	**Normal**	**CKD**	**P value**
	mean / SD	**mean / SD**	
Qualities of hearing	138.21/ 15.30	136.70 / 22.72	0.85
Spatial hearing	137.38 / 22.22	124.50 / 26.15	0.06
Speech comprehension	121.03/ 26.38	107.50 / 31.80	0.06

Speech, spatial, and qualities of hearing scale (SSQ); Chronic kidney diseases (CKD)

Table 3: Correlation of speech, spatial, and qualities of hearing scale questionnaire with consonant-vowel test score in chronic kidney diseases patients and normal individuals

		Speech comprehension	**Spatial hearing**	**Qualities of hearing**
		corr (sig)	**corr (sig)**	**corr (sig)**
Silence	Normal	0.08 (0.64)	0.05 (0.78)	0.07 (0.69)
	CKD	0.25 (0.17)	0.11 (0.55)	0.08 (0.63)
SNR +12	Normal	0.12 (0.51)	0.13 (0.48)	0.07 (0.70)
	CKD	0.24 (0.20)	0.08 (0.65)	0.49 (0.79)
SNR +6	Normal	0.18 (0.30)	0.29 (0.11)	0.16 (0.38)
	CKD	0.28 (0.12)	0.11(0.54)	0.08 (0.65)
SNR 0	Normal	0.20 (0.28)	0.21 (0.26)	0.02 (0.80)
	CKD	0.18 (0.31)	0.07 (0.70)	0.03 (0.83)
SNR -6	Normal	0.22 (0.23)	0.07 (0.67)	0.02 (0.80)
	CKD	0.08 (0.65)	0.10 (0.58)	0.13 (0.47)
SNR -12	Normal	0.03 (0.85)	0.04 (0.81)	0.02 (0.91)
	CKD	0.13 (0.47)	0.13 (0.49)	0.16 (0.38)

Signal-to-noise ratio (SNR); Chronic kidney disease (CKD) as in silence, compared to the CKD patients (P<0.05).

In addition to evaluating speech perception in noise in CKD patients, another aspect of this study involved implementing the self-assessment SSQ questionnaire to assess their communication abilities in speech perception, spatial hearing, and overall hearing quality and comparing the results with those of normal individuals. As shown in Table 2, CKD patients obtained lower scores than normal participants in all three subscales of the SSQ questionnaire. However, the differences between the two groups were not statistically significant (P>0.05).

Our review of previous research yielded no results regarding the behavioral assessment of speech perception in patients with CKD. Therefore, this is the first study to examine these abilities using valid central hearing tests. In summary, the study's findings suggest that CKD leads to impaired speech perception in noise. The current study investigated the auditory nervous system to better understand the effect of CKD on speech processing in noise. It introduced potential causes of hearing impairment, such as urea, electrolyte imbalance, and metabolic disorders, as contributing factors. The end-stage pathophysiology of CKD and biochemical malfunctions may damage the auditory nervous pathway [13, 17].

D'Andrea also linked the changes in the staggered spondee word (SSW) test in CKD patients to difficulties forming and integrating binaural hearing. In other words, patients with CKD may struggle to receive and recognize information in both ears, which could cause damage to the brainstem and its connections in some cases [5]. Two common complications in CKD are encephalopathy and peripheral neuropathy, characterized by premature demyelination and axonal degeneration of nerve fibers [17]. Some authors have reported a considerable delay in the latency of waves in the auditory steady state in the brainstem of CKD patients [5]. This delay indicates a decrease in the transmission speed of auditory stimuli along the central auditory pathway (brainstem and midbrain) and neuropathy at these levels in CKD [5, 9]. The findings of this research align with the present study.

Human studies and animal models have demonstrated the significance of subcortical perceptual structures (brainstem), including the superior olive complex (SOC), medial geniculate body (MGB), and olivocochlear bundle, in auditory processing in noisy environments [22, 23]. Subcortical regions also play a crucial role in the early stages of auditory stream segregation, and the precise timing of signals required for speech perception and auditory stream segregation in the brainstem is maintained through neuronal synchronization [9].

Hence, the presence of encephalopathy and neuropathy resulting from renal failure may partially explain the outcomes of the present study, indicating a decrease in consonant-vowel recognition in noise function in CKD patients. Non-invasive behavioral experiments can be valuable in detecting deficits in the central nervous system (CNS) and can be utilized for their treatment [24].

As evident from Table 2, while patients with CKD reported experiencing more communication disorders than the normal group in the SSQ questionnaire subscales, there was no statistically significant difference between the two groups. Questionnaires serve as valuable tools for evaluating the impact of hearing impairment on the perception of hearing handicaps, and they can be applied in the clinical identification of individuals' abilities and the effectiveness of therapeutic measures [2].

The impact of hearing impairment on emotional and social aspects can vary significantly based on individual life experiences, health expectations, adaptive capacity, and social support. It is reasonable to assume that complex interactions among these factors influence the communication quality reported by patients. As a result, individuals with similar hearing impairments may experience diverse communication and emotional challenges daily, leading to different perceptions of their quality of life [2, 25].

Furthermore, questionnaires offer a valuable means of gathering a wide range of information from individuals relatively quickly and with minimal cost. However, it is important to acknowledge that people may respond differently to the same questions, and biases could influence the answers. Despite the examiner's efforts to provide adequate explanations, some individuals may still struggle to understand how to answer the questions, leading to potential misunderstandings or ambiguities in the respondents' answers. On the other hand, the CV in noise recognition test takes a bottom-up approach to speech perception in noise, focusing mainly on sound processing. This test is not significantly affected by cognitive and other factors, making it a valuable tool for assessing speech perception abilities in noisy environments [11].

On the other hand, the lack of a significant difference in the results of the questionnaire subscales between the patients and normal groups, as well as the absence of a correlation between the questionnaire results and the CV in the noise test, may be attributed to the potential issues associated with questionnaire responses and biases, as mentioned earlier. Additionally, since there is a scarcity of studies on speech processing ability in noise among CKD patients, it is essential to acknowledge that the results of the present study can only provide partial insights into the underlying brain processing mechanisms. Further investigations in this area are warranted to gain a more comprehensive understanding. Furthermore, to ensure the accurate diagnosis of speech processing disorder in noise, it is recommended to employ a comprehensive set of behavioral tests, which can provide more reliable and conclusive results [26 Ref 27-30 ???].

Conclusion

The decline in speech perception abilities in noise among patients with CKD indicates the potential involvement of the central auditory system in the auditory function associated with the disease. It is possible that patients may not report early speech perception impairment in noise as it may not have reached a level that significantly affects communication yet. For the early diagnosis and mitigation of the consequences of speech processing disability on the quality of life, it is essential to conduct regular and periodic assessments of the central auditory system in patients with CKD, in addition to routine evaluations of speech perception. Early detection allows timely intervention and appropriate rehabilitation measures tailored to each patient's needs.

Ethics Committee Approval

This article is the result of a research project with ethics code IR.MUBABOL.REC.1399.269 at the Student Research Committee of Babol University of Medical Sciences, Iran.

Conflict of Interest: None declared.

References

1. Stevens PE, Levin A. Evaluation and management of chronic kidney disease: synopsis of the kidney disease: improving global outcomes 2012 clinical practice guideline. Annals of internal medicine. 2013;158(11):825-30.
2. Costa K, Ferreira SMS, Menezes PL. Hearing handicap in patients with chronic kidney disease: a study of the different classifications of the degree of hearing loss. Brazilian journal of otorhinolaryngology. 2017;83(5):580-4.
3. Gatland D, Tucker B, Chalstrey S, Keene M, Baker L. Hearing loss in chronic renal failure-hearing threshold changes following haemodialysis. Journal of the Royal Society of Medicine. 1991;84(10):587-9.
4. Henrich WL, Thompson P, Bergstrom LV, Lum GM. Effect of dialysis on hearing acuity. Nephron. 1977;18(6):348-51.
5. D'Andrea KF, Zeigelboim BS, Liberalesso PB, Sylvestre Lde C, Jurkiewicz AL, Marques JM. Audiological findings in patients submitted to kidney transplant. CoDAS. 2013;25(3):202-8.
6. Bazzi C, Venturini CT, Pagani C, Arrigo G, D'Amico GD. Hearing loss in short- and long-term haemodialysed patients. Nephrology Dialysis Transplantation. 1995;10(10):1865-8.
7. Olusanya BO, Newton VE. Global burden of childhood hearing impairment and disease control priorities for developing countries. The Lancet. 2007;369(9569):1314-7.
8. Marziyeh Moradi Vastegani SF. Comparison of Auditory Comprehension in Different Levels of Noise in the Elderly and Young Adult Group.
9. Falahzadeh S T, S., Azadi, F.,Farjadi, F. . speech recegnition in noise in patients with type II diabetecs. Indian journal of otology. 2020.
10. Falahzadeh S KS, Rohani S. Systematic review of auditory behavioral tests with speech stimuli. Iran J Rehab Med 2019;8:35-47.
11. Ataollahi M, Amini M, Delavari S, Bazrafkan L, Jafari P. Reliability and validity of the Persian version of readiness for inter-professional learning scale. International journal of medical education. 2019;10:203-7.
12. Gordon-Salant S, Yeni-Komshian GH, Fitzgibbons PJ, Barrett J. Age-related differences in identification and discrimination of temporal cues in speech segments. J Acoust Soc Am. 2006;119(4):2455-66.
13. Krishnan R RR. Hearing assesment in chronic renal failure patients. Orissa Otolaryngology Head Neck Surgery 2018 june;12(1):24-8.
14. Fidan V, Binici D, Borazan A. The Prevalence of Hearing Loss in Dialysis Patients. Acta Acustica United With Acustica. 2012;98:800-3.
15. Peyvandi A, Roozbahany NA. Hearing Loss in Chronic Renal Failure Patient Undergoing Hemodialysis. Indian Journal of Otolaryngology and Head & Neck Surgery. 2013;65(3):537-40.
16. Lasisi AO, Salako BL, Kodiya MA, Amusat MA, Osisanya WP. Hearing threshold in patients with chronic renal failure. Saudi medical journal. 2007;28(5):744-6.
17. 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(4):383-90.
18. Doshad VK. Haring Assessment in Chronic Renal Failure Patients Undergoing Hemodialysis. Journal of Evolution of Medical and Dental.
19. Nikolopoulos TP, Kandiloros DC, Segas JV, Nomicos PN, Ferekidis EA, Michelis KE, et al. Auditory function in young patients with chronic renal failure. Clinical otolaryngology and allied sciences. 1997;22(3):222-5.
20. 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. International Journal of Pediatric Otorhinolaryngology. 2015;79(12):2378-83.
21. Naderpour M, Mortazavi F, Jabbari-Moghaddam Y, Sharifi-Movaghar MH. Auditory brain stem response and otoacoustic emission results in children with end-stage renal disease. International journal of pediatric otorhinolaryngology. 2011;75(5):704-7.
22. Lotfi Y, Nazeri AR, Asgari A, Moosavi A, Bakhshi E. Iranian Version of Speech, Spatial, and Qualities of Hearing Scale: A Psychometric Study. Acta medica Iranica. 2016;54(12):756-64.
23. Lee SY, Lee HJ, Kim YK, Kim SH, Kim L, Lee MS, et al. Neurocognitive function and quality of life in relation to hematocrit levels in chronic hemodialysis patients. Journal of psychosomatic research. 2004;57(1):5-10.
24. Oldfield RC. The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychologia. 1971;9(1):97-113.
25. Lotfi Y KS, Javanbakh tM, Biglarian. Development, Validity and Reliability of the Persian Version of the Consonant-Vowel in White Noise Test. JRSR. 2016;2: 29-34.
26. Kaya Y, Ozturkeri OA, Benli US, Colak T. Evaluation of the cognitive functions in patients with chronic renal failure before and after renal transplantation. Acta Neurologica Belgica. 2013;113(2):147-55.
27. Chandrasekaran Bharath , Jane Hornickel, Erika Skoe, Trent Nicol, Nina Kraus. Context-dependent encoding in the human auditory brainstem relates to hearing speech in noise: Implications for developmental dyslexia. Neuron. 2009 Nov 12; 64(3): 311–319.
28. Anderson S, A Parbery-Clark, T White-Schwoch. Auditory Brainstem Response to Complex Sounds Predicts Self-Reported Speech-in-Noise Performance. J Speech Lang Hear Res. 2013 Feb; 56(1): 31–43
29. Sharifinik Mahya ST, Ghasem Mohammadkhani, Shohreh Jalaie. Comparison of Gaps in noise test (GIN) in adults with normal and conductive hearing loss. JRRS. 2013;9(4).726-34.
30. Tajik S, Adel Ghahraman M, Tahaie AA, Hajiabolhassan F, Jalilvand Karimi L, Jalaie S. Deficit of Auditory Temporal Processing in Children with Dyslexia-Dysgraphia. AVRJ. 2012;21(4):76-83.