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.

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

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...
Procedures
Each participant was assessed as follows.

Acoustic analysis
It was recorded when the patient was seated in a quiet-furnished 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 ($n = 66$) | t    | P-value |
|-----------------------------------|--------------------------|--------------------------|------|---------|
|                                  | Mean                     | SD                       | Mean | SD      |       |
| 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 | 3.939   | 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 ($n = 30$) | t    | P-value |
|-----------------------------------|--------------------------------------------------|----------------------------------------------------|------|---------|
|                                  | Mean                     | SD                       | Mean | SD      |       |
| 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).
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.

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