**Early Effects of Hemodialysis on Pulmonary Function in Patients with End-Stage Renal Disease**

Abstract

**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 effects of hemodialysis on spirometry parameters in ESRD patients.

**Patients and methods:** This prospective study was carried out on a total of 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 hour 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, PEFR) were often below normal. However, hemodialysis led to notable improvements in VC, FVC, FEV1, FEV1/FVC, FEF 25%-75%, PEFR, and ABG parameters (pH, CO2, HCO3, SO2).

**Keywords:** Hemodialysis, End-Stage Renal Disease, Pulmonary Function, Spirometry.

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 (PD), 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 both 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, as a result of anemia, immunological suppression, excessive calcification, malnutrition, electrolyte imbalances, acid-base imbalances, or volume overload [6].

HD mostly affects patients with CKD in relation to 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 to April 2023.

Ethical approval was obtained from Ethical Committee in the Faculty of Medicine Benha University (Institutional Research Board IRB) (Study No. MS-20-4-2022).

**Study population:**

This study included 60 patients with end stage renal disease (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 three 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 COPD, were diagnosed with neuromuscular disorders or cardiovascular diseases, had 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 (KFTs), liver function tests (LFTs), and complete blood count (CBC). Additionally, arterial blood gases (ABG) were measured.

**Pulmonary Function Tests**

Were done for all patients one hour before and one hour after hemodialysis, using computerized pulmonary function apparatus " Jaeger Master Screen PFT: CareFusion UK Ltd, Basingstoke, UK "

A range of pulmonary function parameters were 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, United States). 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 standard deviations 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, gender, and BMI using the Mann-Whitney U test. All statistical tests were two-sided. P values < 0.05 were considered statically significant.

Results

The median age of the studied patients was 41 years, ranging from 20 -70 years. Males represented 58.3%, while females were 41.7%. The mean body mass index was 26.4 ±4.5 kg/m2. 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**

The mean pH increased after dialysis to 7.37 ±0.04 compared to 7.34 ±0.06 before dialysis, with a significant difference (P-value < 0.001). The mean CO2 significantly increased after dialysis to 35 ±4 compared to 32 ±4 before dialysis (P-value < 0.001). HCO3 increased after dialysis to 21 ±2 compared to 18 ±1.9 before dialysis (P-value < 0.001). The mean SaO2 increased after dialysis to 95 ±2 compared to 94 ±3 before dialysis. **Figure 1**

The median vital capacity 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-value < 0.001). The median % change was 11.68%, ranging from -16.5 – 47.37. The mean FEV-1% increased after dialysis to 71.12 ±14.86 compared to 62.58 ±15.29 before dialysis (P-value < 0.001). The median % change was 12.56%, ranging from -2 – 49.43. The mean FEV-1/FVC increased after dialysis to 92.37 ±6.14 compared to 90.54 ±6.91 before dialysis (P-value < 0.001). The median % change was 1.52%, ranging from -9.39 – 17.32. The median PEF% increased after dialysis to 54.85 compared to 48.65 before dialysis (P-value < 0.001). The median % change was 14.86%, ranging from -15.33 – 131.73. The median FEF 25%-75% increased after dialysis to 3 compared to 2.54 before dialysis (P-value < 0.001). The median % change was 13.89%, ranging from -14.29 – 97.56. **Table 2**, **Figure 2.**

There were no significant variations observed between both age groups (≤ 41 years and > 41) regarding post-dialysis percent changes of VC (P = 0.695), FVC% (P = 0.970), FEV-1% (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 gender (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 genders regarding post-dialysis percent changes of VC (P-value = 0. 205), FVC% (P-value = 0. 107), FEV-1% (P-value = 0. 245), PEF% (P-value = 0. 958), and FEF 25-75% (P-value = 0.187). **Table 3**

Patients were also divided according to the mean BMI into two groups: patients with BMI ≤26.4 and those with BMI > 26.4 kg/m2. A significant variation was observed in the median % change of PEF%, with the median being 18.58 and 12.5 in those with BMI ≤26.4 and > 26.4 kg/m2, respectively. No significant differences were observed regarding post-dialysis percent changes of VC (P-value = 0.559), FVC% (P-value = 0.222), FEV-1% (P-value = 0.762), FEC-1/FVC (P-value = 0.387), and FEF 25-75% (P-value = 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 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](https://www.sciencedirect.com/topics/medicine-and-dentistry/lung-function) [in patients](https://www.sciencedirect.com/topics/medicine-and-dentistry/inpatient) on [hemodialysis](https://www.sciencedirect.com/topics/medicine-and-dentistry/hemodialysis" \o "Learn more about hemodialysis from ScienceDirect's AI-generated Topic Pages) may be caused by an underlying [pulmonary disease](https://www.sciencedirect.com/topics/medicine-and-dentistry/silo-fillers-disease), however the effects of hemodialysis [treatment](https://www.sciencedirect.com/topics/medicine-and-dentistry/therapeutic-procedure) and [kidney transplantation](https://www.sciencedirect.com/topics/medicine-and-dentistry/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 end-stage renal disease might lead to pulmonary arterial [vasoconstriction](https://www.sciencedirect.com/topics/medicine-and-dentistry/vasoconstriction) and an increase 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 3 times a week.

The study included patients with a median age of 41 years (mean age 41.9, range: 20-70), with 52% below 41 years, and a male predominance of 58.3%. The mean BMI was 26.4 ± 4.5 kg/m2. 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/m2, similar to our findings. In a study by **Mane et al.** [13], both genders 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 improvement in 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 an increase in 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.** 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 [17].

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 minutes before and after HD session and they reported an increase in mean FEV1/FVC% after HD, although it was not statistically significant. **Ahmed et al**[18], performed spirometry immediately before and after hemodialysis 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 PEFR 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 the elimination of 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 significanzt increase in mean CO2 after dialysis to 35 ± 4 from 32 ± 4 before dialysis (P < 0.001). HCO3 also increased after dialysis to 21 ± 2 from 18 ± 1.9 before dialysis (P < 0.001), and mean SaO2 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 post-dialysis and an increase in HCO3, similar to our findings. However, they observed a paradoxical decrease in PaCO2 levels post-dialysis compared to pre-dialysis 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 CO2 release into the blood, stimulating the respiratory center and resulting in lower PaCO2 levels at the end of the therapy [21].

In our study, no significant differences were observed between two age groups: age ≤ 41 years (n = 31) and age > 41 years (n = 29) concerning post-dialysis percent changes in VC, FVC%, FEV-1%, FEV1/FVC, PEF%, and FEF 25-75%. e. In the study by **Sharma et al**[2], they reported FEV1 and FVC have 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 decrease in the elastic recoil of the lung.

In our study, the median % change in FEV1/FVC significantly differed by gender (P = 0.024), with a median % change of 1.86 in males and 1.14 in females. However, there were no significant gender-based differences in post-dialysis percent changes for VC, FVC%, FEV-1%, PEF%, and FEF 25-75%. **Sharma et al.** [2] found no statistically significant differences in spirometric parameters after hemodialysis when comparing genders, indicating that both males and females showed similar directions of change 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 gender-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 ≤ 26.4 and those with BMI > 26.4. A significant difference was observed in the median % change of PEF%, with a median of 18.58 for those with BMI ≤ 26.4 and 12.5 for those with BMI > 26.4. However, there were no significant differences in post-dialysis percent changes for VC (P = 0.559), FVC%, FEV-1%, 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], who investigated the impact of obesity on spirometry tests and reported no significant differences in FEV1, FVC, FEV1/FVC%, and FEF25-75% between obese and non-obese groups. However, a significant difference was observed in PEF, with obese subjects showing lower PEF values than non-obese subjects. This lower PEF in the second group may be attributed to increased total respiratory resistance 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 normal 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, CO2, HCO3, and SaO2, showed significant improvement after dialysis.

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**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) |
| **Body mass index(**kg/m2**)** | 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 (0.0) |
| 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 |

**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 – 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 – 47.37) |  |
| **FEV-1%** |  |  |  |
| Before | Mean ±SD | 62.58 ±15.29 | **<0.001\*** |
| After | Mean ±SD | 71.12 ±14.86 |  |
| % Change | Median (range) | 12.56 (-2 – 49.43) |  |
| **FEV-1/FVC** |  |  |  |
| Before | Mean ±SD | 90.54 ±6.91 | **<0.001\*** |
| After | Mean ±SD | 92.37 ±6.14 |  |
| % Change | Median (range) | 1.52 (-9.39 – 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 – 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 – 97.56) |  |

\*Significant P-value; FVC: Forced vital capacity; FEV: Forced expiratory volume; PEF: Peak expiratory flow; FEF: Forced expiratory flow.

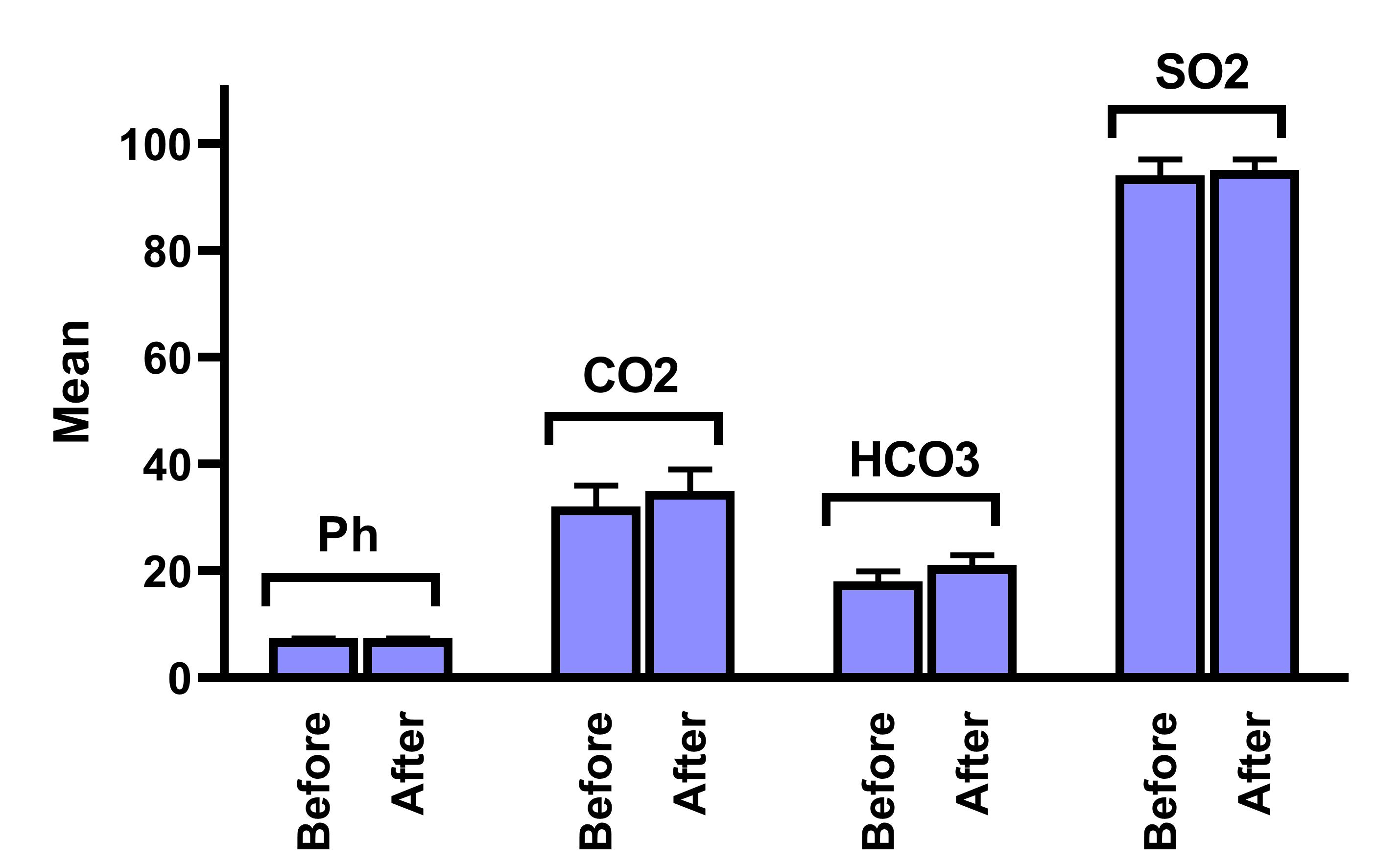
**Table 3: Comparison of pulmonary function parameters according to age, sex and body mass index**

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

\*Significant P-value; VC: Vital capacity; FVC: Forced vital capacity; FEV: Forced expiratory volume; PEF: Peak expiratory flow; FEF: Forced expiratory flow.

**Figure legends:**

**Figure 1:** Changes in ABG parameters before and after dialysis in ESRD patients.



**Figure 2:** Pulmonary function tests before and after dialysis; A: VC; B: FVC; C: FEV-1; D: FEV-1/FVC; E:PEF; F: FEF 25%-75%

