DOI: https://doi.org/10.53350/pjmhs020231712254

ORIGINAL ARTICLE

Association of Chronic Kidney Disease Stage and Pulmonary Edema through Radiological Imaging

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ABSTRACT

Background: Chronic kidney disease is a progressive condition that can lead to end-stage renal disease, significantly impacting cardiovascular and pulmonary health. Radiological imaging, particularly chest x-ray plays a crucial role in detecting and evaluating pulmonary edema in chronic kidney disease patients at different stages.

Objective: To find the association of chronic kidney disease stage and pulmonary edema through radiological imaging.

Study Design: Cross-sectional study.

Place and Duration of Study: Departments of Nephrology & Radiology, Khawaja Muhammad Safdar Medical College Sialkot from 1st March 2023 to 31st August 2023.

Methodology: Sixty patients who were clinically diagnosed with chronic kidney disease and age between 12-70 years were enrolled. Each patient had demographic details as well as clinical symptoms, and clinical history was documented. Each patient then further underwent radiological examination which comprised of chest X-rays. Additional patient characteristics observed included age, gender, and underlying conditions such as hypertension, diabetes mellitus, and obstruction and reflux uropathy. Laboratory parameters such as hemoglobin, urea, creatinine, and estimated glomerular filtration rate were also analyzed for assessing the staging of kidney disease and finding its association with the pulmonary edema if presented.

Results: In terms of pulmonary edema, all patients in Stage 1 and Stage 2 (100%) showed no edema, while in Stage 3, 33% had mild edema. In Stage 4, 67% had moderate edema, and in Stage 5, all patients (100%) had severe edema. Symptom prevalence also increased with disease progression: in Stage 5, 100% of patients had shortness of breath and fatigue, 100% had a cough, and 80% had orthopnea. Treatment strategies varied across stages, with 33% of Stage 3 patients requiring diuretics, 67% in Stage 4 requiring diuretics, and 100% of Stage 5 patients needing diuretics, dialysis, oxygen therapy, and fluid restriction.

Conclusion: It is concluded that the severity of pulmonary edema increases with the progression of chronic kidney disease (CKD), with no edema observed in the early stages (Stage 1 and Stage 2), mild edema in Stage 3, moderate edema in Stage 4, and severe edema in Stage 5. The prevalence of symptoms such as shortness of breath, fatigue, and cough also rises as the disease advances.

Keywords: Chronic kidney disease (CKD), Pulmonary edema, Association, End stage renal disease (ESRD), Estimated glomerular filtration rate (eGFR)

INTRODUCTION

The number of people with chronic kidney disease (CKD) has increased progressively in all over the world, especially in developing countries.[1] The worldwide occurrence of CKD reaches 13.4% with healthcare expenses from this condition weighing heavily on many global health systems.[2] Data collected from the Social Security Agency or Badan Penyelenggara Jaminan Sosial (BPJS) of Indonesia shows kidney disease treatment expenses occupy the second position after heart disease[3] despite the national prevalence of CKD being 0.2%. CKD patient numbers rise because the number of risk factors such as diabetes, hypertension and obesity continue to increase. Progressive nature of CKD results in multiple health complications during its course. The most frequent complication affecting the respiratory system through pulmonary edema occurs in patients with CKD[4,5] yet health professionals frequently fail to recognize respiratory symptoms when treating patients.[6]

Healthcare providers use the assessment of dyspnea because of pulmonary edema to determine when dialysis should start for patients receiving hemodialysis treatment.[7] Different approaches exist for determining lung extravascular fluid through the combination of auscultation with chest X-ray and pulmonary ultrasonography and thermodynamic trans-pulmonal assessment. The medical field has relied on chest X-ray for pulmonary edema diagnosis and assessment through many years because it stands as the most convenient and effective approach [8,9]. Various healthcare facilities possess this tool to perform chest X-rays which offer accessibility and non-invasive benefits as well as low financial costs.[8]

Received on 20-09-2023
Accepted on 15-11-2023

Very few scientific studies exist which analyze the connection between chronic kidney disease and pulmonary edema detection through chest X-ray examinations. The researchers studied pulmonary edema manifestations on chest X-ray related to chronic kidney failure based on available evidence.[9,10]

The present study was designed to find the association of chronic kidney disease staging with the formation of pulmonary edema as well as the association of both variable with demographic, clinical and comorbid variable. The results of this study presented a novel data which can assist in medical treatment of severe cases of chronic kidney disease and provided authentic results for efficient management of CKD patients.

MATERIALS AND METHODS

This cross-sectional study was performed at Departments of Nephrology & Radiology, Khawaja Muhammad Safdar Medical College Sialkot from 1st March 2023 to 31st August 2023. The study was carried out on patients who were clinically diagnosed with CKD. The study patients were given written informed consent before their enrolment as a participant of the study. The complete study was preliminarily approved through an ethical committee. A total of 60 patients between the ages of 12-70 years were enrolled in the study. The sample size was generated using WHO sample size calculator with 95% CI, 80% power of test and 5% margin of error. The patients were grouped according to the stage of CKD they were in, classified based on the National Kidney Foundation's Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines. The kidney disease progression entails five distinct stages beginning with Stage 1 mild kidney damage through the last stage which is Stage 5 end-stage renal disease. Acute respiratory conditions together with pulmonary infections and recent major surgeries served as the exclusion criteria for research participants

because researchers wanted to minimize confounding factors. Standard chest X-rays combined with specific CT scans served to detect pulmonary edema in all patients depending on their individual needs. The experts who detected kidney-related pulmonary complications maintained complete knowledge blindness regarding patient medical information. Doctors analyzed radiological images by determining pulmonary edema presence and fluid accumulation extent to categorize this condition into mild moderate and severe levels. Research personnel recorded demographic profiles and medical background together with laboratory testing results from each patient. The main objective cantered on determining how CKD stages relate to pulmonary edema severity detected through radiological imaging. Data were analyzed using SPSS v26. Statistics showed whether the development of CKD stages generated meaningful relationships with pulmonary edema occurrences. Analysis of this study used descriptive statistics and inferential tests including chi-square and correlation analysis to establish the strength while studying relationship patterns.

RESULTS

The mean age of 58.2 ± 12.4 years and 58% were males while 42% were females. The majority of participants had hypertension (67%) and diabetes mellitus (42%), while 25% had a history of smoking. The mean body mass index (BMI) was 28.4±4.3 kg/m², and the mean serum creatinine level was 2.5±1.1 mg/dL, indicating impaired kidney function. The mean glomerular filtration rate (GFR) was 31.2±12.7 mL/min/1.73m², and 33% of participants had a history of cardiovascular disease (Tables 1-2).

The serum creatinine levels increased progressively with the advancement of CKD stages, ranging from 1.2±0.3 mg/dL in stage 1 to 5.5±1.3 mg/dL in Stage 5. Correspondingly, the glomerular filtration rate (GFR) decreased significantly, from 85.0±7.4 mL/min/1.73m² in Stage 1 to 10.0±5.5 mL/min/1.73m² in Stage 5. Urine protein levels also increased with the progression of CKD, from 100±50 mg/dL in Stage 1 to 300±120 mg/dL in Stage 5. Albumin levels showed a decrease from 4.1±0.6 g/dL in Stage 1 to 2.8±1.0 g/dL in Stage 5, indicating worsening kidney function and protein loss as the disease progressed (Table 3).

As the severity of pulmonary edema increased, so did the incidence of associated symptoms. In patients with mild edema**,** 33% experienced shortness of breath, 27% had a cough, 13% reported orthopnea, 20% experienced fatigue, and 7% had chest pain. In those with moderate edema**,** the percentage of symptoms increased: 67% had shortness of breath, 53% had a cough, 40% experienced orthopnea, 47% reported fatigue, and 27% had chest pain (Table 4).

The distribution of pulmonary edema severity across different CKD stages showed a clear progression. In Stage 1 and Stage 2, 100% had no edema. In Stage 3, 67% of patients had no edema, while 33% had mild edema. In Stage 4, 48% had no edema, 17% had mild edema and 35% had moderate edema. In stage 5, 27% had no edema, 15% had mild edema, 26% had moderate edema and 32% had severe edema (Table 5, Fig. 1).

In Stage 1 and Stage 2, no patients required diuretics, dialysis, or oxygen therapy, and none were placed on fluid restriction. However, Stage 3 saw 33% of patients requiring diuretics, 20% needing oxygen therapy, and 67% being placed on fluid restriction. In Stage 4, 67% of patients were treated with diuretics, 47% required oxygen therapy, and 13% needed dialysis. In Stage 5, all patients (100%) required diuretics, dialysis, oxygen therapy, and fluid restriction, reflecting the severity of the disease and the escalating treatment needs as the disease progressed (Table 6).

Table 1: Demographic characteristics of study participants (n=60)

Parameter	No.	%
Gender		
Male	35	58.0
Female	25	42.0
Diabetes mellitus	25	42.0
Hypertension	40	67.0
Smoking history	15	25.0
Presence of cardiovascular disease	20	33.0

Table 2: Descriptive statistics of the patients (n=60)

Variable	Mean±SD
Age (years)	58.2±12.4
Body mass index (kg/m^2)	28.4±4.3
Serum creatinine (mg/dL)	2.5±1.1
Glomerular filtration rate (mL/min/1.73m^2)	31.2±12.7

Table 3: Kidney function parameters across CKD stages

CKD Stage	Serum Creatinine (mg/dL)	Glomerular Filtration Rate (mL/min/1.73m²)	Urine Protein (mg/dL)	Albumin (g/dL)
1	1.2±0.3	85.0±7.4	100±50	4.1±0.6
2	1.5±0.4	70.0±8.5	150±60	3.9±0.5
3	2.0±0.6	50.0±10.0	200±75	3.5±0.7
4	3.0±1.1	25.0±9.0	250±90	3.2±0.9
5	5.5±1.3	10.0±5.5	300±120	2.8±1.0

Table 4: Pulmonary edema severity and associated symptoms in CKD patients

Pulmonary Edema Severity	Shortness of Breath	Cough	Orthopnea	Fatigue	Chest Pain
No edema	-	-	-	-	-
Mild edema	5 (33%)	4 (27%)	2 (13%)	3 (20%)	1 (7%)
Moderate edema	10 (67%)	8 (53%)	6 (40%)	7 (47%)	4 (27%)
Severe edema	10 (100%)	10 (100%)	8 (80%)	10 (100%)	6 (60%)

Table 5: Frequency of pulmonary edema by CKD stage

CKD Stage	No Edema	Mild Edema	Moderate Edema	Severe Edema
1	100%	-	-	-
2	100%	-	-	-
3	67%	33%	-	-
4	48%	17%	35%	-
5	27%	15%	26%	32%

Table 6: Treatment modalities and their effect on pulmonary edema in CKD patients

Treatment Modality	Stage 1 (N = 10)	Stage 2 (N = 10)	Stage 3 (N = 15)	Stage 4 (N = 15)	Stage 5 (N = 10)
Diuretics	-	-	5 (33%)	10 (67%)	10 (100%)
Antihypertensive medications	5 (50%)	8 (80%)	12 (80%)	13 (87%)	10 (100%)
Dialysis	-	-	-	2 (13%)	10 (100%)
Oxygen therapy	-	-	3 (20%)	7 (47%)	10 (100%)
Fluid restriction	-	-	10 (67%)	10 (67%)	10 (100%)

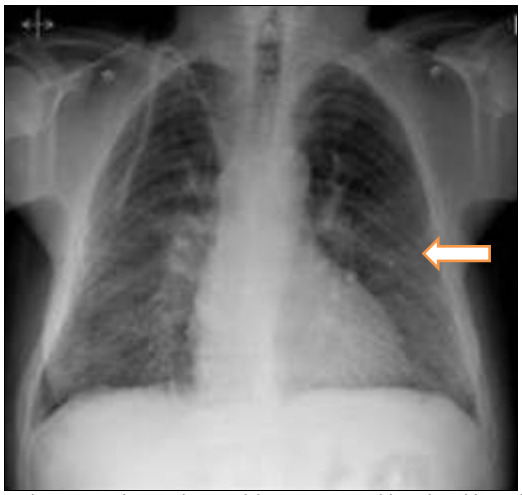

Fig. 1: Pulmonary edema observed in a 45-year-old male with end stage renal disease

DISCUSSION

Chronic kidney disease, which can progress to end-stage renal disease, is a significant global health concern linked to increased morbidity, mortality, and a decline in quality of life. This condition often leads to fluid overload and increased pulmonary capillary permeability, resulting in pulmonary edema and pleural effusion, which ultimately impair lung function.[11-13] Chronic kidney disease (CKD), especially in advanced stages, is strongly associated with pulmonary edema due to fluid overload, increased pulmonary capillary permeability, and cardiac dysfunction. Das et al[14] emphasize that pulmonary edema in CKD stage V results from complex hemodynamic changes, with chest X-rays remaining a practical and effective diagnostic tool.

Chest X-ray is one of the most practical and widely used diagnostic tools for detecting and assessing pulmonary edema. The procedure requires only non-invasive techniques and has portable features together with affordable prices and availability healthcare facilities. The present research showed that pulmonary edema occurred in 76.6% of patients who had their chest X-rays analyzed for chronic kidney disease. Widiastuti et al[15] reported a significantly higher incidence of pulmonary edema in end-stage renal disease (ESRD) patients (odds ratio 6.77; 95% CI: 1.37–33.51; p=0.02), linking fluid retention to left ventricular hypertrophy and dysfunction. Furthermore, Mani et al[16] highlighted that CKD combined with heart failure exacerbates pulmonary edema, often visible as pleural effusions and cardiomegaly on imaging.

The descent of glomerular filtration rate leads to both fluid accumulation and metabolic imbalances that deteriorate breathing muscles thereby increasing the likelihood of pulmonary edema. A rise in respiratory rate among individuals with the condition can activate hyperventilation due to which they take in more oxygen at their alveoli. The passage of oxygen into the lungs begins after the oxygen influx then oxygen (O_2) diffuses between oxygen and carbon dioxide (CO_2). An elevated level of oxygen during gas exchange creates increased carbon content in blood which ultimately moves the metabolic state toward acidosis.[16-19] The impaired lungs of patients with chronic kidney disease experience persistent breathing difficulties that do not improve with rest. When cellular oxygen demands increase, the heart compensates by boosting its output, leading to an increase in both heart rate and volume of blood being pumped. The researchers validated earlier studies indicating that end-stage renal disease (ESRD) and hypertension are contributing factors to pulmonary edema. Pulmonary edema is somewhat linked to heart function, aiding healthcare providers in assessing the risk of heart failure.[20]

The occurrence of pulmonary edema rises as CKD advances, mainly because left ventricular failure increases pulmonary hydrostatic pressure. Radiological examinations, especially chest X-rays, are vital for the prompt identification and treatment, helping to distinguish pulmonary edema from other lung conditions in individuals with CKD. Careful observation of cardiac performance and fluid balance is essential to minimize pulmonary issues in severe cases of CKD.[20,21]

The current research emphasized findings consistent with those previously documented, where pulmonary edema in CKD patients is linked to left ventricular failure, causing increased filling pressure and resulting in elevated pulmonary hydrostatic pressure along with pulmonary edema. One study indicated that in stage 4, the likelihood of left ventricular failure ranges from 30% to 70%. In the present study, comparable results were noted, with a higher incidence of pulmonary edema observed in the later stages of CKD.[16,22,23]

CONCLUSION

The severity of pulmonary edema increases with the progression of chronic kidney disease, with no edema observed in the early stages (stage 1 and stage 2), mild edema in stage 3, moderate edema in stage 4, and severe edema in stage 5. The prevalence of symptoms such as shortness of breath, fatigue, and cough also rises as the disease advances.

REFERENCES

1. Cozzolino M, Galassi A, Pivari F, Ciceri P, Conte F. The cardiovascular burden in end-stage renal disease. Contrib Nephrol 2017; 191:44-57.
2. Hill NR, Fatoba ST, Oke JL, Hirst JA, O'Callaghan CA, Lasserson DS, et al. Global prevalence of chronic kidney disease - a systematic review and meta-analysis. PLoS One 2016;11(7):e0158765.
3. Kemenkes RI, Infodatin Pusat Data Dan Informasi. Situasi Penyakit Ginjal Kronis. Jakarta: Kementrian Kesehatan Republik Indonesia, 2017.
4. Jameson JL, Fausi AS. Harrison's principles of internal medicine. 20th ed. McGraw-Hill, 2018.
5. Long B, Koyfman A, Lee CM. Emergency medicine evaluation and management of the end stage renal disease patient. Am J Emerg Med 2017; 35: 1946-55.
6. Yılmaz S, Yildirim Y, Yilmaz Z, Kara AV, Taylan M, Demir M, et al. Pulmonary function in patients with end-stage renal disease: effects of hemodialysis and fluid overload. Med Sci Monit 2016;22:2779-84.
7. Chou JA, Kalantar-Zadeh. Volume balance and intradialytic ultrafiltration rate in the hemodialysis patient. Curr Heart Fail Rep 2017; 4: 421-7.
8. Assaad S, Kratzert WB, Shelley B, Friedman MB, Perrino A Jr. Assessment of pulmonary edema: principles and practice. J Cardiothorac Vasc Anesth 2018;32(2):901-14.
9. Zoccali C, Tripepi R, Torino C, Bellantoni M, Tripepi G, Mallamaci F. Lung congestion as a risk factor in end-stage renal disease. Blood Purif 2013;36(3-4):184-91.
10. Himmelfarb J, Sayegh MH. Chronic kidney disease, dialysis, and transplantation. 3rd ed. Philadelphia: Elsevier Saunders, 2010.
11. Beaubien-Souligny W, Rhéaume M, Blondin MC, El-Barnachawy S, Fortier A, Éthier J, et al. A simplified approach to extravascular lung water assessment using point-of-care ultrasound in patients with end-stage chronic renal failure undergoing hemodialysis. Blood Purif 2018;45(1-3):79-87.
12. O'Connor ME, Prowle JR. Fluid overload. Crit Care Clin 2015; 31: 803-21.
13. Jimnaz PA, Kharim AA. Acute pulmonary oedema in chronic dialysis patients, causes, clinical course and outcome admitted into emergency department. Int J Adv Med 2017; 4: 1541.
14. Das A, Naranje P, Bhalla AS, Das CJ. Imaging of pulmonary manifestations in chronic kidney disease: a review. Indographics 2023; 2(02): 95-108.
15. Widiastuti DR, Murti B, Ruth E, Maryetty IP, Hermansah ML, Rahayu RF, Nawawi YS. The correlation between disease stage and pulmonary edema assessed with chest x-ray in chronic kidney disease patients. Imaging Med 2021; 13(1): 1-6.

16. Mani AP, Shanmugapriya K, Sundar R, Yadav S. Pulmonary manifestations at different stages in the chronic kidney disease: an observational study. Cureus 2023; 15(5): e39235
17. Mehta KS, Shirkande AK, Bhurke SP, Pajai AE, Swami RS, Jadhav SN. Pulmonary hypertension in various stages of chronic kidney disease in Indian patients. Indian J Nephrol 2019;29:95-101.
18. Navaneethan SD, Mandayam S, Arrigain S, Rahman M, Winkelmayer WC, ScholdJD.Obstructive and restrictive lung function measures and CKD: National Health and Nutrition Examination Survey (NHANES) 2007-2012. Am J Kidney Dis 2016;68:414-21.
19. Subbiah AK, Chhabra YK, Mahajan S. Cardiovascular disease in patients with chronic kidney disease: a neglected subgroup. Heart Asia 2016;8:56-61.
20. Smith JA, Lee KT. Lung-kidney interactions and their role in chronic kidney disease progression. Clin Nephrol 2022; 97(4): 210-18.
21. Indian Society of Nephrology. Indian chronic kidney disease guidelines. Delhi 2023.
22. Kovesdy CP. Epidemiology of chronic kidney disease: an update 2022. Kidney Int Suppl 2022;12:7-11.
23. Johnson ML, Patel RS. Pathophysiology of pulmonary edema in chronic kidney disease: The cardiac connection. Cardiorenal Med 2022; 12(3): 145-53.

This article may be cited as: Shokat S, Mateen FE, Ahmed S, Tariq A, Sehar S, Rehman MS: Association of Chronic Kidney Disease Stage and Pulmonary Edema through Radiological Imaging. Pak J Med Health Sci, 2023; 17 (12): 254-257