

Pulmonary Complications in Patients with Chronic Kidney Disease Undergoing Hemodialysis: An Observational Study

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Abstract

Background: Pulmonary complications are a frequent but often under-recognized cause of morbidity among patients with chronic kidney disease (CKD) undergoing maintenance hemodialysis. Multifactorial mechanisms—including fluid overload, uremic toxins, anemia, and hypoalbuminemia—predispose these individuals to diverse respiratory abnormalities. Early detection and characterization of these complications are essential for improving outcomes and quality of life. The objective is to evaluate the prevalence and spectrum of pulmonary complications in patients with CKD on hemodialysis and to analyze their correlation with biochemical and clinical parameters. **Material and Methods:** A hospital-based observational study was conducted on 100 patients with end-stage renal disease (ESRD) receiving regular hemodialysis for ≥ 6 months. Detailed clinical evaluation, chest X-ray, and high-resolution computed tomography (HRCT) were performed. Pulmonary function tests (PFTs) were analyzed, and biochemical variables, including serum urea, creatinine, albumin, and hemoglobin, were correlated with pulmonary findings using appropriate statistical tests. **Results:** The mean age of the study population was 52.7 ± 11.6 years, with 62 males and 38 females. Pulmonary abnormalities were detected in 63% of cases. The most frequent findings were pleural effusion (21%), pulmonary edema (18%), and pulmonary infection (12%). Spirometry showed restrictive defects in 44%, obstructive in 16%, and normal patterns in 40%. A significant association was observed between dialysis duration > 3 years and restrictive ventilatory defects ($p = 0.01$). Patients with pulmonary complications had higher mean serum urea and creatinine, lower albumin, and reduced hemoglobin (all $p < 0.05$). Hemoglobin levels negatively correlated with PFT values ($r = -0.41$, $p < 0.01$). **Conclusion:** Pulmonary complications are common in CKD patients on long-term hemodialysis, predominantly manifesting as pleural effusion and pulmonary edema. Prolonged dialysis duration, anemia, and hypoalbuminemia significantly contribute to respiratory dysfunction, highlighting the need for routine pulmonary assessment in this high-risk population.

Keywords: Chronic kidney disease; Hemodialysis; Pulmonary complications; Pleural effusion; Pulmonary edema; Spirometry; Hypoalbuminemia.

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INTRODUCTION

Chronic kidney disease (CKD) is a major global health concern characterized by the gradual and irreversible loss of renal function, culminating in the accumulation of metabolic toxins and widespread systemic disturbances. Its global prevalence has been estimated at approximately 10–15% among adults, reflecting an escalating burden across developed and developing nations.^[1] As renal function deteriorates, maintenance hemodialysis remains a cornerstone of life-sustaining therapy; however, it does not completely reverse the complex metabolic, inflammatory, and volume-related derangements associated with end-stage renal disease (ESRD).^[2,3] These disturbances significantly affect multiple organ systems, with the pulmonary system being particularly vulnerable.

Pulmonary complications represent some of the most frequent and clinically relevant non-renal manifestations in CKD. The lung–kidney axis is intricately linked through shared physiological mechanisms involving fluid regulation, acid–base equilibrium, and erythropoietin metabolism. In

advanced renal failure, volume overload, hypoalbuminemia, anemia, and retention of uremic toxins contribute to interstitial edema, diminished lung compliance, and impaired gas exchange.^[4] These structural and functional alterations predispose patients to various respiratory manifestations ranging from mild exertional dyspnea to severe pulmonary edema or effusion.

Furthermore, repeated hemodialysis exposure, chronic inflammation, and a degree of immunosuppression enhance susceptibility to respiratory infections and structural lung changes.^[5] Such pulmonary involvement often remains

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underrecognized due to the overlap of symptoms with uremic manifestations and cardiovascular comorbidities. Therefore, systematic chest imaging and pulmonary function testing evaluation have become essential to facilitate early diagnosis and management.

The present study was therefore undertaken to evaluate the prevalence, pattern, and determinants of pulmonary complications in patients with CKD undergoing maintenance hemodialysis and to assess their correlation with key biochemical and clinical variables.

MATERIALS AND METHODS

Study Design and Setting: A hospital-based observational cross-sectional study was conducted in the Department of General Medicine, Konaseema Institute of Medical Sciences and Research Foundation (KIMS & RF), Amalapuram, over 12 months (June 2024 to May 2025). The study aimed to evaluate the prevalence and spectrum of pulmonary complications among patients with chronic kidney disease (CKD) undergoing maintenance hemodialysis.

Study Population: After fulfilling the eligibility criteria, 100 patients with end-stage renal disease (ESRD) receiving regular hemodialysis at the hospital dialysis unit were enrolled in the study.

Inclusion Criteria

Adult patients aged ≥18 years with a confirmed diagnosis of CKD Stage V (ESRD) as per KDIGO 2021 guidelines.

Patients undergoing maintenance hemodialysis for at least six months.

Individuals who provided written informed consent to participate in the study.

Exclusion Criteria

Patients with known pre-existing chronic respiratory diseases such as chronic obstructive pulmonary disease (COPD), bronchial asthma, or interstitial lung disease.

Patients with acute pulmonary infections or on ventilatory support at enrollment.

Those with connective tissue disorders, malignancy, or recent thoracic surgery.

Patients are unwilling to participate.

Data Collection Procedure

Eligible participants were recruited after obtaining Institutional Ethics Committee (IEC) approval. A structured proforma recorded detailed clinical history, including demographic data, CKD etiology, dialysis duration, and respiratory symptoms (dyspnea, cough, chest discomfort). A

thorough general and systemic examination was performed, emphasizing respiratory system findings.

Investigations

All patients underwent:

Chest X-ray (PA view) and, when indicated, High-Resolution Computed Tomography (HRCT) to identify structural and parenchymal abnormalities.

Pulmonary Function Tests (PFTs) using a standardized spirometer to assess FVC, FEV₁, and FEV₁/FVC ratio; results were interpreted according to ATS/ERS criteria.

During pulmonary evaluation, laboratory investigations, including hemoglobin, serum urea, serum creatinine, and serum albumin levels, were recorded.

Duration of dialysis and number of weekly sessions were documented.

Operational Definitions

Restrictive pattern: FVC <80% predicted with FEV₁/FVC ≥70%.

Obstructive pattern: FEV₁/FVC <70%.

Hypoalbuminemia: Serum albumin <3.5 g/dL.

Anemia: Hemoglobin <11 g/dL (as per KDIGO standards).

Statistical Analysis: Data were entered in Microsoft Excel and analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Quantitative variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequency and percentage. Associations between categorical variables were tested using the Chi-square test or Fisher’s exact test, and continuous variables were compared using the Student’s t-test. Correlation between biochemical and pulmonary parameters was assessed using Pearson’s correlation coefficient (r). A p-value < 0.05 was considered statistically significant.

Ethical Considerations: The Institutional Ethics Committee of KIMS & RF, Amalapuram, reviewed and approved the study protocol. All participants provided written informed consent before enrollment, and confidentiality of patient data was strictly maintained in accordance with the Declaration of Helsinki.

RESULTS

A total of 100 patients with end-stage renal disease (ESRD) on maintenance hemodialysis were evaluated for pulmonary complications. The study cohort comprised 62 males and 38 females, with a mean age of 52.7 ± 11.6 years. The mean duration of dialysis was 3.2 ± 1.4 years. The leading etiologies of chronic kidney disease were diabetic nephropathy (41%), hypertensive nephrosclerosis (36%), and chronic glomerulonephritis (18%), as presented in [Table 1].

Table 1: Baseline Characteristics of Study Population (n = 100)

Parameter	Mean ± SD / n (%)
Age (years)	52.7 ± 11.6
Gender (Male/Female)	62 / 38
Duration of hemodialysis (years)	3.2 ± 1.4
Etiology of CKD	
Diabetic nephropathy	41 (41.0)
Hypertensive nephrosclerosis	36 (36.0)
Chronic glomerulonephritis	18 (18.0)
Others (polycystic kidney, unknown)	5 (5.0)

Clinical and Radiological Findings: Dyspnea was the predominant presenting symptom, reported by 68% of

participants, followed by cough (42%) and chest discomfort (25%). On imaging, 63% of patients exhibited at least one pulmonary abnormality. The most frequent findings were pleural effusion (21%), pulmonary edema (18%), and

infective pathology such as pneumonia or tuberculosis (12%), while 37% had normal chest imaging [Table 2, Figure 1 -3].

Table 2: Clinical and Radiological Findings

Clinical Feature / Complication	No. of Cases (n)	Percentage (%)
Symptoms		
Dyspnea	68	68.0
Cough	42	42.0
Chest discomfort	25	25.0
Radiological abnormalities		
Pleural effusion	21	21.0
Pulmonary edema	18	18.0
Pulmonary infection (pneumonia/tuberculosis)	12	12.0
Atelectasis	4	4.0
Pulmonary fibrosis (uremic lung)	3	3.0
Normal chest findings	37	37.0

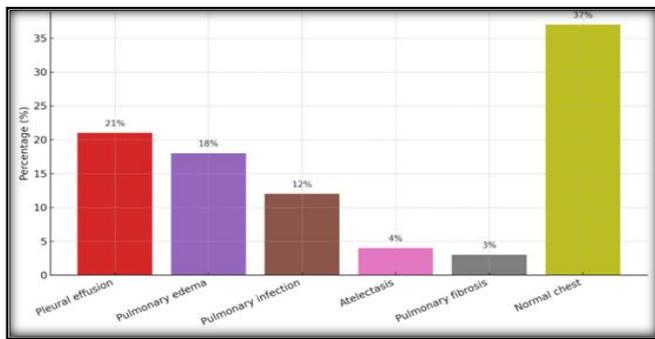


Figure 1: Radiological Abnormalities on CXR/HRCT

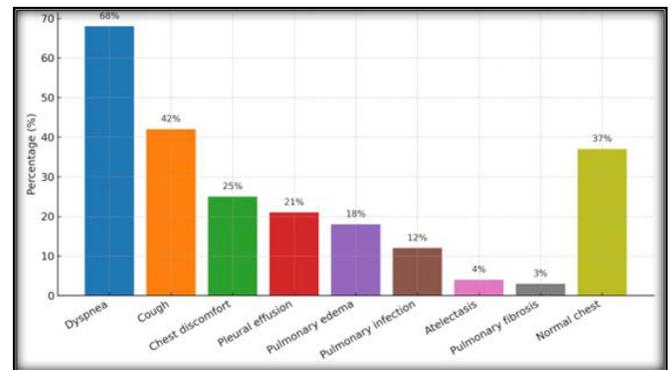


Figure 3: Clinical and Radiological Findings in Hemodialysis Patients

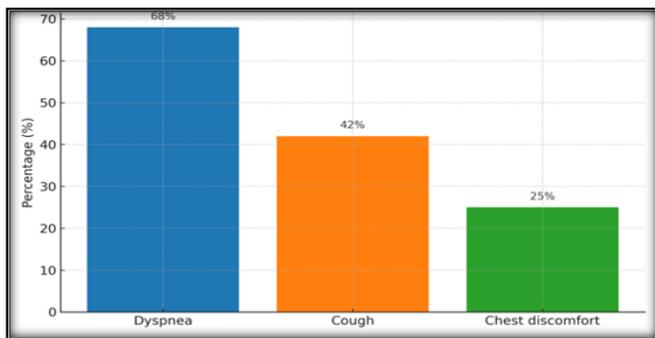


Figure 2: Symptoms at Presentation

Pulmonary Function Tests: Spirometric analysis revealed that 44% of patients demonstrated a restrictive ventilatory pattern, 16% had an obstructive pattern, and 40% exhibited normal lung function. The mean FVC, FEV₁, and FEV₁/FVC ratio were 68.3 ± 14.7%, 71.9 ± 13.2%, and 82.1 ± 7.4%, respectively. A statistically significant association was noted between dialysis duration >3 years and the presence of a restrictive defect (p = 0.01), indicating cumulative pulmonary involvement with longer treatment duration [Table 3].

Table 3: Pulmonary Function Test (PFT) Patterns

Parameter	Mean ± SD / n (%)
Restrictive pattern	44 (44.0)
Obstructive pattern	16 (16.0)
Normal spirometry	40 (40.0)
FVC (% predicted)	68.3 ± 14.7
FEV ₁ (% predicted)	71.9 ± 13.2
FEV ₁ /FVC ratio (%)	82.1 ± 7.4
Association between dialysis duration (>3 years) and restrictive defect	p = 0.01 (significant)

Correlation with Biochemical Parameters: Patients exhibiting pulmonary complications had significantly higher mean serum urea (134 ± 27 mg/dL) and serum creatinine (9.6 ± 2.1 mg/dL) levels than those without pulmonary involvement (p < 0.05). Hypoalbuminemia (<3.5 g/dL) was identified in 54% of cases and showed a positive association

with pleural effusion and pulmonary edema (p = 0.02). Anemia was also more prevalent in the affected group, and hemoglobin levels demonstrated a significant inverse correlation with pulmonary function (r = -0.41, p < 0.01), suggesting that lower hemoglobin contributed to reduced respiratory efficiency [Table 4].

Table 4: Correlation of Pulmonary Complications with Biochemical Parameters

Parameter	With Pulmonary Complications (n = 63)	Without Pulmonary Complications (n = 37)	p-value
Serum urea (mg/dL)	134 ± 27	116 ± 21	< 0.05
Serum creatinine (mg/dL)	9.6 ± 2.1	8.2 ± 1.7	< 0.05
Serum albumin (g/dL)	3.4 ± 0.5	3.9 ± 0.4	0.02
Hemoglobin (g/dL)	8.9 ± 1.3	10.2 ± 1.1	< 0.01
Correlation of Hb with PFT (r)	-0.41	—	< 0.01

DISCUSSION

The present study assessed the prevalence, spectrum, and determinants of pulmonary complications in patients with end-stage renal disease (ESRD) undergoing maintenance hemodialysis at a tertiary care center in coastal Andhra Pradesh. Among the 100 participants evaluated, 63% exhibited one or more pulmonary abnormalities, highlighting the considerable burden of respiratory morbidity among hemodialysis patients. The predominance of pleural effusion (21%) and pulmonary edema (18%) observed in our study mirrors previous evidence that attributes these abnormalities primarily to fluid overload and hypoalbuminemia, which lead to increased pulmonary capillary hydrostatic pressure and reduced oncotic pressure.^[6-8]

Clinical and Radiological Correlation: Dyspnea was the most frequent presenting symptom, observed in 68% of patients. This aligns closely with the report by Sharma et al., who documented exertional dyspnea in 70% of ESRD cases on hemodialysis.^[6] The radiological abnormalities in our series, predominantly pleural effusion and pulmonary edema, are consistent with the meta-analytic observations by Chander et al. showing that kidney replacement therapies significantly alter lung mechanics, particularly by promoting restrictive changes secondary to volume shifts.^[8] Infective complications such as pneumonia and tuberculosis, found in 12% of our patients, further corroborate earlier observations that uremic immunosuppression and recurrent vascular access predispose hemodialysis patients to pulmonary infections.^[6]

Pulmonary Function Impairment: Spirometric evaluation revealed a restrictive ventilatory pattern in 44% and an obstructive pattern in 16% of patients. These findings are consistent with the work of Srithongkul et al., who demonstrated similar restrictive abnormalities that improved following intensive hemodialysis, suggesting reversibility when fluid and uremic toxin control are optimized.^[7] The restrictive defects likely stem from uremic interstitial edema, metabolic acidosis, and respiratory muscle weakness, mechanisms also emphasized in the recent systematic review by Chander et al., which confirmed that hemodialysis exerts measurable effects on lung compliance and diffusion capacity.^[8] Importantly, the observed correlation between dialysis duration > 3 years and restrictive impairment ($p = 0.01$) in our cohort supports the hypothesis of progressive, time-dependent pulmonary involvement, echoing the pathophysiological continuum reported in long-term dialysis populations.^[8,9]

Biochemical Associations: Patients with pulmonary complications demonstrated significantly higher serum urea and creatinine, lower albumin, and reduced hemoglobin than those without pulmonary abnormalities. Hypoalbuminemia

was strongly associated with pleural effusion and pulmonary edema, emphasizing the role of reduced oncotic pressure in transudative fluid accumulation—a relationship also documented by Khemchandani et al., who found similar correlations between albumin levels and pulmonary hypertension risk in ESRD patients.^[10] The inverse relationship between hemoglobin concentration and pulmonary function ($r = -0.41$) in our study reinforces the findings of Aydın Güçlü et al., who demonstrated that anemia significantly impairs lung performance and adversely influences survival in hemodialysis patients.^[11] These results collectively suggest that correcting anemia and improving nutritional status could mitigate pulmonary dysfunction and enhance overall outcomes.

Pulmonary Hypertension and Functional Decline: The interdependence of pulmonary and cardiovascular systems in CKD is well recognized. Our findings correspond with prior reports by Sise et al. and Yu & Zhang, both of whom highlighted a high prevalence of pulmonary hypertension among hemodialysis patients, attributing it to chronic volume overload, vascular remodeling, and endothelial dysfunction.^[9,12] Pulmonary hypertension contributes to further impairment in gas exchange and exercise tolerance, compounding morbidity in this population.

Pathophysiological Insights: The mechanisms underlying pulmonary involvement in CKD are multifactorial. Persistent volume overload increases pulmonary capillary pressure, leading to interstitial and alveolar edema. Retention of uremic toxins disrupts alveolar-capillary permeability, while chronic inflammation, oxidative stress, and microembolic events during dialysis sessions contribute to fibrosis and decreased lung compliance. Nutritional deficits, anemia, and hypoalbuminemia further exacerbate these alterations, resulting in a vicious cycle of progressive restrictive and vascular pulmonary dysfunction.^[7-12]

Clinical Implications: The high prevalence of pulmonary abnormalities identified in this study underscores the importance of routine respiratory screening in CKD patients, particularly those on long-term dialysis. Integrating periodic chest imaging and spirometry into dialysis follow-up can facilitate early detection of reversible conditions and guide fluid management and nutritional interventions. Addressing anemia and hypoalbuminemia through optimized erythropoietin therapy and nutritional support may substantially mitigate pulmonary morbidity.

Limitations: The limitations of this study include its single-center, cross-sectional design and modest sample size, which restrict causal inference. Arterial blood gas analysis and echocardiographic correlation were not performed for all participants, which could have strengthened physiological interpretation. Nonetheless, the findings provide valuable regional data on pulmonary involvement in CKD and form a

basis for longitudinal research.

CONCLUSION

In this observational study conducted among patients with chronic kidney disease undergoing maintenance hemodialysis, pulmonary complications were found to be highly prevalent, affecting nearly two-thirds of the study population. Pleural effusion, pulmonary edema, and restrictive ventilatory defects constituted the most common abnormalities. Prolonged duration of dialysis, anemia, and hypoalbuminemia emerged as significant contributors to pulmonary morbidity. These findings emphasize the necessity of incorporating routine respiratory evaluation, including chest imaging and pulmonary function testing, into the standard care of hemodialysis patients. Early recognition and management of reversible factors such as fluid overload, nutritional deficiency, and anemia can substantially improve respiratory function and overall patient outcomes.

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Conflicts of interest

There are no conflicts of interest.

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