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ORIGINAL RESEARCH

Acoustic Characteristics of Voice in Patients with Chronic Kidney Disease

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Fatma Mohammed Abd El-gaber[1]
Yossra Sallam[2]
Hanaa Mohammed Eid El Sayed[3]

[1]Otorhinolaryngology Department, Faculty of Medicine for Girls, Al-Zahraa Hospital, Al Azhar University, Cairo, Egypt; [2]Phoniatrics, Otorhinolaryngology Department, Faculty of Medicine for Girls, Al-Zahraa Hospital, Al Azhar University, Cairo, Egypt; [3]Internal Medicine Department, Faculty of Medicine for Girls, Al-Zahraa Hospital, Al Azhar University, Cairo, Egypt

Purpose: To investigate the multifactorial effects of chronic kidney disease (CKD) and hemodialysis (HD) on subjects' voices by examining correlations between laboratory investigations, respiratory function, and acoustic voice parameters.

Methods: This case–control study was conducted on 60 participants aged 18−50 years, divided equally into three groups: controls (no health problems or voice disorders), cCKD (stage 3–5, no HD HD]), HD, and CKD stage 5. The study took 21 months. All participants underwent general and otolaryngological examinations, followed by laboratory investigations (hemoglobin, uric acid, HCO_3, estimated glomerular filtration rate, urea, urea-reduction ratio, and creatinine), respiratory function tests, and acoustic voice analysis.

Results: There were significant differences between the control and HD groups for jitter, shimmer, and harmonic:noise (HNR) ratio (P=0 and between the control and CKD groups for shimmer and HNR (P=0), with no significant difference between HD and CKD. There were statistically significant correlations between duration of HD and HNR, jitter percentage, and shimmer percentage (P=0.

Conclusion: Systemic effects of CKD and HD were found to impair the acoustic characteristics of voice in both groups. Regression analysis revealed that hemoglobin, uric acid, and expiratory time were the most significant predictors of impaired acoustic characteristics.

Keywords: CKD, hemodialysis, voice changes, pulmonary functions, eGFR

Introduction

Normal voice production requires interactions among the power source, vibrator, and resonators. The power source (adequate respiratory support) compresses air and forces it toward the larynx. The vocal folds close and open, permitting small bursts of air to escape through them to produce mucosal vibrations.[1] This complex dynamic process requires harmony between the respiratory and laryngeal muscles.

The lungs and kidneys are connected physiologically and pathologically in healthy individuals and patients with CKD, whether on hemodialysis (HD) or not.[2] Chronic kidney disease (CKD) is a beyond-repair condition that impedes the function of various body systems, particularly the respiratory system. The potency of the respiratory and laryngeal muscles, among generalized muscle weakness, is extensively impaired.[3]

CKD may also be complicated by pulmonary edema, pleurisy with subsequent chest pain and fibrothorax, predisposition to such infections as tuberculosis, pulmonary calcifications, and/or urinothorax.[4] In addition, patients on HD often suffer generalized muscle weakness and fatigue that may affect muscles of respiration and phonation, which in turn will affect respiratory support and strongly impair voice quality.[5] With an

Correspondence: Fatma Mohammed Abd El-gaber
Otorhinolaryngology Department, Faculty of Medicine for Girls, Al-Zahraa Hospital, Al Azhar University, 12 Ibrahim-Nagy Street, Nasr, Cairo 11824, Egypt
Tel +20 11-2445-4762
Email fatmamohamed30@hotmail.com

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estimated prevalence of 15.2% among patients on HD, the etiology of dysphonia among these patients should be completely unveiled.[6]

Objectives

This study aimed to investigate the multifactorial effects of CKD and HD on subjects' voices by examining correlations between laboratory investigations, respiratory function, and acoustic voice parameters.

Methods

This was a case–control study conducted on 60 participants presenting to the otorhinolaryngology and internal medicine outpatient clinics at Al-Zahraa University Hospital from September 2018 to June 2020.

participants were aged 18−50 years, and they were divided equally into three groups:

1. Control group: free from any systemic disorder or voice disorders.
2. CKD group: CKD stage 3–5 not on HD. They were diagnosed by nephrologists with clinical and laboratory investigations and estimated glomerular filtration rate (eGFR) using the Modification of Drugs in Renal Disease equation:[7]

   eGFR (mL/min per 1.73 m^2) = 175 × serum creatinine – 1.154 × age – 0.203 × 1.212 (if patient is black) × 0.742 (if female)
3. HD group (CKD stage 5): patients had been on HD >1 year. They underwent three sessions of HD per week, and every session took 4 hours.

All cases underwent full history-taking, general examination(weight and height, and head and neck examination, including, nose, pharynx, and larynx)laryngeal examination using rigid a 70° endoscope (Karl Storz), acoustic analysis of the voice including (fundamental frequency [f_0], shimmer percentage [*S*%], jitter percentage [*J*%], and harmonic:noise ratio [HNR]) using a PreSonus Audio Electronics voice analyzerpulmonary function tests (vital capacity [VC], forced VC[FVC] forced expiratory volume in 1 second [FEV_1]forced expiratory flow[$FEF_{25\%}FEF_{75\%}$], expiratory time, and FEV_1/FVC)and laboratory investigations (hemoglobin, uric acid, HCO_3eGFR,urea, urea-reduction ratio and creatinine). Cases with a history of functional or organic voice disorders (eg, vocal abuse, nodules, or polyps), systemic diseases (bronchial asthma), smokers, females on hormonal therapy, and those who refused to participate were all excluded.

Statistical Analysis

Data were collected, revised, coded and entered into SPSS 20.[8] Qualitative data are presented as numbers and percentages and quantitative data as means ± SD and ranges when their distribution was parametric. Comparisons between two groups with qualitative data were done using #x1D712;[2] tests. Comparisons between two independent groups with quantitative data and parametric distribution was done using independent *t*-tests. ANOVA was used to analyze differences between means of the three studied groups. Post hoc tests were run to confirm differences between groups on one-way ANOVA showed statistically significant differences in group means. Pearson's correlation coefficient was used to measure correlations between quantitative variables. Linear regression analysis was done for prediction of acoustic parameters. The CI was set to 95% and the margin of error accepted set to 5%. $P<0.05$was considered significant.

Results

Figures 1 and 2 show that the groups were matched regarding age and sex($P=0.069$ and 0.714, respectively). Table 1 shows that there were statistically significant differences among the three groups for hemoglobin ($P=0$), uric acid ($P=0$)HCO_3 ($P=0$), eGFR ($P=0$), urea ($P=0$), and creatinine ($P=0$). Post hoc analysis showed significant differences between the control and HD groups ($P=0$) and the control and CKD groups on all laboratory tests ($P=0$). The HD and CKD groups showed significant differencesfor HCO_3 ($P=0.002$), eGFR ($P=0$)urea ($P=0$) and creatinine (P=0).

Table 2 shows that there were statistically significant differences among the three groups for VC ($P=0$), FVC ($P=0$), FEV_1 ($P=0$), FEV_1/FVC ($P=0$), FEF $FEF_{25\%}$ ($P=0$), and $FEF_{75\%}$ ($P=0$). Post hoc analysis showed significant differences between the control and HD groups on all parameters ($P=0$, 0, 0, 0.030, 0, and 0 for VC, FVC, FEV_1, FEV_1/FVC, $FEF_{25\%}$, and $FEF_{75\%}$, respectively) except expiratory time ($P=0.907$) and significant differences between the control and CKD groups on all parameters ($P=0$, 0, 0, 0, 0.010, 0, and 0 for VC, FVC, FEV_1, FEV_1/FVC, $FEF_{25\%}$, and $FEF_{75\%}$, respectively) except expiratory time ($P=0.606$). The HD and CKD groups

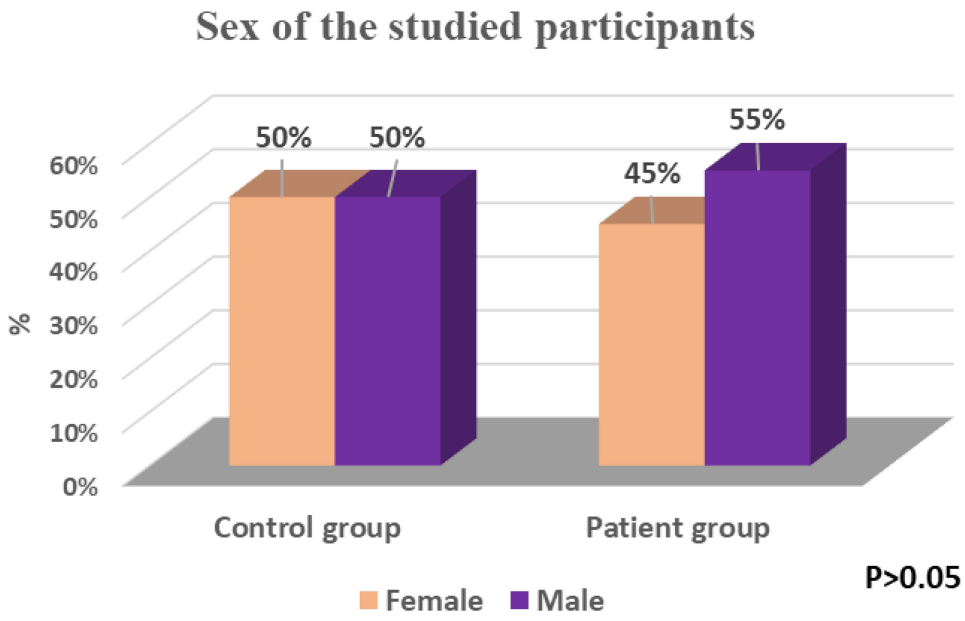


Figure 1 Sex of participants.

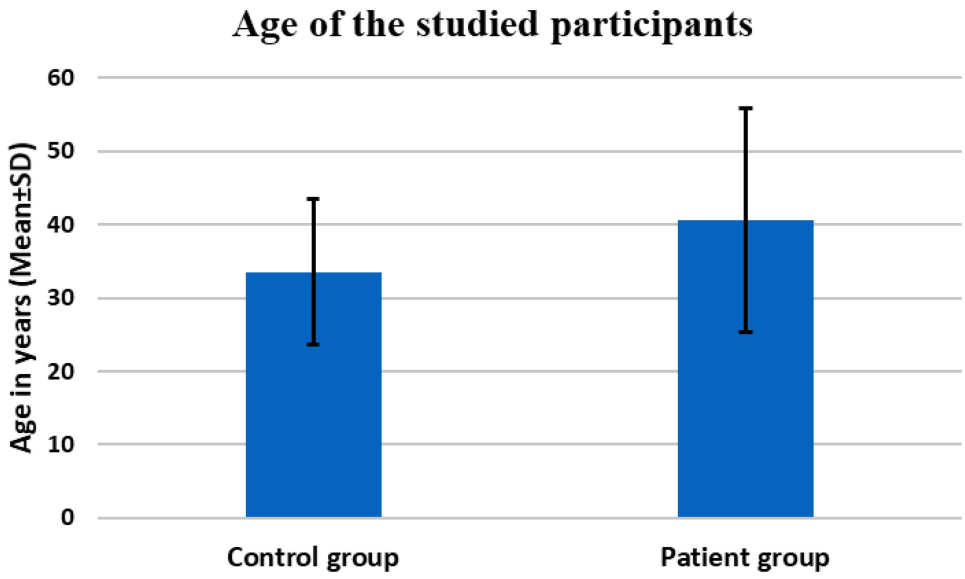


Figure 2 Age of participants.
Abbreviation: SD, Standard deviation.

showed nonsignificant differences on all parameters (P=0.550, 0.037, 0.130, 0.026, 0.777, 0.176, and 0.498 for expiratory time, VC, FVC, FEV_1, FEV_1/FVC, $FEF_{25\%}$, and $FEF_{75\%}$, respectively).Table 3 shows that there were statistically significant differences among the three groups for f_0, S%, J%, and HNR (P=0.013, 00 and 0, respectively). Post hoc analysis showed significant differences between the control and HD groups on all parameters (P=0.018, 00and 0 respectively) and the control and CKD groups on all parameters (P=0.032, 00.017, and 0 respectively). The HD and CKD groups showed nonsignificant differenceson all parameters (P=0.812, 0.176, 0.641, and 0.050, respectively).

Table 4 shows that there was a statistically significant positive correlation between duration of HD and HNR (P=0 and statistically significant negative correlation

Table 1 Comparisons Among Control (n=20), HD (n= 20), and CKD (n=20) groups on Hemoglobin, Uric Acid, HCO_3, eGFR, Urea-Reduction Ratio, Urea, and Creatinine

		Control	HD	CKD	μ*	*P*	Post hoc Analysis		
		n=20	n=20	n=20			P_1	P_2	P_3
Hemoglobin	Mean ± SD	11.93±0.73	9.78±1.35	10.60±1.60	13.719	0	0	0.002	0.098
	Range	10.5–13	8–12	8–13					
Uric acid	Mean ± SD	3.77±0.60	6.80±0.77	7.10±0.79	129.715	0	0	0	0.230
	Range	3–5	6–8	6–8					
HCO_3	Mean ± SD	23.20±1.32	18.60±1.31	16.95±1.85	91.329	0	0	0	0.002
	Range	21–26	16–20	14–20					
eGFR	Mean ± SD	116.25±18.81	8.10±2.95	31.60±5.51	494.045	0	0	0	0
	Range	79–142	5–12	23–40					
Urea-reduction ratio	Mean± SD	—	64.60±6.84	—	NA	NA			
	Range	—	55–76	—					
Urea	Mean ± SD	32.45±6.37	177.30±20.09	110.30±13.80	496.621	0	0	0	0
	Range	23–41	140–200	96–135					
Creatinine	Mean ± SD	0.88±0.18	8.80±0.89	3.42±1.38	358.480	0	0	0	0
	Range	0.5–1.2	8–11	1.3–6					

Notes: *One-way ANOVA; P_1, control vs HD; P_2, control vs CKD; P_3, HD vs CKD.
Abbreviation: eGFR, estimated glomerular filtration rate.

Table 2 Comparisons Among Control (n=20), HD (n= 20), and CKD (n=20) Groups on Respiratory Function Tests

		Control	HD	CKD	μ*	*P*	Post hoc Analysis		
		n=20	n=20	n=20			P_1	P_2	P_3
Expiratory time (seconds)	Mean ± SD	3.21±1.01	3.24±0.49	3.35±0.65	0.194	0.825	0.907	0.606	0.550
	Range	1.5–4.5	2.4–4	3–5					
VC	Mean ± SD	106.50±11.98	57.70±14.66	67.30±13.39	74.559	0	0	0	0.037
	Range	93–125	47–85	55–87					
FVC	Mean ± SD	94.30±7.89	55.90±14.48	62.40±11.93	61.165	0	0	0	0.130
	Range	83–112	45–83	45–85					
FEV_1	Mean ± SD	97.55±8.38	60.40±15.49	70.60±12.16	48.283	0	0	0	0.026
	Range	83–112	49–90	50–84					
FEV_1/FVC	Mean ± SD	1.04±0.12	1.12±0.31	1.20±0.10	1.296	0	0.030	0.010	0.777
	Range	0.77–1.32	0.69–1.96	0.99–1.28					
$FEF_{25\%}$	Mean ± SD	7.32±0.98	63.40±1.67	64.50±3.15	4,690.336	0	0	0	0.176
	Range	5.82–8.56	60–65	60–69					
$FEF_{75\%}$	Mean ± SD	2.79±0.57	63.40±1.39	63.70±1.38	17,731.312	0	0	0	0.498
	Range	1.62–3.42	62–65	62–65					

Notes: *One-way ANOVA; P_1, control vs HD; P_2, control vs CKD; P_3, HD vs CKD.
Abbreviations: FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; FEF, forced expiratory flow.

Table 3 Comparisons Among Control (n=20), HD (n= 20), and CKD (n=20) Groups on Acoustic Parameters

		Control	HD	CKD	μ^*	P	Post hoc snalysis		
		n=20	n=20	n=20			P_1	P_2	P_3
Fundamental frequency	Mean ± SD Range	144.15±47.14 98–213	177.02±35.77 135.2–225.7	174.23±37.74 127.9–216.8	4.046	0.013	0.018	0.032	0.812
Shimmer percentage	Mean ± SD Range	0.63±0.13 0.5–0.99	2.40±0.59 1.84–3.75	2.67±0.64 1.95–3.4	93.492	0	0	0	0.176
Jitter percentage	Mean ± SD Range	2.00±0.61 0.55–2.8	1.10±1.12 0.43–3.98	1.43±0.81 0.39–2.77	3.732	0	0	0.017	0.641
Harmonic:noise ratio	Mean ± SD Range	7.80±0.23 7.4–8.2	6.29±1.22 3.7–7.3	6.87±0.40 6.2–7.4	20.544	0	0	0	0.050

Notes: *One-way ANOVA; P_1, control vs HD; P_2, control vs CKD; P_3, HD vs CKD.
Abbreviation: CKD, chronic kidney disease.

Table 4 Correlations between duration of HD and demographic data, laboratory tests, respiratory function tests, and acoustic parameters

	Duration of HD	
	R	P
Age	−0.415	0.069
Hb	−0.178	0.479
Uric acid	0.362	0.117
HCO_3	−0.602*	0.005
eGFR	−0.362	0.117
Urea-reduction ratio	0.266	0.257
Urea	−0.310	0.184
Creatinine	−0.311	0.182
Expiratory time (seconds)	−0.275	0.241
VC	−0.579*	0.007
FVC	−0.576*	0.008
FEV_1	−0.511*	0.021
FEV_1/FVC	−0.019	0.936
$FEF_{25\%}$	−0.334	0.151
$FEF_{75\%}$	−0.123	0.605
Fundamental frequency	0.066	0.783
Shimmer percentage	−0.781*	0
Jitter percentage	−0.823*	0
Harmonic:noise ratio	0.850*	0

Note: *P<0.05.
Abbreviations: Hb, hemoglobin; eGFR, estimated glomerular filtration rate; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; FEF, forced expiratory flow.

between duration of HD and *S*% (P=0) and duration of HD and *J*%(*P*=0).

Table 5 shows that in the HD group, there were statistically significant positive correlations between creatinine and f_0, *Sh*%, and *J*%percent (*P*=0.002, 0.014, and 0.004 respectively) and a statistically significant negative correlation between creatinine and HNR (*P*=0.044). There was statistically significant positive correlations between expiratory time, VC, FVC, and FEV_1 and *J*%(*P*=0.024, 0.001, 0.001, and 0 respectively) and between FEV_1 and *S* % and $FEF_{25\%}$ and *S*% (*P*=0.002 and 0.009, respectively). There was statistically significant negative correlations between VC, FVC, FEV_1, and $FEF_{25\%}$ and HNR (*P*=0.037, 0.040, 0, and 0.022, respectively).

Table 6 shows that in the CKD group, there were statistically significant positive correlations between hemoglobin, eGFR, FVC and FEV1 and HNR (*P*=0.002, 0, 0.019, and 0.022 respectively), and statistically significant negative correlations between both urea and creatinine and HNR ratio (*P*=0 and 0.001, respectively). It also reveals a statistically significant negative correlation between HCO_3 and f_0 (*P*=0.020), and between expiratory time and *J*% (*P*=0.037). In addition to statistically significant negative correlation between $FEF_{25\%}$ and *S*% and between $FEF_{75\%}$ and *J*% (P=0.029 and 0.024 respectively).

Table 7 shows that the most relevant significant factors predicting f_0 were Hb, uric acid, eGFR, urea-reduction ratio, urea, expiratory time, and FVC and the most relevant significant factors predicting *J*% were Hb, uric acid, HCO_3, urea-reduction ratio, creatinine, expiratory time, VC, and $FEF_{25\%}$. It also shows that the most relevant significant factors predicting *S*% were uric acid, eGFR, urea-reduction ratio, urea, expiratory time, FVC, FEV_1/FEV_5, and $FEF_{75\%}$ and the most relevant significant factors predicting HNR were Hb, HCO_3, eGFR, creatinine, FVC, FEV_1/FEV_5, $FEF_{25\%}$, and$FEF_{25\%}$. Regression analysis revealed that hemoglobin, uric acid, and expiratory time were the most significant predictors for impaired acoustic characteristics.

Table 5 Correlations Between Laboratory Tests and Respiratory Function Tests Against Acoustic Parameters in the HD Group

	Fundamental Frequency		Shimmer Percentage		Jitter Percentage		Harmonic:Noise Ratio	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Hb	0.369	0.132	−0.073	0.773	0.153	0.544	−0.044	0.863
Uric acid	−0.242	0.303	−0.156	0.512	−0.107	0.654	0.278	0.235
HCO_3	0.191	0.421	0.365	0.114	0.394	0.085	−0.403	0.078
eGFR	−0.129	0.588	0.323	0.165	0.217	0.357	−0.297	0.203
Urea-reduction ratio	0.202	0.394	−0.127	0.593	0.078	0.745	−0.032	0.893
Urea	−0.255	0.278	0.347	0.134	0.383	0.095	−0.250	0.288
Creatinine	0.638*	0.002	0.539*	0.014	0.613*	0.004	−0.455*	0.044
Expiratory time (seconds)	0.423	0.063	0.181	0.444	0.502*	0.024	−0.217	0.357
VC	0.369	0.110	0.416	0.068	0.694*	0.001	−0.469*	0.037
FVC	0.364	0.114	0.409	0.073	0.693*	0.001	−0.462*	0.040
FEV_1	0.170	0.475	0.658*	0.002	0.836*	0	−0.827*	0
FEV_1/FVC	−0.283	0.227	0.216	0.362	0.198	0.403	−0.383	0.096
$FEF_{25\%}$	−0.121	0.611	0.567*	0.009	0.438	0.053	−0.510*	0.022
$FEF_{75\%}$	0.015	0.951	0.435	0.055	0.384	0.095	−0.443	0.050

Note: *P<0.05.
Abbreviations: Hb, hemoglobin; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; FEF, forced expiratory flow.

Table 6 Correlations between Laboratory Tests and Respiratory Function Tests Against Acoustic Parameters in the CKD Group

	Fundamental Frequency		Shimmer Percentage		Jitter Percentage		Harmonic:Noise Ratio	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Hb	0.021	0.930	−0.144	0.545	−0.084	0.725	0.660*	0.002
Uric acid	0.051	0.830	0.319	0.171	0.061	0.798	−0.072	0.763
HCO_3	−0.514*	0.020	−0.121	0.612	−0.355	0.124	−0.248	0.292
eGFR	0.165	0.486	−0.357	0.122	−0.197	0.404	0.731*	0
Urea	−0.054	0.820	−0.141	0.553	0.238	0.311	−0.716*	0
Creatinine	0.079	0.742	−0.372	0.106	−0.139	0.560	−0.666*	0.001
Expiratory time (seconds)	−0.362	0.117	−0.122	0.609	−0.468*	0.037	0.162	0.495
VC	−0.272	0.245	0.418	0.067	−0.131	0.582	0.376	0.103
FVC	−0.323	0.165	0.152	0.523	−0.159	0.503	0.521*	0.019
FEV_1	−0.277	0.237	0.423	0.063	0.046	0.846	0.510*	0.022
FEV_1/FVC	0.051	0.832	0.391	0.088	0.315	0.176	−0.071	0.766
$FEF_{25\%}$	−0.195	0.411	−0.098	0.682	0.073	0.759	0.017	0.943
$FEF_{75\%}$	0.191	0.421	−0.488*	0.029	−0.503*	0.024	0.113	0.636

Note: *P<0.05.
Abbreviations: Hb, hemoglobin; eGFR, estimated glomerular filtration rate; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; FEF, forced expiratory flow.

Discussion

Dysphonia has been reported among chronic kidney disease and hemodialyzed patients. However, its exact etiology has been little discussed. For optimal vibration to occur, the vocal folds need sufficient hydration, both systemic within the tissues of the larynx and superficial to its lumen. The kidneys play the major role in maintaining and balancing hydration within the human body, and their impairment will in turn affect voice production. Sivasankar and Leydon assumed that vocal hygiene and phonatory competence improved with adequate hydration.[9]

All patients in the current study underwent laboratory investigations and respiratory function tests. Laboratory investigations were Hb, uric acid, HCO_3, eGFR, urea-reduction ratio, urea, and creatinine. Urea-reduction ratio was used to assess the efficiency of HD before voice analysis. If the HD had been inefficient, the voice analysis

Table 7 Linear Regression for Predictors of Changes of Acoustic Parameters

	Fundamental Frequency		Jitter Percentage		Shimmer Percentage		Harmonic:Noise Ratio	
	Unstandardized β Coefficient	*P*	Unstandardized β Coefficient	*P*	Unstandardized β Coefficient	*P*	Unstandardized β coefficient	*P*
Hb	−52.236	0*	0.488	0*			0.404	0*
Uric acid	−27.697	0*	0.888	0*	0.829	0*		
HCO3			0.437	0*			−0.162	0*
eGFR	3.411	0*			−0.200	0*	−0.077	0*
Urea-reduction ratio	4.597	0*	0.058	0*	−0.105	0*		
Urea	−2.702	0*			−0.008	0*		
Creatinine			0.912	0*			−0.347	0*
Expiratory time (seconds)	43.650	0*	−1.690	0*	−0.273	0*		
VC			0.045	0*				
FVC	2.630	0*			−0.040	0*	−0.025	0*
FEV_1								
FEV_1/FVC					0.285	0*	−0.082	0*
$FEF_{25\%}$			0.114	0*			−0.089	0.002*
$FEF_{75\%}$					−0.414	0*	0.211	0.001*
Constant	−752.85	0*	−26.559	0*	11.297	0*	9.915	0.015*

Note: *$P<0.05$.

Abbreviations: Hb, hemoglobin; eGFR, estimated glomerular filtration rate; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; FEF, forced expiratory flow.

would be postponed. eGFR was used to assess residual kidney function in HD patients because it is more convenient than isotope scans. The results of the current study showed significant increases in uric acid, urea, and creatinine and significant decreases in Hb, HCO_3, and eGFR in all patients in comparison to the normal group. The increases in urea and creatinine were responsible for increases in f_0 and *S*%, in patients on HD, and increase in urea and creatinine together with decreases in Hb and eGFR were responsible for the reduction in HNR in patients with CKD. Similarly, Sagiroglu and Doganer declared that increases uric acid, creatinine, and Na^+ are most probably responsible for changes in vocal parameters in patients with renal failure, particularly after HD.[10]

Cases et al reported that patients with reduced eGFR frequently suffer from anemia.[11] They proposed that anemia may be responsible in part for the generalized muscle weakness and fatigue in those patients. In addition, HCO_3 reflects the degree of regulation of extracellular fluid buffering. The lungs and kidneys cooperate to maintain this system.[12] Reduction in HCO_3 induces hyperventilation (respiratory alkalosis) and subsequently impairs respiratory function.[13] Patients in the current study showed significant restrictive patterns in respiratory function (reduced FVC, increased mean FEV_1/FVC, and increased mean FEF), with nonsignificant difference between those with CKD and those on HD. Mukai et al postulated that 36%–79% of patients with CKD may show restrictive respiratory patterns.[14] Hassan performed acoustic and aerodynamic analysis of the voices of patients with CKD.[15] She found that they exhibited higher f_0 and *S*% and lower HNR and maximal phonation time than normal. Maximal phonation time is affected by reductions in respiratory and/or glottal efficiency; however, it cannot differentiate between them. In the current study, FEV_1 was found to be responsible for increased *J*% and *Sh*% and decreased HNR in patients on HD. Reduced VC and FVC were responsible for increased *J*% in patients on HD. On the contrary, Kumar and Clark noted that increased f_0 in male patients may occur due to reduced testosterone levels as a result of CKD.[16]

Acoustic voice analysis is the least invasive and most convenient and objective valid measure of vocal parameters. Any change in the vocal fold mass and tension affects the acoustic characteristics of voice.

All patients in the current study showed significant changes in all acoustic parameters when compared to the control group (increase in f_0, *S*%, *J*%, and reduction in HNR: P=0.013, 0, 0, and 0, respectively). Differences between patients with CKD and patients on HD was

nonsignificant on all acoustic parameters (P=0.812, 0.176, 0.641, and 0.050, respectively). Similarly, Unver et al studied the effect of HD on voice quality and found that all patients had significant increases in f_0 and HNR after HD.[17] They attributed these findings to ultrafiltration and changes in extracellular fluid volume. According to Raphael et al, changes in the vibratory patterns of vocal folds after HD could be attributed to changes in their length, mass, and tension.[18] They proposed that the muscles function normally after HD. On the other hand, Nesić et al recorded no changes in f_0 after HD.[19]

The results of the current study show that the changes in voice observed in patients with CKD and patients on HD resulted from a combination of impaired hydration, acid–base imbalance, circulating toxins, and weakness of the muscles of respiration and phonation. They also reveal that HD has a detrimental effect on voice quality, both instantly after the session and in the long term, as this effect increases with the duration of HD.

Conclusion

The systemic effect of CKD and HD were found to impair the acoustic characteristics of voice in both groups. Regression analysis revealed that Hb, uric acid, and expiratory time were the most significant predictors of impaired acoustic characteristics.

Ethics Approval and Informed Consent

This study was approved by the Research Ethics Committee of the Faculty of Medicine, Al Azhar University. All participants were informed about the study, and written informed consent was obtained. The study was conducted in accordance with the Declaration of Helsinki.

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Disclosure

The authors report no conflict of interest in this work.

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