Early effects of hemodialysis on pulmonary function in patients with end-stage renal disease

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Background
Patients with end-stage renal disease (ESRD) often develop various health complications, including pulmonary dysfunction. Hemodialysis (HD) is a common treatment for these patients, but its effects on pulmonary function remain an area of investigation. This study aimed to assess the impact of HD on spirometry parameters in ESRD patients.

Patients and methods
This prospective study was carried out on 60 patients with ESRD on HD. Spirometry parameters, including vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), FEV1/FVC ratio, peak expiratory flow (PEF), and forced expiratory flow between 25 and 75% of FVC (FEF 25–75%), were measured 1 h before and after HD.

Results
After HD, significant improvements were observed in several spirometry parameters. The median % change in VC was 9.92% (range, −27.05 to 47.66%), in FVC% was 11.68% (range, −16.5 to 47.37%), in FEV1% was 12.56% (range, −2 to 49.43%), in FEV1/FVC was 1.52% (range, −9.39 to 17.32%), in PEF% was 14.86% (range, −15.33 to 131.73%), and in FEF 25–75% was 13.89% (range, −14.29 to 97.56%).

Conclusions
In ESRD patients, pulmonary abnormalities, primarily restrictive and mixed disorders, were common. Spirometry parameters (FVC, FEV1, PEF rate) were often below normal. However, HD led to notable improvements in VC, FVC, FEV1, FEV1/FVC, FEF 25–75%, PEF rate, and arterial blood gases parameters (pH, CO_2, HCO_3, SO_2).

Keywords:
end-stage renal disease, hemodialysis, pulmonary function, spirometry

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Introduction

Chronic kidney disease (CKD) is a global public health concern characterized by persistent and permanent impairment of renal functions and impaired homeostatic regulation by the kidneys. CKD can result in a gradual decline in renal function. In due course, it may progress to a condition known as end-stage renal disease (ESRD) following an unpredictable time since the initial injury. ESRD denotes a state in which kidney function becomes so compromised that it cannot sustain life, necessitating the use of replacement therapy like peritoneal dialysis, hemodialysis (HD), or kidney transplantation to act as substitutes for the natural renal function [1].

The correlation between the lungs and the kidneys holds significant clinical implications for well-being and pathology [2].

Renal failure affects the mechanics and ventilatory function of the lungs both directly and indirectly; a portion of this effect can be attributed to medication therapy and HD [3,4].

Complications of the pulmonary system are prevalent in patients with severe chronic renal disease. Patients in this group are diagnosed with various pulmonary disorders, including but not limited to obstructive apnea, pleural effusion, pulmonary fibrosis, acute respiratory distress syndrome, increased pulmonary capillary permeability, pulmonary calcification, pulmonary hypertension, pleural fibrosis, hemosiderosis, myopathy, and decreased respiratory muscle strength [5]. They may arise from uremic toxins either directly or indirectly, due to anemia, immunological suppression, excessive calcification, malnutrition, electrolyte imbalances, acid–base imbalances, or volume overload [6].

HD mostly affects patients with CKD about changes in body fluid volume, resulting in a decrease in the quantity of fluids present in the lungs after dialysis. Therefore, while HD does enhance pulmonary function, it can also lead to pulmonary problems resulting from a range of pulmonary injuries caused by several factors. Furthermore, CKD patients continue to experience malnutrition and degenerative changes, which exacerbate muscle atrophy and significantly raise the risk of exhaustion characterized by elevated respiration rate and work of breathing [7].

Within the first stages of some respiratory illnesses, dialysis may be advantageous for CKD patients without underlying lung disease. It is possible that respiratory symptoms and pulmonary function test values might improve [2,8].

The aim of this research was to assess the effects of HD on spirometry parameters in ESRD patients.

Patients and methods

Study design

This prospective analytical observational cross-sectional study was conducted to assess the impact of HD on pulmonary function in ESRD patients. The research was performed at Benha University Hospital Dialysis Unit and Chest Department (Pulmonary Function Unit) in the period between April 2022 and April 2023.

Ethical approval was obtained from the Ethical Committee in the Faculty of Medicine, Benha University (Institutional Research Board IRB) (Study No. MS-20-4-2022). All participants included had signed a consent form.

Study population

This study included 60 patients with ESRD attending Dialysis Unit at Benha University Hospital from April 2022 to April 2023 who fulfilled the criteria and who agreed to participate in the study.

Inclusion criteria were patients with ESRD who were above 18 years of age, had a history of receiving HD at least three times a week for a minimum of 3 months, possessed a KT/V value exceeding 1.2, were capable of performing pulmonary function tests, and maintained hemodynamic stability.

Exclusion criteria were patients who were smokers, had pulmonary diseases such as asthma, acute pulmonary infection, or chronic obstructive pulmonary disease, were diagnosed with neuromuscular disorders or cardiovascular diseases, had a history of thoracic or abdominal surgery, or had pulmonary distress.

Methods

All patients underwent the following: medical history and physical examination, laboratory investigations, including kidney function tests, liver function tests, and complete blood count. Additionally, arterial blood gases (ABG) were measured.

Pulmonary function tests

Pulmonary function testes were done for all patients 1 h before and 1 h after HD, using a computerized pulmonary function apparatus (Jaeger Master Screen PFT: CareFusion UK Ltd, Basingstoke, UK).

A range of pulmonary function parameters was calculated, including vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), FEV1/FVC ratio, peak expiratory flow (PEF), and forced expiratory flow between 25 and 75% of FVC (FEF 25–75%). These measurements were taken to assess changes in pulmonary function associated with HD in ESRD patients.

Statistical analysis

Data management and statistical analysis were done using SPSS, version 28 (IBM, Armonk, New York, USA). Quantitative data were assessed for normality using the Kolmogorov–Smirnov test, the Shapiro–Wilk test, and direct data visualization methods. According to normality, quantitative data were summarized as means and SDs or medians and ranges. Categorical data were summarized as numbers and percentages.

ABG and pulmonary function tests were compared before and after dialysis using the paired *t* test or Wilcoxon signed ranks test for normally and non-normally distributed quantitative variables, respectively. Percent changes in ABG parameters and pulmonary function tests after dialysis were compared according to age, sex, and BMI using the Mann–Whitney *U* test. All statistical tests were two-sided. *P* values less than 0.05 were considered statistcally significant.

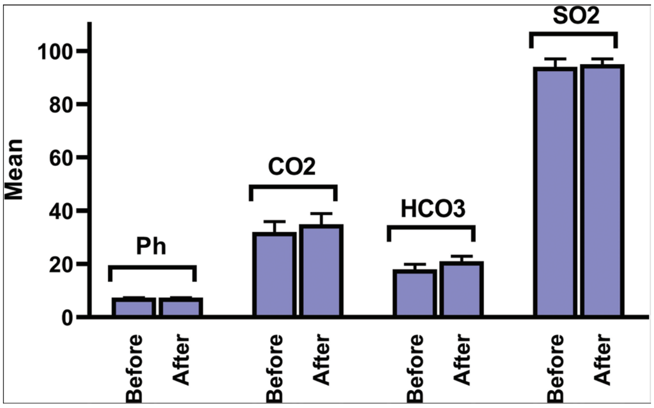
Results

The median age of the patients studied was 41 years, ranging from 20 to 70 years. Males represented 58.3%, while females were 41.7%. The mean BMI was 26.4 ± 4.5 kg/m^2. The median dialysis duration was 3.75 years, ranging from 3 months to 15 years. Most patients demonstrated restrictive pulmonary disease (91.7%). Only two patients showed mixed disease. Three patients were normal (Table 1).

Table 1 General characteristics of the studied patients

General characteristics		
Age (years)	Median (range)	41 (20–70)
Sex		
Males	*n* (%)	35 (58.3)
Females	*n* (%)	25 (41.7)
BMI (kg/m^2)	Mean±SD	26.4±4.5
Dialysis duration (years)	Median (range)	3.75 (0.25–15)
Disease type		
Restrictive disease	*n* (%)	55 (91.7)
Obstructive disease	*n* (%)	0
Mixed disease	*n* (%)	2 (3.3)
Normal finding	*n* (%)	3 (5)
Urea (mg/dl)	Mean±SD	132±26
Creatinine (mg/dl)	Mean±SD	7.9±1.3

Figure 1



Changes in ABG parameters before and after dialysis in ESRD patients. ABG, arterial blood gases; ESRD, end-stage renal disease.

The mean pH increased after dialysis to 7.37±0.04 compared to 7.34±0.06 before dialysis, with a significant difference (P<0.001). The mean CO_2 significantly increased after dialysis to 35±4 compared to 32±4 before dialysis (P<0.001). HCO_3 increased after dialysis to 21±2 compared to 18±1.9 before dialysis (P<0.001). The mean SaO_2 increased after dialysis to 95±2 compared to 94±3 before dialysis (Fig. 1).

The median VC increased after dialysis to 2.36 l compared to 2.15 l before dialysis (P<0.001). The median % change was 9.92%, ranging from −27.05 to 47.66. The mean FVC% increased after dialysis to 65.64±13.9 compared to 58.64±14.22 before dialysis (P<0.001). The median % change was 11.68%, ranging from −16.5 to 47.37. The mean FEV1% increased after dialysis to 71.12±14.86 compared to 62.58±15.29 before dialysis (P<0.001). The median % change was 12.56%, ranging from −2 to 49.43. The mean FEV1/FVC increased after dialysis to 92.37±6.14 compared to 90.54±6.91 before dialysis (P<0.001). The median % change was 1.52%, ranging from −9.39 to 17.32. The median PEF% increased after dialysis to 54.85 compared to 48.65 before dialysis (P<0.001). The median % change was 14.86%, ranging from −15.33 to 131.73. The median FEF 25–75% increased after dialysis to 3 compared to 2.54 before dialysis (P<0.001). The median % change was 13.89%, ranging from −14.29 to 97.56 (Table 2, Fig. 2).

There were no significant variations observed between both age groups (≤41 and >41 years) regarding postdialysis percent changes of VC (P=0.695), FVC% (P=0.970), FEV1% (P=0.970), FEV1/FVC (P=0.442), PEF% (P=0.668), and FEF 25–75% (P=0.073) (Table 3).

The median % change of FEV1/FVC significantly differed according to sex (P=0.024), with the median % change being 1.86 in males compared to 1.14 in females. No significant variations were noted between both sexes regarding postdialysis percent changes of VC (P=0. 205), FVC% (P=0. 107), FEV1% (P=0. 245), PEF% (P=0.958), and FEF 25–75% (P=0.187) (Table 3).

Patients were also divided according to the mean BMI into two groups: patients with BMI less than or equal to 26.4 and those with BMI more than 26.4 kg/m^2. A significant variation was observed in the median % change of PEF%, with the median being 18.58 and 12.5 in those with BMI less than or equal to 26.4 and more than 26.4 kg/m^2, respectively. No significant differences were observed regarding postdialysis percent changes of VC (P=0.559), FVC% (P=0.222), FEV1% (P=0.762), FEC-1/FVC (P=0.387), and FEF 25–75% (P=0.063) (Table 3).

Discussion

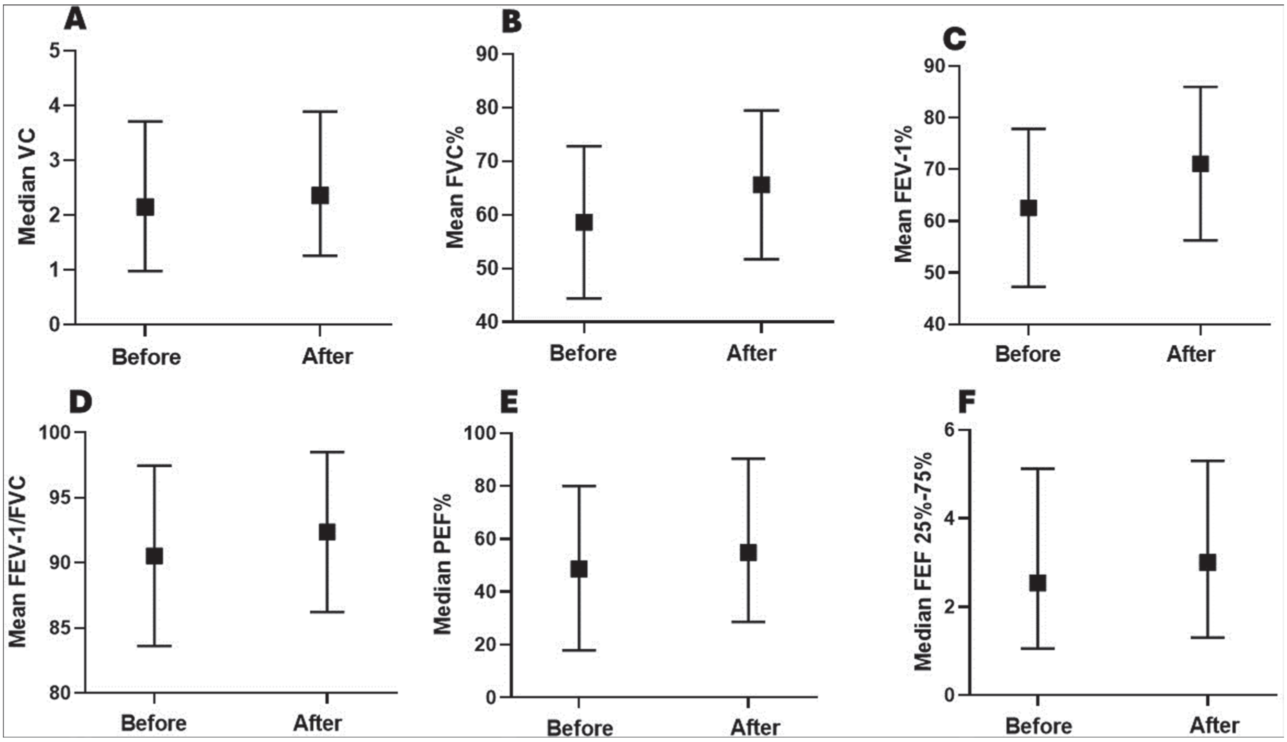
CKD is a global public health concern, characterized by sustained, irreversible renal dysfunction, ultimately leading to ESRD necessitating HD or other forms of

Table 2 Pulmonary function tests before and after dialysis

PFT			*P* value
Vital capacity			
Before (l)	Median (range)	2.15 (0.98–3.71)	<0.001*
After (l)	Median (range)	2.36 (1.26–3.89)	
% Change	Median (range)	9.92 (−27.05 to 47.66)	
FVC%			
Before	Mean±SD	58.64 ± 14.22	<0.001
After	Mean±SD	65.64 ± 13.9	
% Change	Median (range)	11.68 (−16.5 to 47.37)	
FEV1%			
Before	Mean±SD	62.58 ± 15.29	<0.001*
After	Mean±SD	71.12 ± 14.86	
% Change	Median (range)	12.56 (−2 to 49.43)	
FEV1/FVC			
Before	Mean±SD	90.54 ± 6.91	<0.001*
After	Mean±SD	92.37 ± 6.14	
% Change	Median (range)	1.52 (−9.39 to 17.32)	
PEF%			
Before	Median (range)	48.65 (17.9–80)	<0.001*
After	Median (range)	54.85 (28.6–90.4)	
% Change	Median (range)	14.86 (−15.33 to 131.73)	
FEF 25–75%			
Before	Median (range)	2.54 (1.05–5.12)	<0.001*
After	Median (range)	3 (1.3–5.3)	
% Change	Median (range)	13.89 (−14.29 to 97.56)	

FEF, forced expiratory flow; FEV, forced expiratory volume; FVC, forced vital capacity; PEF, peak expiratory flow.
*Significant *P* value.

Figure 2



Pulmonary function tests before and after dialysis; (a) VC; (b) FVC; (c) FEV1; (d) FEV-1/FVC; (e)PEF; (f) FEF 25–75%. FEF 25–75%, forced expiratory flow between 25 and 75% of FVC; forced expiratory flow between 25 and 75% of FVC; FEV, forced expiratory volume in the first second; FVC, forced vital capacity; PEF, peak expiratory flow; VC, vital capacity.

Table 3 Comparison of pulmonary function parameters according to age, sex, and BMI

% Change	Age		*P* value
	≤41 years (*N*=31)	> 41years (*N*=29)	
VC			
Median (range)	10.81 (−27.05 to 47.66)	9.49 (−4.69 to 35.04)	0.695
FVC%			
Median (range)	13.38 (−16.5 to 28.53)	10.66 (2.67–47.37)	0.959
FEV1%			
Median (range)	14.65 (−2 to 34.2)	12.2 (3.06–49.43)	0.970
FEV1/FVC			
Median (range)	1.69 (−9.39 to 17.32)	1.27 (−7.52 to 10.28)	0.442
PEF%			
Median (range)	16.36 (−15.33 to 131.73)	14.72 (2.03–57.14)	0.668
FEF (25–70%)			
Median (range)	16.28 (−14.29 to 97.56)	10.75 (−11.24 to 32.8)	0.073
	Sex		
	Males (*N*=35)	Females (*N*=25)	*P* value
VC			
Median (range)	8.06 (−27.05 to 47.66)	10.48 (−4.69 to 35.04)	0.205
FVC%			
Median (range)	10 (−16.5 to 46.48)	13.77 (3.42–47.37)	0.107
FEV1%			
Median (range)	12.2 (−2 to 47.38)	14.42 (6.1–49.43)	0.245
FEV1/FVC			
Median (range)	1.86 (−9.39 to 17.32)	1.14 (−7.52 to 7.76)	0.024*
PEF%			
Median (range)	14.72 (−15.33 to 131.73)	16.89 (1.38–74.29)	0.958
FEF (25–70%)			
Median (range)	15.13 (0.94–92.59)	9.49 (−14.29 to 97.56)	0.187
	BMI		
	≤26.4 (*N*=29)	>26.4 (*N*=31)	*P* value
VC			
Median (range)	11.5 (−27.05 to 47.66)	9.49 (2.7–35.04)	0.559
FVC%			
Median (range)	13.95 (−16.5 to 30.82)	10 (0.89–47.37)	0.222
FEV1%			
Median (range)	14.65 (−2 to 44.86)	12.46 (−0.48 to 49.43)	0.762
FEV1/FVC			
Median (range)	1.14 (−9.39 to 17.32)	1.67 (−1.36 to 7.76)	0.387
PEF%			
Median (range)	18.58 (−15.33 to 131.73)	12.5 (2.03–57.14)	0.036*
FEF (25–70%)			
Median (range)	18.04 (−14.29 to 97.56)	12.82 (−11.24 to 53.5)	0.063

FEF, forced expiratory flow; FEV, forced expiratory volume; FVC, forced vital capacity; PEF, peak expiratory flow; VC, vital capacity.
*Significant *P* value.

renal replacement therapy. Kidney failure, along with HD and medication treatments, can influence lung function, affecting both fluid volume regulation and pulmonary complications [9].

Impaired pulmonary function in patients on HD may be caused by an underlying pulmonary disease, however the effects of HD treatment and kidney transplantation are not well understood [10].

The impact of HD on CKD patients is primarily related to fluid volume adjustments, which can improve respiratory function but may also lead to multifactorial pulmonary injuries. Additionally, malnutrition and degenerative changes persist in CKD patients, worsening muscle loss and contributing to fatigue, increased respiratory rate, and increased respiratory effort [8,11]. Hormonal and metabolic derangement associated with ESRD might lead to pulmonary arterial vasoconstriction and increased in pulmonary vascular resistance [12].

Therefore, in this study, we evaluated the impact of HD on spirometry parameters in ESRD patients.

This prospective study was conducted at Benha University Hospital Dialysis Unit and Pulmonary Function Unit in the Chest Department on 60 patients with ESRD attending the dialysis unit three times a week.

The study included patients with a median age of 41 years (mean age, 41.9; range, 20–70), 52% below 41 years, and a male predominance of 58.3%. The mean BMI was 26.4 ± 4.5 kg/m^2. A study by Sharma *et al.* [2] found a mean age of 45.8 ± 10.0 years, with 64% males and a mean BMI of 21.6 ± 3.0 kg/m^2, similar to our findings. In a study by Mane *et al.* [13], both sexes were almost equally distributed.

This study showed improved kidney function tests after dialysis, with a significant decline in mean urea (108 ± 26 mg/dl) and creatinine (6.1 ± 1.2 mg/dl) compared to baseline. These findings align with Mane *et al.* [13], who observed significant improvement in urea and creatinine with HD.

In this study, the majority of patients (91.7%) had a normal FEV1/FVC ratio (>70%) and low predicted FVC values (<80% pred), indicating restrictive pulmonary disorders. Only 3.3% had FEV1/FVC ratio of less than 70%, while 5% had normal pulmonary function. These findings align with Sharma *et al.* [2], who reported similar results, with 82% having a normal FEV1/FVC ratio with reduced FVC and 12% having a normal pulmonary function. Kabil *et al.* [14] also found that pulmonary functions were affected in nearly half of patients with ESRD on HD, with a predominance of obstructive (29.5%), restrictive (56.38%), and mixed (14.12%) impairments.

The prevalence of restrictive impairment in our study may be due to fluid overload, interstitial edema, bronchial congestion, uremia, muscle wasting, protein-energy wasting, inflammation, and thoracic wall compliance reduction [6].

Additionally, our study revealed a significant increase in VC after dialysis, with a median % change of 9.92%. This contrasts with Momeni *et al.* [15], who found no significant differences in VC before and after dialysis.

In our study, the mean FVC% increased significantly after dialysis to 65.64 ± 13.9 from 58.64 ± 14.22 before dialysis, indicating improved pulmonary function. This agrees with findings from Sharma *et al.* [2], who observed a statistically significant increase in mean FVC% after HD in ESRD patients. Mane *et al.* [13] also reported increases FVC after HD. Yilmaz *et al.* [6] and Navari *et al.* [16] had similar observations of FVC improvement with dialysis.

The restrictive pattern and decreased FVC seen in our research may be ascribed to persistent subclinical pulmonary edema caused by hypoalbuminemia and increased capillary permeability. However, Anees *et al.* [17] reported no significant improvement in pulmonary functions after HD and suggested that severe lung damage or abnormal BMI in their patient population might be contributing factors.

In our study, the mean FEV1% significantly increased after dialysis to 71.12 ± 14.86 from 62.58 ± 15.29 before dialysis. These findings are consistent with Sharma *et al.* [2], who observed a statistically significant increase in mean FEV1% after HD in ESRD patients. Mane *et al.* [13] also reported an increase in FEV1 after dialysis. However, Anees *et al.* [17] reported no significant improvement in FEV1 after HD in their study. It is worth mentioning that the majority of patients in our study exhibited normal FEV1/FVC ratios despite having low FEV1 values. This suggests that the major airways remained unaffected and that the primary cause of the FEV1 reduction was a diminished FVC, which closely resembles the pattern observed in restrictive pulmonary disease.

In our study, the mean FEV1/FVC increased significantly after dialysis to 92.37 ± 6.14% from 90.54 ± 6.91% before dialysis (P<0.001). These findings are in line with Sharma *et al.* [2], who recorded spirometric parameters 15 min before and after HD session and they reported an increase in mean FEV1/FVC% after HD, although it was not statistically significant. Hasan *et al.* [18], performed spirometry immediately before and after HD session and observed significant improvement in FEV1/FVC % of the studied patients (67 ± 20.8% pred. and 82.3 ± 20.1% pred. respectively). Mane *et al.* [13] showed a significant increase in FEV1/FVC% before and after HD. In contrast, Anees *et al.* [17] found a decrease in FEV1/FVC% after dialysis, and Momeni *et al.* [15] reported a significant decrease in FEV1/FVC% after dialysis compared to before.

In our study, the median PEF% significantly increased after dialysis to 54.85 from 48.65 before dialysis. This is compatible with Sharma *et al.* [2], where PEF rate increased significantly after HD, although it was initially below the normal range. Mane *et al.* [13] also reported an increase in PEFR before and after HD. However, Davenport and Williams [19] found that PEF decreased during HD sessions, with potential airway constriction due to blood–membrane interactions.

In our study, the median FEF 25–75% increased significantly after dialysis to 3 l/min from 2.54 l/min before dialysis (P<0.001). This aligns with Sharma *et al.* [2], who observed a statistically significant increase in mean FEF 25–75% after HD. However, Momeni *et al.* [15] reported a decrease in FEF 25–75% after dialysis in their study. In our research, the 25–75% improvement in FEF was likely attributable to eliminating extra lung fluid that had been obstructing tiny airways and causing a reversible blockage. Nonetheless, fibrosis, chronic subclinical pulmonary edema, and peri-bronchial cuffing may also lead to persistent anomalies in the small airways and a decrease in FEF values by 25–75%.

In our study, mean pH increased after dialysis to 7.37 ± 0.04 compared to 7.34 ± 0.06 before dialysis (P<0.001), along with a significant increase in mean CO_2 to 35 ± 4 from 32 ± 4 before dialysis (P<0.001). HCO_3 also increased after dialysis to 21 ± 2 from 18 ± 1.9 before dialysis (P<0.001), and mean SaO_2 increased after dialysis to 95 ± 2 compared to 94 ± 3 before dialysis. In a study by Cely *et al.* [20] focusing on acid–base disturbances in patients with chronic HD at high altitudes, they reported a rise in pH values postdialysis and an increase in HCO_3, similar to our findings. However, they observed a paradoxical decrease in $PaCO_2$ levels postdialysis compared to predialysis values, which differs from our results. This discrepancy may be attributed to the use of high-efficiency filters and bicarbonate bath dialysate in the dialysis therapy, which can lead to substantial CO_2 release into the blood, stimulating the respiratory center and resulting in lower $PaCO_2$ levels at the end of the therapy [21].

In our study, no significant differences were observed between two age groups: age less than or equal to 41 years (n=31) and age more than 41 years (n=29) concerning postdialysis percent changes in VC, FVC%, FEV1%, FEV1/FVC, PEF%, and FEF 25–75%. In the study by Sharma *et al.* [2], they reported FEV1 and FVC have a negative correlation with age in patients with HD. It has been observed that with increasing age, there is a progressive increase in the rigidity of the chest wall and a decrease in the elastic recoil of the lung.

In our study, the median % change in FEV1/FVC significantly differed by sex (P=0.024), with a median % change of 1.86 in males and 1.14 in females. However, there were no significant sex-based differences in postdialysis percent changes for VC, FVC%, FEV1%, PEF%, and FEF 25–75%. Sharma *et al.* [2] found no statistically significant differences in spirometric parameters after HD when comparing sexes, indicating that both males and females showed similar change directions after HD.

In contrast, Momeni *et al.* [15] reported that HD did not significantly change spirometry parameters in women but significantly increased FEV1 and FVC and decreased FEV1/FVC in men, highlighting sex-based variations in the effects of HD on pulmonary function.

In our study, patients were categorized based on their mean BMI into two groups: those with BMI less than or equal to 26.4 and those with BMI more than 26.4. A significant difference was observed in the median % change of PEF%, with a median of 18.58 for those with BMI less than or equal to 26.4 and 12.5 for those with BMI more than 26.4. However, there were no significant differences in post-dialysis percent changes for VC (P=0.559), FVC%, FEV1%, FEV1/FVC, and FEF 25–75% between the two BMI groups.

Our findings align with those of Sharma *et al.* [2], who found that FEV1 and FVC have negative correlation with BMI. Al Ghobain [22] investigated the impact of obesity on spirometry tests and reported no significant differences in FEV1, FVC, FEV1/FVC%, and FEF 25–75% between obese and nonobese groups. However, a significant difference was observed in PEF, with obese patients showing lower PEF values than nonobese patients. This lower PEF in the second group may be attributed to increased total respiratory and airway resistance associated with obesity.

Conclusions

In conclusion, this study revealed that pulmonary function abnormalities were common among patients with ESRD, with a predominance of restrictive and mixed respiratory disorders. Spirometric parameters such as FVC, FEV1, and PEFR were often below the predicted values. However, the findings indicate that patients with ESRD who undergo HD may experience significant improvements in their pulmonary function after dialysis sessions, particularly in VC, FVC, FEV1, FEV1/FVC ratio, FEF 25–75%, and PEFR. Additionally, ABG parameters, including pH, CO_2, HCO_3, and SaO_2, showed significant improvement after dialysis.

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for the analysis and interpretation of data. E.A.E.M and A.M.M were responsible for drafting the article. A.A.O., E.A.E.M., and S.M.A.Y. revised it critically for final approval of the version to be published. All authors have read and approved the manuscript.

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Conflicts of interest

There are no conflicts of interest.

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