Effect of chronic renal failure on voice: an acoustic and aerodynamic analysis

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Objective

This study was conducted to investigate the effect of chronic renal failure (CRF) on acoustic and aerodynamic parameters of voice and to compare the results with a group of individuals with normal renal function.

Design

The participants in this study were divided into two groups. A clinical group (the patient group) consisted of 66 adults diagnosed as having CRF (26 male patients and 40 female patients), with their age ranging from 19 to 68 years. The control group consisted of 66 healthy adults (36 male individuals and 30 female individuals). Their age ranged from 20 to 60 years and they did not have any impairment in renal function or any complaints concerning their voice. All participants underwent evaluation of their voice acoustically and aerodynamically. Acoustic analysis was performed using computerized speech lab. The acoustic parameters studied include average pitch, jitter, shimmer, and noise-to-harmonic ratio. Aerodynamic analysis was performed using Aerophone II Model 6800. The aerodynamic parameters studied include vital capacity, maximum phonation time, phonation quotient, mean flow rate, subglottic pressure, and glottal efficiency. The data were analyzed using the independent *t*-test to compare the significance of difference between means across the two groups.

Results

In acoustic analysis, there was a significant increase in pitch in male patients with CRF and an increase in shimmer with borderline significance in the total group with CRF. The total group as well as the female subgroup with CRF showed a significant increase in noise-to-harmonic ratio. With respect to the aerodynamic analysis, the total group as well as the male and female subgroups with CRF showed a significant decrease in the vital capacity. There was also a significant decrease in the maximum phonation time in the total and female subgroup with CRF.

Conclusion

Participants with CRF exhibit clinical evidence of voice disorders both acoustically and aerodynamically. Hence, the present study sheds light on the interplay of different body systems and laryngeal muscles.

Keywords:
acoustic analysis, aerodynamic analysis, chronic renal failure

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Introduction

The kidneys are essential organs that filter wastes and excess fluids from the blood, which are to be excreted in urine. In both healthy and illness conditions, the lung and kidney functions are related to maintain the acid–base balance in the body [1]. Any change in the renal system alters the function of the respiratory system and the reverse is also true. The phonatory system reflects a person's overall well-being. The patient's behavior and medical condition contribute to his or her vocal characteristics. As a product of well-coordinated processes, respiration, phonation, resonation, the vocal sound reflects the delicate laryngeal muscular interplay with breathing [2].

Chronic renal failure (CRF) is a pathophysiological process with multiple etiologies, resulting in the inexorable attrition of nephron number and function [3]. It is an irreversible medical condition that impairs the kidney's ability to function. When CRF reaches an advanced stage, dangerous levels of fluid, electrolytes, and wastes can accumulate in the body.

CRF also affects various body systems such as cardiovascular, nervous, respiratory, musculoskeletal, immune, endocrine, and metabolic systems [4]. The respiratory system is specifically affected by the disease [5]. Bark *et al.* [6] and Karacan *et al.* [7] stated that, when compared with healthy individuals, CRF patients also present decreased endurance and strength of the respiratory muscles. Pierson [1] stated that the function of respiratory muscles in CRF is characterized by a reduction in the maximal inspiration and expiration pressure. Because respiration is the prime source for speech, vocal dysfunctions are expected to be present in patients with CRF [8]. Muscle weakness in CRF patients can be caused by acid–base imbalance, electrolyte disorders, circulating uric toxins, immune suppression, volume overload, and anemia. This muscle weakness, in turn, may affect the production of voice [5,9].

Prezant [5] mentioned that patients with CRF have been noticed to have generalized weakness, fatigue, and shortness of breath, affecting their voice rendering it weak perceptually. As the respiratory system is the generator of the vocal signal, any respiratory system changes (e.g. respiratory flow) can affect the vocal signal intensity and frequency, at least hypothetically. Hamdan *et al.* [10] hypothesized that the intrinsic laryngeal muscles can be affected in a similar manner to the respiratory muscles in patients with CRF. Sala *et al.* [11] stated that physiological abnormalities are frequent in the skeletal muscle structure of patients with CRF; however, little is known about laryngeal muscle performance.

The purpose of this study was to investigate the effect of CRF on acoustic and aerodynamic parameters of voice and to compare them with a group of adult without impaired renal function.

Materials and methods

Participants

It is a retrospective (case–control) study in which the participants were divided into two groups. The clinical group (the patient group) consisted of 66 adults diagnosed as having CRF (26 male patients and 40 female patients), with their age ranging from 19 to 68 years. They were recruited from Assiut and Sohag University Hospitals. The control group consisted of 66 healthy adults (36 male individuals and 30 female individuals) matched for body height, age, and sex. Their age ranged from 20 to 60 years and they did not have any impairment in renal function as confirmed by urine analysis.

The participant-inclusion criteria for the patient group were patients with CRF as diagnosed by an experienced nephrologist, depending on their clinical features, biochemical parameters, and renal biopsy or renal scan, and patients undergoing hemodialysis thrice a week for more than 1 year. The exclusion factors were prior history of vocal hyperfunction, vocal hypofunction, presence of other vocal etiologies (such as vocal abuse/misuse), exposure to toxic fumes, smoking, asthma, or other respiratory or systemic diseases. The control group consisted of individuals with no health problems and with normal voice parameters as judged perceptually by an experienced speech pathologist.

All participants were nonsmokers or ex-smokers (having given up smoking at least 1 year before this study). All patients were ambulatory and in stable clinical condition without the symptoms of severe uremia.

Procedures

Each participant was assessed as follows.

Acoustic analysis

It was recorded when the patient was seated in a quiet-furnituted room. A dynamic microphone, Sure Prolouge 14 Hz (Sure Brothers Incorporation, USA) was used and positioned 10 cm from the patient's mouth. The patient was asked to phonate a sustained vowel/a:/at comfortable pitch and intensity levels. The signal was evaluated using a computerized speech lab (4300; Kay Elemetrics Corp. New Jersey, USA). Acoustic parameters included fundamental frequency, jitter, shimmer, and noise-to-harmonic ratio (NHR).

Aerodynamic analysis

It was performed using a hand-held transducer module Aerophone II Model 6800 (Kay Elemetrics Corp.).

Each participant was asked to:

(1) Take a deep breath and then exhale as much as possible. Vital capacity (VC) was measured.
(2) Take a deep breath and a sustain/a:/phonation for as long as possible in his/her comfortable pitch and intensity level. The duration of phonation was noted. Maximum phonation time (MPT), phonation quotient, and the mean flow rate were measured.
(3) Repeat the vowel–consonant–vowel train 'ipipi' at comfortable pitch and intensity levels. Subglottal pressure and glottal efficiency were measured.

Statistical analysis

This was performed with SPSS (version 17.0, Chicago, Illinois, USA). The independent *t*-test was administered to compare the significance of difference between means across the two groups, the male and female subgroups. The data were expressed as mean±SD. A *P*-value of less than 0.05 was considered statistically significant.

Results

This study was conducted on 66 patients with CRF, 26 male patients (39.4%) and 40 female patients (60.6%) with age ranging from 19 to 68 years and mean age of 43.78 years (the patient group), and 66 healthy adults, 36 male individuals (54.5%) and 30 female individuals (45.5%) matched for body height, age, and sex with the study group. Their age ranged from 20 to 60 years and mean age was 37.6 years (the control group).

When the results of acoustic and aerodynamic analysis were compared between the patient and control groups, there was an increase in shimmer with borderline significance ($P = 0.055$) and a significant increase in NHR ($P = 0.049$) in the patient group. In aerodynamic analysis, there was a statistically significant decrease in VC ($P = 0.000$) and MPT ($P = 0.002$) in the patient group. The rest of the parameters did not show any significant difference (Table 1).

In the female subgroup, there was a statistically significant increase in NHR ($P = 0.046$) in the patient group. In aerodynamic analysis, there was a significant decrease in VC ($P = 0.003$) and MPT ($P = 0.002$) in the patient group. The rest of the parameters did not show any significant difference (Table 2).

In the male subgroup, there was a statistically significant increase in pitch ($P = 0.022$) and decrease in VC ($P = 0.019$) in the patient group. The rest of the parameters did not show any significant difference (Table 3).

Discussion

This study was conducted to shed light on the changes in acoustic and aerodynamic characteristics of voice, if any, in patients with CRF. CRF is characterized by progressive and irreversible destruction of the renal structures [5].

Actually, there is not much available literature pertaining to voice manifestations or changes in CRF patients. Effect of CRF on voice was assessed only in one previous study reported by Kumar and Bhat [8].

With respect to acoustic analysis, in the present study, male patients with CRF exhibited higher fundamental frequency compared with normal male individuals. However, there was no significant difference in fundamental frequency in the total group and in the female subgroup. This can be explained by the decreased serum testosterone level in male patients with CRF [12]. Kumar and Bhat [8] found an increase in fundamental frequency in the CRF group (both male patients and female patients) compared with normal

Table 1 Comparison of the results of acoustic and aerodynamic analysis between the patient and control groups (the total group)

	Patient group (*n* = 66)		Control group (*n* = 66)			
	Mean	SD	Mean	SD	*t*	*P*-value
Acoustic analysis						
Pitch	185.027	41.694	167.429	44.318	1.661	0.102
Jitter	0.957	0.414	0.946	0.411	0.112	0.911
Shimmer	1.533	1.879	0.808	0.947	1.952	0.055
NHR	9.022	3.780	7.251	3.393	2.003	0.049*
Aerodynamic analysis						
VC	2.986	1.023	4.056	1.022	4.245	0.000*
MPT	11.029	6.081	15.993	6.506	3.202	0.002*
Phonation quotient	0.378	0.197	0.370	0.184	0.155	0.877
Mean flow rate	0.120	0.127	0.117	0.064	0.115	0.909
Subglottal pressure	4.726	2.404	5.542	1.470	1.657	0.102
Glottal efficiency	10.369	12.241	15.476	15.324	1.436	0.156

MPT, maximum phonation time; NHR, noise-to-harmonic ratio; VC, vital capacity, *Significant (*P*-value < 0.05).

Table 2 Comparison of the results of acoustic and aerodynamic analysis between the patient and control groups (the female subgroup)

	Female individuals in the patient group (*n* = 40)		Female individuals in the control group (*n* = 30)			
	Mean	SD	Mean	SD	*t*	*P*-value
Acoustic analysis						
Pitch	201.436	35.248	208.480	240.411	0.663	0.512
Jitter	0.998	0.420	1.114	0.453	0.778	0.442
Shimmer	1.959	2.114	1.279	1.269	1.073	0.291
Noise-to-harmonic	8.562	3.747	6.193	2.899	2.032	0.046*
Aerodynamic analysis						
VC	2.801	0.922	3.806	0.939	3.163	0.003*
MPT	9.338	4.695	14.328	4.052	3.295	0.002*
Phonation quotient	0.389	0.218	0.426	0.210	0.442	0.662
Mean flow rate	0.119	0.156	0.093	0.048	0.638	0.528
Subglottal pressure	4.533	2.078	5.745	1.464	1.913	0.065
Glottal efficiency	10.752	12.796	19.697	14.966	1.823	0.078

MPT, maximum phonation time; VC, vital capacity, *Significant (*P*-value < 0.05).

Table 3 Comparison of the results of acoustic and aerodynamic analysis between the patient and control groups (the male subgroup)

	Male individuals in the patient group (*n* = 26)		Male individuals in the control group (*n* = 36)			
	Mean	SD	Mean	SD	*t*	*P*-value
Acoustic analysis						
Pitch	159.784	39.108	133.221	21.919	2.413	0.022*
Jitter	0.895	0.415	0.806	0.324	0.666	0.510
Shimmer	0.876	1.255	0.442	0.281	1.427	0.164
Noise-to-harmonic	9.729	3.870	8.133	3.596	1.181	0.247
Aerodynamic analysis						
VC	3.271	1.140	4.264	1.068	2.482	0.019*
MPT	13.630	7.185	17.381	7.853	1.359	0.185
Phonation quotient	0.353	0.188	0.324	0.149	0.463	0.647
Mean flow rate	0.121	0.069	0.137	0.071	0.649	0.521
Subglottal pressure	5.008	2.883	5.373	1.495	0.461	0.649
Glottal efficiency	9.826	11.945	11.958	15.125	0.410	0.685

MPT, maximum phonation time; VC, vital capacity, *Significant (*P*-value < 0.05).

controls. Hamdan *et al.* [10] explained this increase in fundamental frequency by the improvement in the muscle performance after repeated dialysis. Another important factor to be considered is the changes in the subglottal pressure. An increase in the subglottal pressure, with laryngeal tension held constant, could produce a negligible rise in pitch [13]. Nesić *et al.* [9] reported that the increase in pitch may be because of the anticipatory stress preceding the dialysis.

In the present study, there was an increase in shimmer in the total group with CRF only with borderline significance ($P = 0.055$). This is in accordance with the study by Kumar and Bhat [8] who found an increase in shimmer in both male patients and female patients with CRF. They explained this result by the inability of the participants to maintain a constant intensity during the phonation of /a/.

NHR was increased in the present study in both total group and female subgroup with CRF compared with the control group. NHR was not assessed in the study by Kumar and Bhat [8]. This result can be explained by the inability of the patient to control the phonatory system, which results in changes in the glottic opening. A prolonged glottic opening results in excessive airflow that perceived as a periodic noise. This turbulence of noise has no harmonics.

With respect to aerodynamic analysis, the results demonstrated that there was a decrease in the VC among the total group as well as the male and female subgroups with CRF. This is in accordance with the study by Prezant [5] and Dujic *et al.* [14] who described a decrease in forced VC. This has been attributed to several factors such as the reversible obstructions in the airways and to trapped air caused by accumulations of liquid near the airways. Siafakas *et al.* [15] showed that patients with CRF may demonstrate limitations in their airflow. According to these authors, the reduction in VC may be associated with diminished muscular strength, which is responsible for the delays in muscle fiber contraction. Pierson [1] stated that patients with CRF showing a restrictive pattern on pulmonary function testing and reduced airflow can also be observed on spirometry. Kovelis *et al.* [16] mentioned that forced VC was low in CRF patients. This is because of a significant decrease in respiratory muscle strength. Other studies stated that patients with CRF might have VC values within the normal range because of greater preservation of pulmonary functions [17].

In the present study, the MPT was significantly decreased in the total group and in the female subgroup with CRF. This is in concordance with the study by Kumar and Bhat [8] who found a reduction in the MPT in patients with CRF. This could be attributed to various factors such as fluid overload, reduction in the size of normally aerated area, recurrent infection, and respiratory muscle weakness.

Conclusion

Participants with CRF exhibit clinical evidence of voice disorders both acoustically and aerodynamically. Hence, the present study sheds light on the interplay of different body systems and laryngeal muscles.

Recommendation

Further studies that include perceptual and stroboscopic assessment may help in determining even subtle changes that occur with CRF. In addition, a correlation between the degree of renal failure as well as the electrolyte imbalance and the acoustic and aerodynamic analysis may be beneficial to determine the stage at which the disease has its effect on voice.

Acknowledgements

Conflicts of interest

None declared.

References

1 Pierson DJ. Respiratory considerations in the patients with renal failure. Respir Care 2006; 51:413–422.

2 Mckinney JC. The diagnosis and correction of vocal faults. Nashville, TN: Genevox Music Group; 1994.

3 Kumar S, Chakravarti A, Sahni JK, Dubey NK. Ear, Nose and Throat manifestations in pediatric chronic renal failure patients undergoing peritoneal dialysis. Indian J Otolaryngol Head Neck Surg 2004; 56:205–207.

4 Riella MC(editor). Princípios de nefrologia e distúrbios hidroeletrolíticos. 2nd ed. Rio de Janeiro: Guanabara Koogan; 1996.

5 Prezant DJ. Effect of uremia and its treatment on pulmonary function. Lung 1990; 168:1–14.

6 Bark H, Heimer D, Chaimovitz C, Mostoslovski M. Effect of chronic renal failure on respiratory muscle strength. Respiration 1988; 54:153–161.

7 Karacan O, Tutal E, Colak T, Sezer S, Eyübolu Fo, Haberal M. Pulmonary function in renal transplant recipients and end stage renal disease patients undergoing maintenance dialysis. Transplant Proc 2006; 38:396–400.

8 Kumar RB, Bhat JS. Voice in chronic renal failure. J Voice 2010; 24:690–693.

9 Nesić M, Veljković S, Obrenović J, Cekić S, Velicković D, Radenković M. Voice frequencies in patients treated with chronic hemodialysis. Srp Arh Celok Lek 1996; 124:99–101.

10 Hamdan AL, Medawa W, Younes A, Bikhazi H, Fuleihan N. The effect of hemodialysis on voice: an acoustic analysis. J Voice 2005; 19:290–295.

11 Sala E, Noyszewski EA, Campistol JM, Marrades RM, Dreha S, Torregrossa JV, *et al*. Impaired muscle oxygen transfer in patients with chronic renal failure. Am J Physiol Regul Integr Comp Physiol 2001; 280:1240–1248.

12 Kumar P, Clark M. Clinical medicine: a textbook for medical students and doctors. 4th ed., 1999, W.B. Saunders, London.

13 Seikel JA, King DW, Drumwright DG. Anatomy and physiology for speech, language and hearing. New York: Thomson Delmer Learning; 2005.

14 Dujic Z, Tocilj J, Ljutic D, Eterovic D. Effects of hemodialysis and anemia on pulmonary diffusing capacity, membrane diffusing capacity and capillary blood volume in uremic patients. Respiration 1991; 58:277–281.

15 Siafakas NM, Argyrakopoulos T, Andreopoulos K, Tsoukalas G, Tzanakis N, Bouros D. Respiratory muscle strength during continuous ambulatory peritoneal dialysis (CAPD). Eur Respir J 1995; 8:109–113.

16 Kovelis D, Pitta F, Probst VS, Peres CA, Delfino VD, Mocelin AJ, *et al*. Pulmonary function and respiratory muscle strength in chronic renal failure patients on hemodialysis. J Bras Pneumol 2008; 34:907–912.

17 Bush A, Gabriel R. Pulmonary function in chronic renal failure, effects of dialysis and transplantation. Thorax 1991; 46:424–428.