Research Article

Sound and Renal Health: Understanding the Connection between Chronic Kidney Disease and Hearing Loss

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ABSTRACT

End-stage renal disease (ESRD) is a systemic condition impacting multiple organ functions. Hearing loss is notably prevalent among patients with chronic kidney disease (CKD), with rates up to 85% higher than in the general population. The kidney and cochlea share anatomical, physiological, pharmacological, and pathological similarities, along with common antigenicity and genetic regulation. Both organs perform active fluid and electrolyte transport facilitated respectively by the glomerulus and stria vascularis. Studies have observed cochlear damage in ESRD patients, correlating hearing impairment with electrolyte abnormalities exacerbated by hemodialysis. Factors such as plasma viscosity changes, electrolyte imbalances, and medication toxicity further contribute to hearing loss risk in dialysis patients. Diabetes, hypertension, and medication use also play significant roles. This review underscores the intricate relationship between CKD and hearing loss, highlighting the need for comprehensive audiological monitoring and management in renal care settings. The study was conducted with sample size of 80-40 CKD patients and 40 healthy control. Pure tone audiometry was analysed in each sample along with the biochemical parameters. Significant hearing loss were observed in patients with CKD when compared with healthy control.

Keywords: Pure tone audiometry (PTA); Chronic kidney disease (CKD); Hearing loss.

1. INTRODUCTION

End stage renal disease is a systemic disease that affects the functions of various organs. The prevalence of hearing loss in patients with chronic kidney disease can be up to 85% higher than the normal population. The kidney and cochlea have anatomical, physiological, pharmacological and pathological similarities with common antigenicity. Their development is regulated by similar genetic factors and is influenced by similar immunological factors. The cochlea and kidney have similar physiological mechanisms namely the active transport of fluids and electrolytes accomplished by the stria vascularis and glomerulus respectively. Human temporal studies have observed cochlear damage in patients with end stage renal disease [1]. The risk of hearing loss is significantly higher in patients with chronic kidney disease. Dialysis may sometimes result in change in auditory functions. In previous studies, prevalence of hearing loss was increased in renal failure and there was a positive correlation between hearing loss and electrolyte abnormalities in hemodialysis patients [3]. Change in plasma viscosity, hypocalcaemia, hemoglobin level, serum level of calcium, potassium, urea and creatinine are the risk factors for the development of hearing loss in dialysis patient. The common physiological mechanism explains the association between hearing loss and chronic kidney disease [1, 2]. Other factors are diabetes, hypertension and medication (both ototoxic and nephrotoxic). Chronic kidney disease is an increasing public health problem [1] and end stage renal disease is a systemic disease that affects the functions of various organs [2]. Dialysis affects the function of multiple systems

in the body. There are many structural (anatomical), physiological, pharmacological and pathological similarities between the renal tubular cells and the stria vascularis of the cochlea. Epithelial cells of both have microvilli which contain numerous mitochondria and plays an active role in the transport of fluids and electrolytes with the help of a sodium potassium pump and the enzyme carbonic anhydrase enzyme [1, 3-5]. Hemodialysis causes electrolyte and metabolic disturbances within a few hours and audiological tests (Pure Tone Audiometry, and Otoacoustic emissions test) show worsening hearing loss in chronic renal failure patients undergoing hemodialysis [6]. There is a high incidence of hypoacusis in dialysis, even at the beginning of the treatment [7]. Cochlear neurosensory hearing loss is present in a high percentage of patients on dialysis; even at the beginning of the treatment and an abnormality in the eight nerve is responsible for the disturbances of vestibular functions [8]. The deterioration of hearing in chronic kidney disease patients occurs in parallel to the progression of the disease and necessity for dialysis. Hearing loss in hemodialysis is due to change in equilibrium of electrolytes [1]. Chronic kidney disease has been associated with hearing loss since 1972, when Alport first described a case in which hearing loss was associated. Other smaller studies have been done which showed association between hearing loss and hemodialysis and documented acute and long-term changes in hearing loss due to hemodialysis [9]. Several etiological factors have been linked to hearing loss in renal failure including the use of ototoxic mediations, electrolyte disturbances, hypertension and hemodialysis [10]. The aim of the study was to define the prevalence of hearing loss in patients with chronic kidney disease and compare the threshold levels of hearing loss in age and sex matched controls.

1.1 Hypothesis

Inner ear and kidney development are influenced by similar genetic factors in hereditary conditions, such as Alport's syndrome and branchio-oto-renal syndrome. The prevalence of hearing loss in chronic kidney disease is up to 85% higher than the normal populations. This is due to the fact that the kidneys and the inner ear share a similar pathophysiological mechanism. The severity of hearing loss is more in patients on dialysis than those on conservative management with different thresholds of hearing loss in patients with differing degrees of renal failure.

1.2 Justification

Measurement of hearing function in the early stage of chronic kidney disease can identify patients at risk for hearing loss and steps to prevent further deterioration of hearing can be taken. Therefore, the clinicians should be encouraged to include questions about hearing functions in their preventive care protocols, to refer all patients reporting hearing loss to a hearing health professional for evaluation and recommend that patients avoid further treatment with ototoxic medications to preserve their hearing ability.

2. MATERIALS AND METHODS

A cross sectional study was carried out with a sample size (N) of 80 with CKD cases 40 and age and sex matched controls (n=40). After explaining the study and getting duly signed consent form from the patients clinical data was collected. Prospective convenient sampling method was employed in the study.

2.1 Sample collection

Blood sample was collected and audiometric evaluation was done in dialysis patient after obtaining approval from the Institutional Review board at the institute and written consent forms were taken from all test subjects. Corresponding age and sex matched control samples were obtained from individuals with no prior health conditions. The samples were stored immediately at -80° Celsius until analysis.

Plain blood samples from the patients were collected and serum samples were separated. Evaluation of serum creatinine, urea, sodium, potassium, calcium, phosphorus & uric acid was done. The parameters were evaluated to see the state of condition during the audiometry findings & to compare with the audiometry findings.

2.2 Inclusion criteria

Chronic kidney disease patients undergoing hemodialysis.

2.3 Exclusion criteria

Patients who have a history of hearing loss prior to the development of kidney disease and patients on ototoxic drugs (diuretics), patients who were bedridden and pregnant woman were excluded from the study.

2.4 Statistical analysis

The sample size estimation was calculated using a power of 80%, with a level of significance of 0.05 and an effect size of 0.6. The total estimated sample size is approximately 80 subjects (40 cases and 40 controls).

2.5 Ethical clearance

The study was conducted after obtaining the approval from the institutional ethical committee YEC-1- 2018/108. For the collection of sample, informed consent was obtained.

2.6 Confidentiality

All the information provided remain confidential and will only be reported as group data with no identifying information. The data was anonymized. After the research was completed, the samples were discarded.

3. RESULTS

The study explained the biochemical changes and hearing loss in patients with CKD when compared with healthy control.

Table 1: CKD and healthy control-age in years

CKD	Healthy Control
48.7500±4.635	41.5000±4.385

Table 2: Biochemical changes in CKD patients and healthy controls

	Mean ±SD			Reference Range
Parameters	**CKD**	**Healthy Controls**	**P Value**	
Hemoglobin(g/dL)	9.124±3.2045	10.734±2.0123	<0.001*	**12-15 mg/dL**
Sodium mmol/L	134.03±4.247	135.45+6.310	<0.001*	**137-145 mmol/L**
Chloride mmol/L	103.67±8.377	107.64±6.184	0.003	**98-107 mmol/L**
Potassium mmol/L	3.81±0.7288	3.894±0.9216	0.271	**3.4-5 mmol/L**

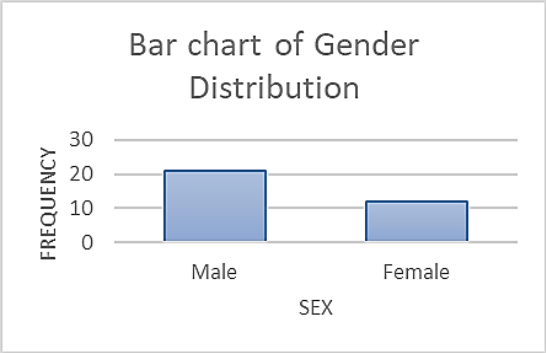

Fig. 1: Gender distribution shown in the bar graph

Table 1 explains the age of the CKD patients and the healthy control. Table 2 explains biochemical changes in patients CKD with the healthy control. This shows there was a very significant change in hemoglobin levels and potassium levels with p value <0.001, significant difference in chloride p value 0.003 and chloride with p value 0.271 shows no significant difference. There was significant hearing loss was observed in patients with CKD when compared with healthy control (Table 3).

Table 3: Pure tone audiometry report- the number of cases of hearing loss under pure tone audiometry

CKD	Healthy Controls	p Value
Mild-8 Modrate-21 Bilateral hearing loss-11	Mild-32 Moderate-7 Bilateral hearing loss- 1	<0.001*

4. DISCUSSION

This study aimed to explore the association between chronic kidney disease (CKD) and hearing loss, revealing a significant relationship between the two conditions in age- and gender-matched groups. The findings underscore the importance of recognizing CKD as a potential risk factor for hearing impairment and highlight the shared risk factors between CKD and hearing loss, such as age, diabetes, hypertension, and cardiovascular disease. These shared risk factors are crucial in understanding the underlying mechanisms contributing to hearing loss in CKD patients.

Shared Risk Factors

Both CKD and hearing loss are influenced by common risk factors, which may contribute to

the simultaneous occurrence of these conditions. **Age**, a well-known risk factor for both CKD and hearing loss, plays a critical role in the increased susceptibility to these health issues. As individuals age, kidney function naturally declines, and hearing loss becomes more prevalent due to age-related degeneration of the auditory system. Diabetes**,** hypertension**,** and cardiovascular disease further compound the risk, as these conditions often coexist with CKD and have been linked to vascular damage, which can adversely affect both kidney function and the auditory system. The overlap of these risk factors suggests that individuals with these comorbidities should be closely monitored for both CKD and hearing loss, especially as they age [12].

Mechanisms Linking CKD to Hearing Loss

Several mechanisms explain the association between CKD and hearing loss, which are mediated through systemic changes in the body caused by kidney dysfunction.

1. **Systemic Inflammation**: CKD leads to a state of chronic low-grade systemic inflammation, which is thought to affect multiple organs, including the inner ear. Inflammation can damage the delicate cochlear structures, impairing hearing function. Inflammatory cytokines and other markers found in CKD patients may contribute to cellular damage within the auditory system, exacerbating hearing loss [10].
2. **Oxidative Stress**: CKD is characterized by increased oxidative stress, which leads to the accumulation of reactive oxygen species (ROS) in tissues. The cochlea, being highly metabolically active and sensitive to oxidative damage, is particularly vulnerable. Oxidative stress can damage cochlear hair cells, which are essential for sound transduction. The resulting cellular damage can progressively impair hearing, especially in patients with severe or end-stage CKD [13].
3. **Fluid and Electrolyte Imbalance**: One of the primary functions of the kidneys is to maintain fluid and electrolyte balance. In CKD, this balance is disrupted, leading to changes in the body's fluid levels and ion concentrations. The inner ear is highly sensitive to these imbalances, as alterations in fluid and electrolyte levels can affect the cochlear fluid environment, impairing auditory processing and contributing to hearing loss.
4. **Medication-Induced Ototoxicity**: Many CKD patients are prescribed medications, such as certain antibiotics (e.g., aminoglycosides) and diuretics, that are known to be ototoxic. These medications can cause damage to the inner ear structures, particularly the cochlea, leading to sensorineural hearing loss. The risk of ototoxicity is heightened in CKD patients, as renal impairment can affect the clearance of these drugs from the body, increasing their concentration in the bloodstream and exacerbating their toxic effects on the ear.
5. **Anemia**: Anemia is a common complication of CKD, resulting from reduced erythropoietin production by the kidneys and impaired red blood cell production. Anemia reduces the oxygen-carrying capacity of the blood, leading to decreased oxygen supply to various tissues, including the inner ear. Hypoxia in the cochlea can damage the hair cells and other structures involved in hearing, contributing to the development of hearing loss [11].
6. **Endothelial Dysfunction**: CKD is also associated with endothelial dysfunction, which impairs the ability of blood vessels to dilate and regulate blood flow. This dysfunction can affect the microvascular circulation to the cochlea, reducing the delivery of oxygen and nutrients necessary for maintaining cochlear health. Inadequate perfusion may accelerate the progression of hearing loss, particularly in CKD patients who already have compromised blood flow due to vascular disease [14].

Clinical Implications and Management

The findings of this study have significant clinical implications. First, they highlight the importance of early detection and management of CKD to prevent or delay the onset of hearing loss. Regular monitoring of hearing in CKD

patients, particularly those with shared risk factors, could facilitate the early identification of hearing impairment, allowing for timely intervention. Moreover, healthcare providers should be vigilant about the potential ototoxic effects of medications used to manage CKD. Adjusting treatment regimens to minimize exposure to ototoxic drugs could reduce the risk of hearing loss in these patients. Additionally, managing anemia and controlling systemic inflammation in CKD patients may help mitigate some of the pathways leading to hearing impairment.

Incorporating hearing conservation strategies, such as recommending regular hearing tests and advising on noise protection, could also be beneficial for CKD patients. For patients with advanced CKD or those undergoing dialysis, ensuring optimal fluid and electrolyte balance and addressing endothelial dysfunction might help preserve hearing function.

Kusakari *et al.*, [7] reported an inner function of 229 patients on hemodialysis and found 60% had hearing loss, 36% had vestibular dysfunction and 26% had combination of both. They found that there is significant hearing loss in CKD patients, the change in the hearing level was quite minimal in healthy control observation period (11).

Boateng [1] concluded that higher hearing thresholds were found across all the frequencies tested among the CKD patients than the control group ($p < 0.05$) in both ears. There was no significant association observed between the duration of the disease and the hearing loss ($p = 0.16$). This study showed that CKD patients are more prone to hearing loss than healthy controls. This shows how the dialysis results in deteriorated audiometry function and it is due to the development of kidney and cochlea regulation by similar genetic factors due to common antigenicity. There is an association between the length of dialysis treatment and hearing states of the patient [12, 13].

Smith *et al.*, reported a study regarding the prevalence of hearing loss in CKD patients when compared to healthy controls. The study demonstrated that there is significantly higher hearing loss across various frequencies in CKD patients ($p < 0.05$), showing a likelihood of hearing loss in in CKD. This study suggests that there is a consistent pattern needed for the increased susceptibility among CKD patients to hearing loss than in healthy controls (14).

5. CONCLUSION

In conclusion, this study reinforces the significant association between CKD and hearing loss, shedding light on the shared risk factors and underlying mechanisms that contribute to this dual burden on health. Given the complexity of the relationship between CKD and hearing loss, healthcare providers should adopt a multidisciplinary approach to managing patients with CKD, addressing both kidney function and hearing health. Early detection, proactive management, and patient education are key to mitigating the risk of hearing loss and improving the quality of life for CKD patients.

Detection of hearing loss in early stage could be better to avoid the future complete dysfunction. It could give the clear picture of the percentage level of hearing loss and be able to manage in the early stages of deterioration.

6. FUTURE DIRECTIONS

Further research is needed to better understand the exact mechanisms linking CKD and hearing loss, as well as the potential for targeted therapies to prevent or reduce hearing impairment in CKD patients. Longitudinal studies examining the progression of hearing loss in CKD patients and the impact of early interventions would provide valuable insights. Additionally, exploring the role of genetic factors and biomarkers in predicting hearing loss in CKD could offer new avenues for personalized treatment.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

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