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CAUSES, CLINICAL COURSE, AND OUTCOMES OF ACUTE PULMONARY EDEMA IN CHRONIC DIALYSIS PATIENTS IN A TERTIARY CARE CENTRE

Dr Selvarajan Chettiar KP[1], Dr. Gayathri J[2]

1. *Professor, Department of General Medicine, Sree Mookambika Institute of Medical Sciences, Kanyakumari, Tamil Nadu*
2. *Junior Resident, Department of General Medicine, Sree Mookambika Institute of Medical Sciences, Kanyakumari, Tamil Nadu*

***Corresponding Author – Dr. Gayathri J[2],** *Junior Resident, Department of General Medicine, Sree Mookambika Institute of Medical Sciences, Kanyakumari, Tamil Nadu*

ABSTRACT

Background: Acute pulmonary edema (APE) is a prevalent and life-threatening emergency among patients on chronic dialysis. These patients are especially susceptible owing to preexisting cardiovascular conditions, fluid overload, and diminished renal clearance. Acute pulmonary embolism often requires immediate medical attention and is linked to significant morbidity and death rates. Recognizing the underlying reasons and comprehending the clinical trajectory is essential for prompt intervention. Severity grading systems such as SOFA and APACHE II assist in prognostication and informing therapy options for critically ill patients.

Aim: To identify the causes, evaluate the clinical course, and assess outcomes of acute pulmonary edema in chronic dialysis patients

Methods: This observational study included chronic dialysis patients presenting with APE to the emergency department over a defined period. Patient demographics, comorbidities, dialysis profiles, and precipitating causes were recorded. Clinical parameters during hospitalization were monitored, and disease severity was assessed using SOFA and APACHE II scores at admission and during the clinical course. Patient outcomes were categorized as survival, need for mechanical ventilation, ICU admission, or mortality. Data was entered in Microsoft Excel spread sheet and analyzed using SPSS software. Descriptive analysis and chi square test was done.

Results: The mean age was 58.4 ± 10.6 years, and 60% were male. Hypertension (86.7%) and diabetes (62.7%) were the most common comorbidities. Missed dialysis was the leading cause (48%), followed by uncontrolled hypertension and cardiac events. ICU admission was required in 65.3%, and 77.3% underwent emergency dialysis. Non-invasive ventilation was used in 54.7%, while 30.7% required mechanical ventilation. Mortality was 21.3%, significantly associated with SOFA ≥8 and APACHE II ≥25. Survivors had lower scores and longer hospital stays than non-survivors.

Conclusions: APE in chronic dialysis patients is primarily precipitated by fluid overload and cardiovascular factors. Elevated SOFA and APACHE II scores at presentation were strongly associated with poor outcomes, including increased ICU admissions and mortality. Early recognition and prompt intervention, guided by severity scoring, are essential to improve prognosis in this high-risk population.

Keywords: Acute Pulmonary Edema, APACHE II Score, Chronic Dialysis, End-Stage Renal

Disease, SOFA Score.

INTRODUCTION

Acute pulmonary edema (APE) is a critical clinical emergency marked by the fast buildup of fluid in the lungs, leading to significant respiratory distress and hypoxia. This consequence is notably common and severe in individuals with end-stage renal disease (ESRD) undergoing continuous dialysis.[1] These patients are susceptible to fluid overload and cardiovascular instability owing to their compromised renal function, concomitant conditions such as hypertension and heart failure, and the episodic nature of dialysis treatments. APE is a primary contributor to emergency department visits and hospital admissions among the dialysis population, correlating with significant morbidity, healthcare resource consumption, and fatality rates.[2,3]

Patients undergoing chronic dialysis face distinct physiological and hemodynamic problems. The equilibrium between fluid extraction and the maintenance of intravascular volume is precarious, and even slight deviations can trigger APE.[4] Missed or abbreviated dialysis treatments, excessive fluid consumption, inadequate blood pressure regulation, myocardial dysfunction, and arrhythmias are prevalent factors.[5] Moreover, vascular stiffness and compromised heart diastolic function frequently exacerbate the risk. The pathophysiological alterations render the chronic dialysis population particularly vulnerable to abrupt decompensation.[6]

Despite its commonality and clinical importance, acute pulmonary embolism in chronic dialysis patients remains under researched, especially regarding its triggering factors, in-hospital clinical progression, and patient-centered outcomes. Timely diagnosis and risk assessment are essential for commencing prompt and suitable therapies.[7] Historically, clinical judgment has directed the therapy of APE; however, objective severity rating systems such as the Sequential Organ Failure Assessment (SOFA) and Acute Physiology and Chronic Health Evaluation II (APACHE II) have become increasingly significant in recent years. Although these scores were originally designed for wider intensive care populations, they provide significant predictive insights for dialysis patients experiencing critical conditions like APE.[8]

The SOFA score assesses the degree of organ dysfunction in six systems (respiratory, cardiovascular, hepatic, coagulation, renal, and neurological), providing a dynamic evaluation of clinical decline.[9] The APACHE II score integrates physiological characteristics, age, and chronic health conditions to forecast mortality risk. Both ratings can inform clinical decision-making on the necessity for intensive care admission, the beginning of mechanical breathing, or the escalation of dialysis support.[10]

This study is to assess the etiology, clinical development, and consequences of acute pulmonary embolism in chronic dialysis patients presenting to the emergency department. Through the examination of clinical parameters and the identification of presentation patterns, we aim to enhance recognition and triage. Furthermore, by utilizing SOFA and APACHE II scores, we seek to evaluate their effectiveness in predicting outcomes and informing clinical interventions. Comprehending these elements can enhance risk classification, facilitate early intervention methods, and perhaps improve patient outcomes in this high-risk population.

MATERIALS AND METHODS

This was a prospective observational study conducted in the Department of General Medicine at a tertiary care hospital over a period of 18 months. The study was approved by the Institutional Ethics Committee, and informed consent was obtained from all patients or their legal guardians. The study included 75 adult patients (aged ≥18 years) with ESRD on maintenance hemodialysis who presented to the General Medicine Department with clinical and radiological features suggestive of APE.

Inclusion Criteria:

- Patients with ESRD on maintenance dialysis (minimum of 2 sessions/week for at least 3 months)
- Presentation with signs and symptoms of APE (acute onset breathlessness, orthopnea, crackles on auscultation)
- Radiological evidence of pulmonary edema (chest X-ray showing bilateral infiltrates or CT evidence)
- Consent to participate in the study

Exclusion Criteria:

- Patients with chronic lung diseases (e.g., COPD, pulmonary fibrosis)
- Non-dialysis CKD patients
- Patients with active infections like pneumonia mimicking APE
- Patients with incomplete medical records or who left against medical advice

Upon admission to the Medical Intensive Care Unit, detailed clinical information was collected for all 75 patients meeting the inclusion criteria. This included demographic data such as age and sex, duration and frequency of dialysis, date of the last dialysis session, and associated comorbidities like hypertension, diabetes mellitus, ischemic heart disease, and heart failure.

A focused history was taken to identify possible precipitating factors for APE, including missed dialysis sessions, fluid overload, uncontrolled hypertension, dietary indiscretion, arrhythmias, infections, or ischemic cardiac events. Each patient underwent a thorough physical examination including respiratory rate, heart rate, blood pressure, oxygen saturation, and signs of fluid overload such as crackles and peripheral edema.

Laboratory investigations performed at admission included complete blood count, serum urea, creatinine, electrolytes, cardiac biomarkers (Troponin I, NT-proBNP), and arterial blood gas analysis. Chest radiography was done in all patients, and echocardiography and ECG were performed when indicated to assess cardiac function and detect rhythm abnormalities. Severity scoring was done using the SOFA and APACHE II systems within 24 hours of presentation.

All patients received initial stabilization in the emergency department followed by individualized management according to their clinical status. Oxygen supplementation was administered via face mask or high-flow nasal cannula. Non-invasive ventilation (NIV) was initiated in cases of moderate to severe respiratory distress, and invasive mechanical ventilation was employed when NIV failed or the patient exhibited worsening gas exchange. Hemodynamic monitoring guided fluid management decisions.

Patients with evident fluid overload and stable cardiovascular parameters underwent emergency dialysis or ultrafiltration. Diuretics were used cautiously in those with residual renal function. Inotropic agents were initiated in cases of hypotension or cardiogenic shock. Continuous monitoring of vital signs, oxygen saturation, urine output, and neurological status was conducted throughout hospitalization. Repeat laboratory investigations and imaging were performed based on clinical need. SOFA and APACHE II scores were reassessed at 48 hours to evaluate disease progression or response to treatment.

The primary outcomes assessed in the study included in-hospital mortality, requirement for intensive care unit (ICU) admission, need for mechanical ventilation, and total length of hospital stay. The severity of illness was correlated with the SOFA and APACHE II scores recorded at admission and at 48 hours. Secondary outcomes included the predictive value of these scores for ICU requirement and mortality risk. The association between scoring systems and patient prognosis was analyzed statistically to determine their utility in guiding clinical decisions and improving outcomes in chronic dialysis patients presenting with APE.

Data were entered into Microsoft Excel and analyzed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation, and categorical variables as frequencies and percentages. The association between SOFA/APACHE II scores and

outcomes was assessed using the chi-square test, t-test, and logistic regression analysis. A p-value <0.05 was considered statistically significant.

RESULTS

The mean age was 58.4 ± 10.6 years, and 60% (n = 45) were males. The most common comorbidity was hypertension 65(86.7%), followed by diabetes mellitus 47(62.7%)**,** ischemic heart disease 23(30.7%), and congestive heart failure 18(24%)**.** The average duration on dialysis was 3.8 ± 2.1 years**.**

The leading cause of pulmonary edema was missed dialysis sessions (48%). Multiple etiological factors were identified in some cases. (Table 1)

Cause	Number of Patients (%)
Missed Dialysis	36 (48%)
Uncontrolled Hypertension	20 (26.7%)
Ischemic Cardiac Events (ACS)	14 (18.7%)
Arrhythmias	7 (9.3%)
Fluid Overload / Dietary Indiscretion	11 (14.7%)

Table 1: Precipitating Causes of Acute Pulmonary Edema

During hospitalization, 65.3% (n = 49) of patients required ICU admission, and 30.7% (n = 23) underwent invasive mechanical ventilation. Non-invasive ventilation (NIV) was utilized in 54.7% (n = 41)**.** Emergency dialysis or ultrafiltration was required in 77.3% (n = 58) of patients. Severity scores were calculated on admission. Patients who died had significantly higher SOFA and APACHE II scores compared to survivors. (Table 2) A strong positive correlation was observed between increasing scores and mortality. SOFA scores ≥8 and APACHE II scores ≥25 was significantly associated with poor outcomes.

Score	Survivors (n = 59)	Non-Survivors (n = 16)	p-value
SOFA Score (mean ± SD)	6.2 ± 2.1	9.5 ± 3.0	< 0.001
APACHE II Score (mean ± SD)	18.4 ± 4.2	26.3 ± 5.7	< 0.001

Table 2: Severity Scores – Survivors vs Non-Survivors

The overall in-hospital mortality rate was 21.3% (n = 16)**.** Mortality Based on SOFA and APACHE II Score was given in table 3. Mortality was high in patients with SOFA ≥ 8 and APACHE II ≥ 25. Among survivors, the mean hospital stay was 6.8 ± 2.3 days, compared to

4.2 ± 1.7 days in non-survivors. Patients with high severity scores had longer ICU stays and a higher likelihood of requiring mechanical.

Score Group	Mortality Rate (%)
SOFA < 8	9.6%
SOFA ≥ 8	52.0%
APACHE II < 25	7.3%
APACHE II ≥ 25	61.1%

Table 3: Mortality Based on SOFA and APACHE II Score Cutoffs

DISCUSSION

APE in individuals with ESRD undergoing maintenance hemodialysis constitutes a critical emergency that frequently necessitates intensive care intervention. This study examined 75 cases and offers significant insights into the etiologies, clinical progression, and consequences of APE in this at-risk population.

The mean age of the group was 58.4 years, with a minor male majority (60%). The significant incidence of comorbidities, especially hypertension (86.7%) and diabetes mellitus (62.7%), indicates the substantial burden of cardiovascular and metabolic illnesses that often coexist with ESRD. These comorbidities not only facilitate the etiology of pulmonary edema but also complicate care and influence outcomes. Ischemic heart disease (30.7%) and congestive heart failure (24%) were significant factors, highlighting the interconnectedness of cardiac and renal pathophysiology.

The predominant precipitating factor for APE was missed dialysis sessions (48%), an avoidable condition that underscores a significant deficiency in adherence to dialysis schedules. This conclusion aligns with prior evidence indicating that non-compliance with fluid elimination schedules results in volume overload and consequent lung congestion. Additional significant factors comprised uncontrolled hypertension (26.7%), acute coronary syndromes (18.7%), and arrhythmias (9.3%), suggesting that a multifaceted strategy is essential for both prevention and therapy. The occurrence of food indiscretion and fluid overload in 14.7% of cases underscores the necessity of patient education and nutritional counseling in the management of ESRD patients.

Jimnaz PA et al.[11] reported that the primary etiological factor of chronic kidney disease (CKD) was type 2 diabetes mellitus (T2 DM) at 56%, followed by chronic glomerulonephritis at 20%, drug-induced causes at 12%, with other factors comprising the remaining 8%.

The study by Halle MP et al.[12] identified hypertension (36.3%), chronic glomerulonephritis (25.5%), and diabetes mellitus (17.6%) as the primary etiological causes of chronic renal failure, with 38.2% of participants having a prior history of APE. Acute lung infection (26%), excessive interdialytic weight increase (25%), and improper dry weight prescription (23%) were the primary causes of APO. Hypertension (36.3%), chronic glomerulonephritis (25.5%), and diabetes mellitus (17.6%) were the primary etiological causes of chronic renal failure; 38.2% had a prior history of APE. Acute lung infection (26%), excessive interdialytic weight increase (25%), and improper dry weight prescription (23%) were the primary contributors to APE.

The severity of APE was significant, as seen by the elevated rates of ICU hospitalization (65.3%), non-invasive ventilation (54.7%), and invasive mechanical ventilation (30.7%). Emergency dialysis or ultrafiltration was necessary in more than three-quarters of patients (77.3%), highlighting the urgent requirement for immediate renal replacement therapy to alleviate fluid overload and diminish lung congestion.

Outcome analysis utilizing the SOFA and APACHE II scoring systems demonstrated a significant connection between elevated scores and heightened death rates. Non-survivors exhibited markedly higher SOFA values (9.5 vs. 6.2, $p < 0.001$) and APACHE II levels (26.3 vs. 18.4, $p < 0.001$). Mortality rates in patients with SOFA scores of 8 or higher (52%) and APACHE II scores of 25 or higher (61.1%) were significantly elevated, validating these thresholds as indicators of unfavorable prognosis. These findings coincide with previous research that corroborate the application of these scoring systems in critically sick ESRD patients for risk classification and prognostication.

In their study, Jimnaz PA et al.[11] noted that the mean APACHE II score was 25.5 ± 4, with only 4 patients evaluated using the SOFA score, which had a mean of 8.8 ± 2.5 in our study. No patients with high SOFA scores among sepsis patients had expired. The mortality rate was 8 percent. The study indicates that 100% of patients survived with an APACHE II score below 29, but 50% of patients succumbed with an APACHE II score over 34, with a significant P value of less than 0.001. Surviving patients had a mean APACHE II score of 24±3.4, while deceased patients had a mean APACHE II score of 32.9±2.5.

The overall in-hospital death rate was 21.3%, which, while alarming, is comparable to rates observed in analogous populations. The average hospital stay was higher for survivors (6.8 days) compared to non-survivors (4.2 days), likely indicating a more rapid clinical decline in fatal cases. Moreover, patients with increased severity scores had prolonged ICU admissions

and heightened instances of mechanical breathing, indicating the substantial demand for intensive care resources necessitated by this subgroup.

Halle MP et al.[12] observed that 60% of patients had a hospitalization duration of less than 4 days. Nine fatalities were documented, four of which were attributable to cardiac causes. Wang H et al.[13] demonstrated that the SOFA score was substantially correlated with both 28-day and 90-day mortality in AKI patients receiving CRRT, with adjusted hazard ratios (HRs) between 1.14 and 1.31 for 28-day mortality and 1.09 to 1.19 for 90-day mortality across three models. The APACHE II score demonstrated no significant correlation with death at any time point.

Recent investigations have elucidated the origins, clinical progression, and consequences of APO in patients undergoing chronic dialysis, especially within tertiary care environments. A recent review by Zoccali et al.[14] highlighted the prevalent under-recognition of subclinical pulmonary congestion in patients undergoing hemodialysis. The study utilized lung ultrasonography (LUS) to identify B-lines, revealing a robust, dose-dependent correlation between congestion and negative cardiovascular outcomes. The LUST trial further investigated ultrasound-guided decongestion, demonstrating a reduction in recurrent heart failure events, however it did not significantly affect mortality rates.

A retrospective study by Brunet P et al.[15] investigated chronic dialysis patients who were hospitalized to the ICU with APE. It found acute lung infections, fluid overload, and inaccuracies in dry-weight estimation as primary causes. Although hospitalizations were generally short, mortality rates were elevated, particularly among patients referred late from general wards, underscoring the necessity of prompt critical care referral.

A study conducted by Hasegawa et al.[16] investigated the impact of cardiovascular comorbidities and the time of hospital presentation on outcomes in maintenance hemodialysis patients with APE. The study revealed that early presentation and the lack of high-risk comorbidities correlated with improved survival rates. These studies indicate that the primary causes of APE in chronic dialysis patients are fluid overload, pulmonary infections, and inaccurate dry-weight targets.

CONCLUSION

APE is a common and serious complication in patients on chronic hemodialysis, frequently precipitated by missed dialysis sessions, fluid overload, and cardiovascular events. This study highlights the significant morbidity and mortality associated with such episodes, particularly in patients requiring ICU care and ventilatory support.

Higher SOFA and APACHE II scores at admission were strongly associated with poor outcomes, including increased risk of mechanical ventilation, prolonged hospitalization, and mortality. These scoring systems proved to be valuable tools for early risk stratification and prognostication in emergency settings.

Prompt recognition of precipitating factors, timely initiation of dialysis or ultrafiltration, and application of standardized severity scores can improve triage and guide critical care decisions. Strengthening patient education, dialysis compliance, and follow-up care may help reduce recurrence and improve long-term outcomes in this vulnerable population.

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CONFLICTS OF INTEREST:

There are no conflicts of interest

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