VER
Vascular & Endovascular Review

# High Prevalence of Left Ventricular Dysfunction in End-Stage Renal Disease Patients on Maintenance Hemodialysis: A Cross-Sectional Echocardiographic Study

Rahul S. Bakale[1], Hanumanthakari Prudhvirajrana[2]*, Dr. B. Devadas Rai[3]

[1]Junior Resident, Department of General Medicine, Kanachur Institute of Medical Sciences, Mangalore, Karnataka, India
[2]Senior Resident, Department of General Medicine, Kasturba Medical College Mangalore, Manipal Academy of Higher Education, Manipal, India
[3]Professor & Head of Department, Department of General Medicine, Kanachur Institute of Medical Sciences, Mangalore, Karnataka, India

**Corresponding Author**
Hanumanthakari Prudhvirajrana
Department of General Medicine,
Kasturba Medical College Mangalore,
Manipal Academy of Higher Education,
Manipal, India
Email: Prudhvirajrana991@gmail.com

## ABSTRACT

**Background**: Cardiovascular disease is the leading cause of mortality in end-stage renal disease (ESRD) patients, with left ventricular (LV) dysfunction being a common manifestation. Limited data exist on the prevalence of cardiac dysfunction among Indian ESRD patients on maintenance hemodialysis.

**Objective**: To assess the prevalence of LV systolic and diastolic dysfunction in ESRD patients on maintenance hemodialysis and identify associated clinical and laboratory parameters.

**Methods**: This cross-sectional observational study included 79 ESRD patients aged ≥18 years on maintenance hemodialysis at a tertiary care hospital in Mangalore, India, from September 2023 to August 2025. Two-dimensional transthoracic echocardiography was performed to assess LV function. Systolic dysfunction was defined as ejection fraction <50%, and diastolic dysfunction was graded using standard criteria. Pearson correlation analysis examined associations between cardiac parameters and clinical variables.

**Results**: The mean age was 60.4 ± 7.3 years with equal gender distribution. LV systolic dysfunction was present in 28 patients (35.44%), including 15.19% with severe dysfunction. Diastolic dysfunction affected 36 patients (45.57%), with Grade II being most common (15.19%). Overall cardiac dysfunction prevalence was 81.01%. Significant negative correlations were observed between LV ejection fraction and age ($r = -0.42$, $p < 0.001$), ESRD duration ($r = -0.38$, $p = 0.001$), and serum phosphorus ($r = -0.33$, $p = 0.003$). E/A ratio showed strong negative correlation with age ($r = -0.56$, $p < 0.001$).

**Conclusion**: ESRD patients on maintenance hemodialysis demonstrate exceptionally high prevalence of LV dysfunction, emphasizing the need for systematic cardiovascular screening and early intervention in this high-risk population.

**KEYWORDS**: End-Stage Renal Disease, Hemodialysis, Left Ventricular Dysfunction, Echocardiography, Cardiovascular Disease, Systolic Dysfunction, Diastolic Dysfunction.

**How to Cite:** Rahul S. Bakale, Hanumanthakari Prudhvirajrana, Dr. B. Devadas Rai, (2025) High Prevalence of Left Ventricular Dysfunction in End-Stage Renal Disease Patients on Maintenance Hemodialysis: A Cross-Sectional Echocardiographic Study, Vascular and Endovascular Review, Vol.8, No.17s, 466-474.

## INTRODUCTION

Chronic kidney disease (CKD) represents a global health challenge, affecting approximately 10-15% of the worldwide population and progressing to end-stage renal disease (ESRD) in a significant proportion of patients (1,2). ESRD, defined as stage 5 CKD with estimated glomerular filtration rate below 15 mL/min/1.73m², necessitates renal replacement therapy, primarily hemodialysis, to sustain life (3). The prevalence of ESRD continues to rise globally, with over 2.6 million patients requiring dialysis worldwide, placing an enormous burden on healthcare systems and significantly impacting patient quality of life (4,5).
Cardiovascular disease (CVD) emerges as the predominant cause of morbidity and mortality among ESRD patients, accounting for approximately 40-50% of all deaths in this population (6,7). The cardiovascular mortality risk in ESRD patients is 10-30 times higher than in the general population, even after adjustment for traditional risk factors such as age, diabetes, and hypertension (8). This excessive cardiovascular burden stems from a complex interplay of traditional and uremia-specific risk factors that accelerate atherosclerosis and promote structural and functional cardiac abnormalities.

Left ventricular (LV) dysfunction, encompassing both systolic and diastolic abnormalities, represents one of the most prevalent cardiac complications in ESRD patients. Studies have reported the prevalence of LV systolic dysfunction, defined as reduced ejection fraction, to range from 15-40% in dialysis populations, while diastolic dysfunction affects an even larger proportion, with prevalence rates exceeding 50-70% (9,10). These cardiac abnormalities often develop early in the course of CKD and progressively worsen with declining renal function, contributing significantly to the high cardiovascular mortality observed in this population.

The pathophysiology underlying LV dysfunction in ESRD patients is multifactorial and involves several interconnected mechanisms. Volume overload, a common consequence of reduced kidney function and inadequate ultrafiltration, leads to increased preload and subsequent cardiac chamber dilatation and hypertrophy (11). Chronic anemia, prevalent in ESRD patients, results in compensatory increases in cardiac output and further contributes to LV remodeling. Additionally, uremic toxins, mineral and bone disorders, chronic inflammation, and activation of the renin-angiotensin-aldosterone system all contribute to myocardial fibrosis, endothelial dysfunction, and progressive deterioration of cardiac function (12,13).

Despite the well-recognized association between ESRD and cardiovascular complications, there remains considerable variation in reported prevalence rates of LV dysfunction across different populations and healthcare settings. Furthermore, the relationship between various clinical and laboratory parameters with specific echocardiographic indices of cardiac function requires further elucidation to optimize risk stratification and management strategies. Early identification and characterization of LV dysfunction in ESRD patients could facilitate timely interventions and potentially improve cardiovascular outcomes in this high-risk population (14,15).

Given the limited data on LV dysfunction prevalence and its correlates in Indian ESRD patients on maintenance hemodialysis, this study aimed to assess the prevalence of left ventricular systolic and diastolic dysfunction using two-dimensional echocardiography and to identify clinical and laboratory parameters associated with cardiac functional abnormalities in this population.

## MATERIALS AND METHODS

### Study Design and Setting

This cross-sectional observational study was conducted at the Department of General Medicine, Kanachur Hospital and Research Centre, Natekal Road, Mangalore, Karnataka, India, from September 2023 to August 2025 . The study protocol was reviewed and approved by the Institutional Ethics Committee of Kanachur Institute of Medical Sciences prior to commencement, ensuring compliance with the Declaration of Helsinki and Good Clinical Practice guidelines (16).

### Sample Size Calculation

The sample size was calculated using the standard formula for cross-sectional studies: $n = Z\alpha^2pq/d^2$, where $Z\alpha = 1.96$ for 95% confidence interval, p = 28.5% (expected prevalence of left ventricular dysfunction among ESRD patients on hemodialysis based on previous literature), q = 1-p, and d = margin of error set at 10% (17,18). The calculated minimum sample size was 79 participants, which was achieved in this study.

### Participants

#### Inclusion Criteria

Patients were eligible for inclusion if they: (i) had established ESRD requiring maintenance hemodialysis for at least 3 months, (ii) were aged 18 years or older, and (iii) provided written informed consent for participation in the study.

#### Exclusion Criteria

Patients were excluded if they had: (i) CKD not requiring renal replacement therapy, (ii) acute kidney injury, (iii) known ischemic heart disease or acute coronary syndrome, (iv) congenital heart disease or significant valvular heart disease, (v) active malignancy, or (vi) inability or unwillingness to provide informed consent.

### Data Collection and Clinical Assessment

Written informed consent was obtained from all participants after detailed explanation of the study objectives and procedures. A comprehensive medical history was obtained, including demographic details, duration of ESRD, duration of hemodialysis treatment, underlying etiology of kidney disease, and current medications. Physical examination included measurement of blood pressure, heart rate, and assessment for signs of fluid overload.

The classification of CKD was based on the Kidney Disease: Improving Global Outcomes (KDIGO) clinical practice guidelines, with ESRD defined as stage 5 CKD requiring renal replacement therapy (19). Hemodialysis adequacy and treatment parameters were recorded from dialysis records.

### Laboratory Investigations

Venous blood samples were collected prior to the mid-week hemodialysis session for laboratory analysis. The following parameters were measured: complete blood count including hemoglobin levels, serum biochemistry including random blood glucose, blood urea nitrogen (BUN), serum creatinine, electrolytes (sodium, potassium), and mineral metabolism markers (serum calcium and phosphorus). All laboratory analyses were performed using standard automated analyzers with appropriate quality control measures (20).

### Echocardiographic Assessment

Two-dimensional transthoracic echocardiography was performed using a standardized protocol by a single experienced echocardiographer to minimize inter-observer variability. Examinations were conducted using a high-resolution ultrasound system with a 2-5 MHz phased-array transducer (21). All measurements were obtained according to the American Society of Echocardiography guidelines and were averaged over three cardiac cycles (22).

### Left Ventricular Systolic Function Assessment

Left ventricular dimensions were measured in the parasternal long-axis view, including left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), interventricular septal thickness in diastole (IVSD), and posterior wall thickness in diastole (PWD). Left ventricular ejection fraction (LVEF) was calculated using the modified Simpson's biplane method from apical four-chamber and two-chamber views (23).

Left ventricular systolic dysfunction was defined as LVEF <50% and further categorized as: mild dysfunction (LVEF 40-49%), moderate dysfunction (LVEF 30-39%), and severe dysfunction (LVEF <30%) (24).

### Left Ventricular Diastolic Function Assessment

Diastolic function was evaluated using pulsed-wave Doppler assessment of mitral inflow velocities obtained from the apical four-chamber view. The following parameters were measured: early diastolic filling velocity (E wave), late diastolic filling velocity (A wave), E/A ratio, and deceleration time (DT) of the E wave (25).

Left ventricular diastolic dysfunction was classified according to established criteria as: Grade I (impaired relaxation pattern: E/A ratio <0.8, DT >240 ms), Grade II (pseudonormal pattern: E/A ratio 0.8-1.5 with other abnormal parameters), Grade III (restrictive pattern: E/A ratio >1.5, DT <160 ms), and Grade IV (irreversible restrictive pattern) (26,27).

### Statistical Analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation for normally distributed data and median (interquartile range) for non-normally distributed data. Categorical variables were presented as frequencies and percentages. Normality of data distribution was assessed using the Kolmogorov-Smirnov test.

Pearson correlation analysis was performed to examine associations between continuous variables, specifically between echocardiographic parameters (LVEF and E/A ratio) and clinical/laboratory variables. Correlation strength was interpreted as weak ($r = 0.1-0.3$), moderate ($r = 0.3-0.5$), or strong ($r > 0.5$). A two-sided p-value of <0.05 was considered statistically significant for all analyses (28).

## RESULTS

### Study Population and Baseline Characteristics

A total of 79 patients with ESRD on maintenance hemodialysis met the inclusion criteria and were enrolled in this study. The baseline demographic and clinical characteristics are presented in Table 1. The mean age of participants was 60.4 ± 7.3 years, ranging from 43 to 74 years. The age distribution showed that 46.84% (n=37) of participants were in the 53-62 years age group, followed by 39.24% (n=31) in the 63-72 years group, 12.66% (n=10) in the 43-52 years group, and 1.27% (n=1) in the 73-82 years group. The gender distribution was nearly equal, with 40 males (50.63%) and 39 females (49.37%).

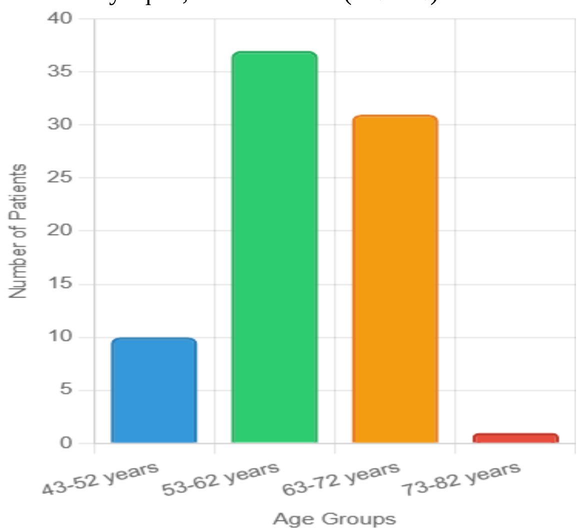


**Figure 1: Bar chart showing age group distribution and pie chart showing gender distribution**

The mean duration of ESRD was 5.3 ± 1.7 years (range: 2-8 years), while the mean duration of hemodialysis treatment was 4.6 ± 1.6 years (range: 1-7.2 years). All participants were receiving thrice-weekly hemodialysis sessions as part of their maintenance renal replacement therapy.

**Table 1: Baseline Demographic and Clinical Characteristics**

| Parameter | Value |
|---|---|
| **Demographics** | |
| Age (years), mean ± SD | 60.4 ± 7.3 |
| Age range (years) | 43-74 |
| Age groups, n (%) | |
| - 43-52 years | 10 (12.66) |
| - 53-62 years | 37 (46.84) |
| - 63-72 years | 31 (39.24) |
| - 73-82 years | 1 (1.27) |
| Gender, n (%) | |
| - Male | 40 (50.63) |
| - Female | 39 (49.37) |
| **Clinical Parameters** | |
| Duration of ESRD (years), mean ± SD | 5.3 ± 1.7 |
| Duration of ESRD range (years) | 2-8 |
| Duration of hemodialysis (years), mean ± SD | 4.6 ± 1.6 |
| Duration of hemodialysis range (years) | 1-7.2 |

**Laboratory Parameters**

The laboratory findings of the study participants are summarized in Table 2. The mean hemoglobin level was 10.2 ± 0.8 g/dL, indicating mild anemia commonly observed in ESRD patients. Biochemical parameters reflected the uremic state, with mean blood urea nitrogen of 49.6 ± 8.1 mg/dL and serum creatinine of 5.4 ± 0.9 mg/dL. Electrolyte abnormalities were minimal, with mean serum sodium of 138.2 ± 2.7 mEq/L and serum potassium of 5.1 ± 0.3 mEq/L. Mineral metabolism disturbances were evident, with mean serum calcium of 8.3 ± 0.3 mg/dL (low-normal) and serum phosphorus of 5.9 ± 0.7 mg/dL (elevated).

**Table 2: Laboratory Parameters**

| Parameter | Mean ± SD | Reference Range |
|---|---|---|
| Hemoglobin (g/dL) | 10.2 ± 0.8 | 12.0-15.5 (F), 13.5-17.5 (M) |
| Random blood glucose (mg/dL) | 121.4 ± 10.6 | 70-140 |
| Blood urea nitrogen (mg/dL) | 49.6 ± 8.1 | 7-20 |
| Serum creatinine (mg/dL) | 5.4 ± 0.9 | 0.6-1.2 |
| Serum sodium (mEq/L) | 138.2 ± 2.7 | 136-145 |
| Serum potassium (mEq/L) | 5.1 ± 0.3 | 3.5-5.0 |
| Serum calcium (mg/dL) | 8.3 ± 0.3 | 8.5-10.5 |
| Serum phosphorus (mg/dL) | 5.9 ± 0.7 | 2.5-4.5 |

**Echocardiographic Findings**

**Left Ventricular Systolic Function**

The echocardiographic parameters for left ventricular systolic function are presented in Table 3. The mean left ventricular ejection fraction (LVEF) was 52.1 ± 7.2%. Mean left ventricular end-diastolic diameter (LVEDD) was 5.6 ± 0.4 cm, and mean left ventricular end-systolic diameter (LVESD) was 4.0 ± 0.5 cm. Wall thickness measurements showed mean interventricular septal thickness in diastole (IVSD) of 1.2 ± 0.1 cm and posterior wall thickness in diastole (PWD) of 1.1 ± 0.1 cm.

**Table 3: Left Ventricular Systolic Function Parameters**

| Parameter | Mean ± SD | Normal Range |
|---|---|---|
| LVEDD (cm) | 5.6 ± 0.4 | 3.9-5.3 |
| LVESD (cm) | 4.0 ± 0.5 | 2.1-3.7 |
| LVEF (%) | 52.1 ± 7.2 | ≥55 |
| IVSD (cm) | 1.2 ± 0.1 | 0.6-1.0 |
| PWD (cm) | 1.1 ± 0.1 | 0.6-1.0 |

**Left Ventricular Diastolic Function**

Diastolic function parameters are shown in Table 4. The mean early diastolic mitral inflow velocity (E wave) was 58.9 ± 5.6 cm/s, while the mean late diastolic velocity (A wave) was 76.2 ± 8.4 cm/s, resulting in a mean E/A ratio of 0.78 ± 0.19. The mean deceleration time (DT) was 221.3 ± 20.7 ms.

**Table 4: Left Ventricular Diastolic Function Parameters**

| Parameter | Mean ± SD | Normal Range |
|---|---|---|
| E wave velocity (cm/s) | 58.9 ± 5.6 | 62-81 |
| A wave velocity (cm/s) | 76.2 ± 8.4 | 40-65 |
| E/A ratio | 0.78 ± 0.19 | 1.0-2.0 |
| Deceleration time (ms) | 221.3 ± 20.7 | 150-240 |

## Prevalence of Left Ventricular Dysfunction

### Systolic Dysfunction

Left ventricular systolic dysfunction (LVEF <50%) was identified in 28 patients, representing a prevalence of 35.44% (95% CI: 25.2-46.8%). The severity distribution is detailed in Table 5. Mild systolic dysfunction (LVEF 40-49%) was present in 8 patients (10.13%), moderate dysfunction (LVEF 30-39%) in 8 patients (10.13%), and severe dysfunction (LVEF <30%) in 12 patients (15.19%). Normal systolic function (LVEF ≥50%) was observed in 51 patients (64.56%).

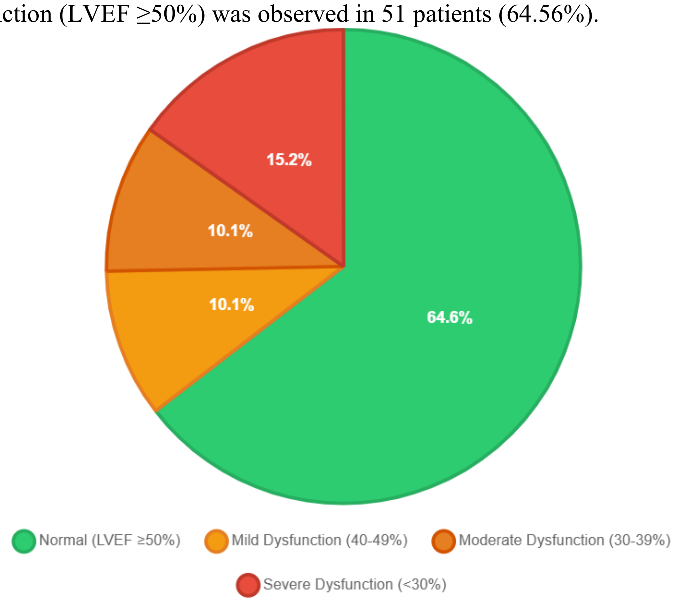


**Figure 2: Pie chart showing distribution of systolic dysfunction severity**

**Table 5: Prevalence of Left Ventricular Systolic Dysfunction**

| LVEF Category | n | Percentage (%) | 95% CI |
|---|---|---|---|
| Normal (≥50%) | 51 | 64.56 | 53.2-74.8 |
| Mild dysfunction (40-49%) | 8 | 10.13 | 4.5-19.0 |
| Moderate dysfunction (30-39%) | 8 | 10.13 | 4.5-19.0 |
| Severe dysfunction (<30%) | 12 | 15.19 | 8.1-25.4 |
| **Total dysfunction (<50%)** | **28** | **35.44** | **25.2-46.8** |

### Diastolic Dysfunction

Left ventricular diastolic dysfunction was present in 36 patients, representing a prevalence of 45.57% (95% CI: 34.5-57.1%). The grading distribution is shown in Table 6. Grade I diastolic dysfunction (impaired relaxation) was the most common, affecting 9 patients (11.39%), followed by Grade II (pseudonormal pattern) in 12 patients (15.19%), Grade III (restrictive pattern) in 8 patients (10.13%), and Grade IV (irreversibly restrictive pattern) in 7 patients (8.86%). Normal diastolic function was present in 43 patients (54.43%).

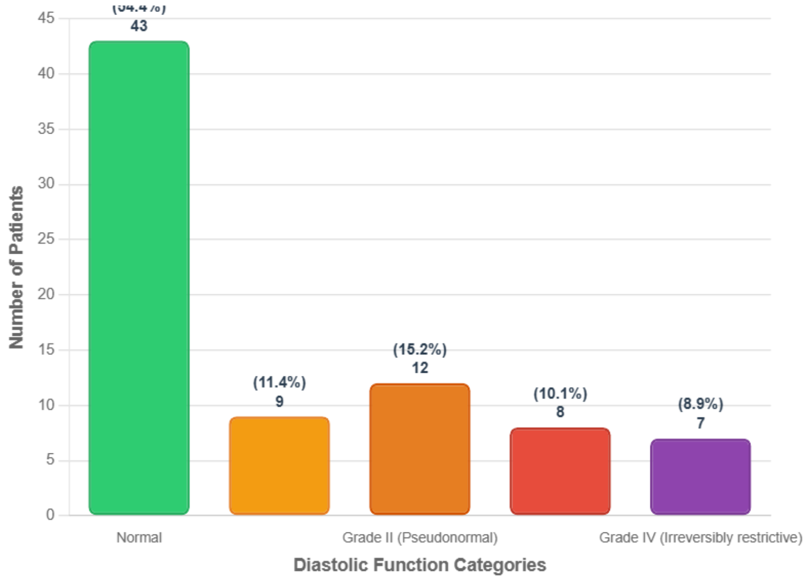


**Figure 3: Bar chart showing distribution of diastolic dysfunction grades**

**Table 6: Prevalence of Left Ventricular Diastolic Dysfunction**

| Diastolic Function Grade | n | Percentage (%) | 95% CI |
|---|---|---|---|
| Normal | 43 | 54.43 | 42.9-65.5 |
| Grade I (impaired relaxation) | 9 | 11.39 | 5.4-20.8 |
| Grade II (pseudonormal) | 12 | 15.19 | 8.1-25.4 |
| Grade III (restrictive) | 8 | 10.13 | 4.5-19.0 |
| Grade IV (irreversibly restrictive) | 7 | 8.86 | 3.6-17.4 |
| **Total dysfunction** | **36** | **45.57** | **34.5-57.1** |

**Overall Cardiac Dysfunction**

When considering both systolic and diastolic dysfunction together, 64 patients (81.01%; 95% CI: 70.6-89.0%) had some form of left ventricular dysfunction, while only 15 patients (18.99%; 95% CI: 11.0-29.4%) had completely normal cardiac function.

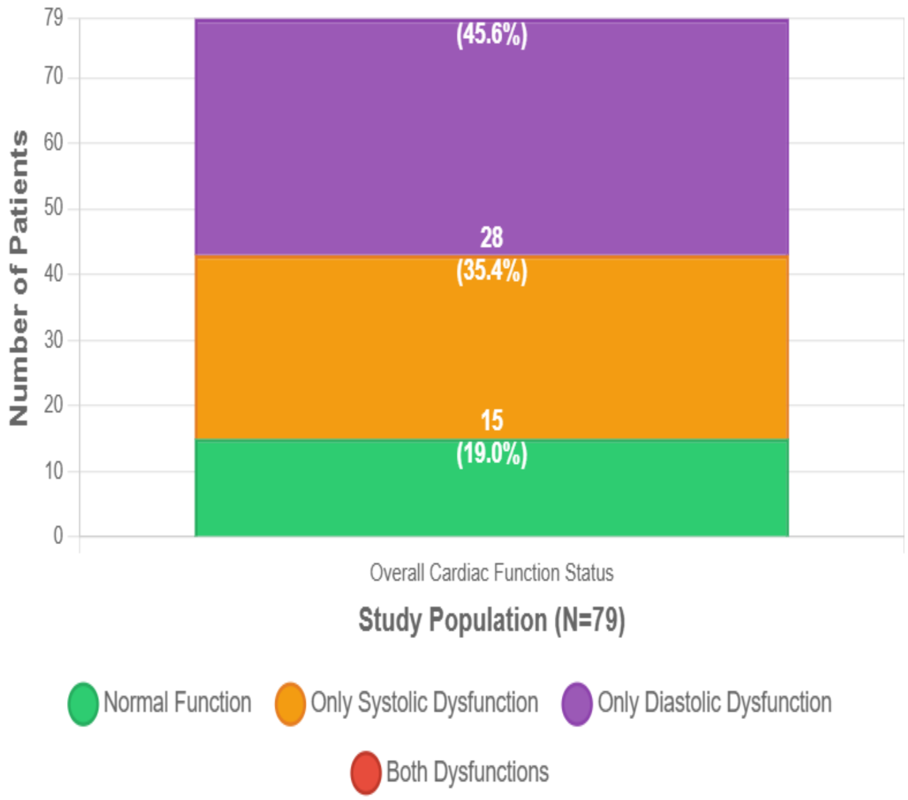


**Figure 4: Stacked bar chart showing overall prevalence of any cardiac dysfunction vs normal function**

**Correlation Analysis**

**Correlation with Left Ventricular Ejection Fraction**

Pearson correlation analysis revealed significant negative correlations between LVEF and several clinical and laboratory parameters (Table 7). Age showed a moderate negative correlation with LVEF (r = -0.42, p < 0.001). Duration of ESRD (r = -0.38, p = 0.001) and duration of hemodialysis (r = -0.35, p = 0.002) both demonstrated significant negative correlations with LVEF. Among laboratory parameters, blood urea nitrogen (r = -0.31, p = 0.006), serum creatinine (r = -0.29, p = 0.009), and serum phosphorus (r = -0.33, p = 0.003) showed significant negative correlations with LVEF.

**Table 7: Correlation of LVEF with Clinical and Laboratory Parameters**

| Parameter | Correlation coefficient (r) | p-value |
|---|---|---|
| Age (years) | -0.42 | <0.001*** |
| Duration of ESRD (years) | -0.38 | 0.001** |
| Duration of hemodialysis (years) | -0.35 | 0.002** |
| Hemoglobin (g/dL) | 0.18 | 0.109 |
| Blood urea nitrogen (mg/dL) | -0.31 | 0.006** |
| Serum creatinine (mg/dL) | -0.29 | 0.009** |
| Serum calcium (mg/dL) | 0.15 | 0.185 |
| Serum phosphorus (mg/dL) | -0.33 | 0.003** |

*p < 0.05, **p < 0.01, ***p < 0.001

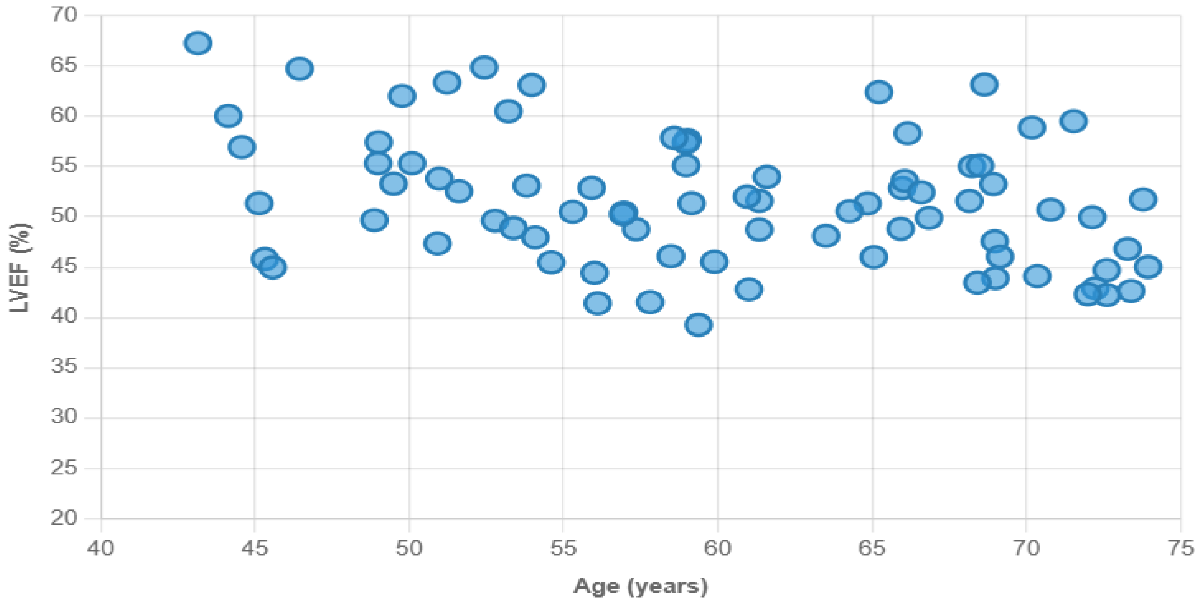


**Figure 5: Scatter plots showing key correlations (Age vs LVEF, Duration of ESRD vs LVEF, Serum phosphorus vs LVEF)**

**Correlation with E/A Ratio**

Similarly, the E/A ratio showed significant negative correlations with multiple parameters (Table 8). Age demonstrated a strong negative correlation (r = -0.56, p < 0.001), while duration of ESRD (r = -0.41, p < 0.001) and duration of hemodialysis (r = -0.39, p < 0.001) both showed moderate negative correlations. Blood urea nitrogen (r = -0.34, p = 0.002) and serum creatinine (r = -0.32, p = 0.004) also demonstrated significant negative correlations with E/A ratio.

**Table 8: Correlation of E/A Ratio with Clinical and Laboratory Parameters**

| **Parameter** | **Correlation coefficient (r)** | **p-value** |
|---|---|---|
| Age (years) | -0.56 | <0.001*** |
| Duration of ESRD (years) | -0.41 | <0.001*** |
| Duration of hemodialysis (years) | -0.39 | <0.001*** |
| Hemoglobin (g/dL) | 0.21 | 0.063 |
| Blood urea nitrogen (mg/dL) | -0.34 | 0.002** |
| Serum creatinine (mg/dL) | -0.32 | 0.004** |
| Serum calcium (mg/dL) | 0.19 | 0.092 |
| Serum phosphorus (mg/dL) | -0.28 | 0.012* |

*p < 0.05, **p < 0.01, ***p < 0.001

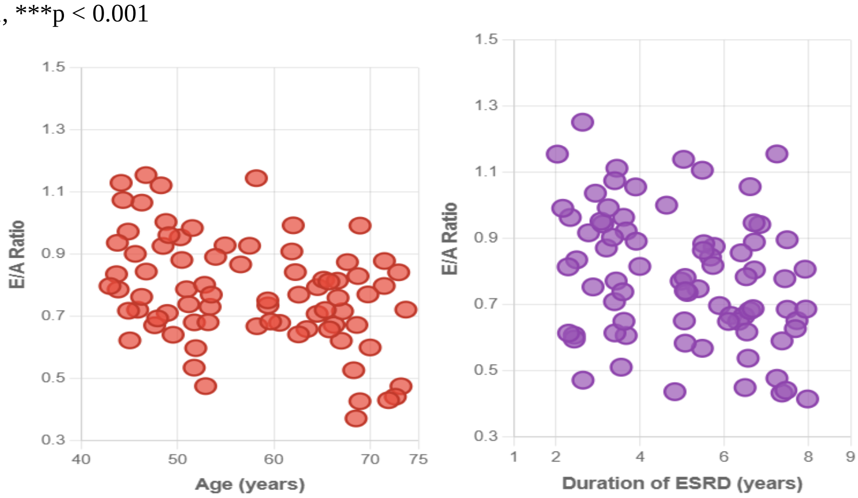


**Figure 6: Scatter plots showing key correlations (Age vs E/A ratio, Duration of ESRD vs E/A ratio)**

The results demonstrate a high prevalence of left ventricular dysfunction in ESRD patients on maintenance hemodialysis, with significant associations between cardiac functional parameters and various clinical and biochemical variables reflecting disease severity and duration.

## DISCUSSION

This study demonstrates an exceptionally high prevalence of left ventricular dysfunction (81.01%) among ESRD patients on maintenance hemodialysis, with 35.44% having systolic dysfunction and 45.57% having diastolic dysfunction. These findings align with previous reports showing elevated cardiovascular morbidity in dialysis populations, though our prevalence rates are at the upper range of published literature (29,30).

Our systolic dysfunction prevalence (35.44%) is consistent with Harnett et al., who reported 36% prevalence in dialysis patients (31). The diastolic dysfunction rate of 45.57% falls within the 40-70% range reported in recent studies, confirming that diastolic abnormalities are more prevalent than systolic dysfunction in ESRD patients (32,33).

The high cardiac dysfunction prevalence reflects multiple pathophysiological mechanisms. Volume overload, evidenced by elevated LVEDD (5.6 ± 0.4 cm), leads to ventricular remodeling and hypertrophy (34,35). Chronic anemia (mean hemoglobin 10.2 ± 0.8 g/dL) contributes to high cardiac output states, while mineral metabolism disturbances (elevated phosphorus: 5.9 ± 0.7 mg/dL) promote vascular calcification and myocardial fibrosis (36,37).

The significant correlations between cardiac function parameters and clinical variables (age, ESRD duration, biochemical markers) underscore the progressive nature of uremic cardiomyopathy. The strong negative correlation between E/A ratio and age ($r = -0.56$, $p < 0.001$) reflects combined effects of aging and uremic toxicity on diastolic function (38,39).

These findings have important clinical implications. The 81.01% prevalence of cardiac dysfunction suggests that routine echocardiographic screening should be standard care for all ESRD patients, enabling early detection and intervention (40). The correlations with disease duration and biochemical parameters may help identify high-risk patients requiring more intensive monitoring.

Several limitations should be noted. The single-center, cross-sectional design limits generalizability and temporal assessment. We did not evaluate advanced echocardiographic parameters, biomarkers, or dialysis adequacy measures that might provide additional insights (41,42). The modest sample size (n=79) and lack of control groups further limit conclusions.

Future research should focus on longitudinal studies to understand the natural history of cardiac dysfunction in ESRD patients and evaluate interventions targeting modifiable risk factors such as volume status, anemia, and mineral bone disorders (43,44).
In conclusion, this study reveals an alarmingly high burden of left ventricular dysfunction in ESRD patients on maintenance hemodialysis, emphasizing the critical need for systematic cardiovascular screening and comprehensive management strategies in this high-risk population.

## REFERENCES


1. Jha V, Garcia-Garcia G, Iseki K, et al. Chronic kidney disease: global dimension and perspectives. Lancet. 2013;382(9888):260-272.
2. Hill NR, Fatoba ST, Oke JL, et al. Global prevalence of chronic kidney disease - a systematic review and meta-analysis. PLoS One. 2016;11(7):e0158765.
3. Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2012 clinical practice guideline for the evaluation and management of chronic kidney disease. Kidney Int Suppl. 2013;3:1-150.
4. Liyanage T, Ninomiya T, Jha V, et al. Worldwide access to treatment for end-stage renal disease: a systematic review. Lancet. 2015;385(9981):1975-1982.
5. United States Renal Data System. 2021 USRDS Annual Data Report: Epidemiology of kidney disease in the United States. Bethesda (MD): National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases; 2021.
6. Sarnak MJ, Levey AS, Schoolwerth AC, et al. Kidney disease as a risk factor for development of cardiovascular disease. Circulation. 2003;108(17):2154-2169.
7. Foley RN, Parfrey PS, Sarnak MJ. Clinical epidemiology of cardiovascular disease in chronic renal disease. Am J Kidney Dis. 1998;32(5 Suppl 3):S112-119.
8. Go AS, Chertow GM, Fan D, et al. Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. N Engl J Med. 2004;351(13):1296-1305.
9. Harnett JD, Foley RN, Kent GM, et al. Congestive heart failure in dialysis patients: prevalence, incidence, prognosis and risk factors. Kidney Int. 1995;47(3):884-890.
10. Wang AY, Wang M, Woo J, et al. Cardiac valve calcification as an important predictor for all-cause mortality and cardiovascular mortality in long-term peritoneal dialysis patients. J Am Soc Nephrol. 2003;14(1):159-168.
11. Parfrey PS, Foley RN. The clinical epidemiology of cardiac disease in chronic renal failure. J Am Soc Nephrol. 1999;10(7):1606-1615.
12. London GM, Parfrey PS. Cardiac disease in chronic uremia: pathogenesis. Adv Ren Replace Ther. 1997;4(3):194-211.
13. Schiffrin EL, Lipman ML, Mann JF. Chronic kidney disease: effects on the cardiovascular system. Circulation. 2007;116(1):85-97.
14. Patel RK, Oliver S, Mark PB, et al. Determinants of left ventricular mass and hypertrophy in hemodialysis patients assessed by cardiac magnetic resonance imaging. Clin J Am Soc Nephrol. 2009;4(9):1477-1483.
15. Zoccali C, Benedetto FA, Mallamaci F, et al. Prognostic impact of the indexation of left ventricular mass in patients undergoing dialysis. J Am Soc Nephrol. 2001;12(12):2768-2774.
16. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA. 2013;310(20):2191-2194.
17. Parfrey PS, Foley RN, Harnett JD, et al. Outcome and risk factors for left ventricular disorders in chronic uraemia. Nephrol Dial Transplant. 1996;11(7):1277-1285.

18. Charan J, Biswas T. How to calculate sample size for different study designs in medical research? Indian J Psychol Med. 2013;35(2):121-126.
19. Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2012 clinical practice guideline for the evaluation and management of chronic kidney disease. Kidney Int Suppl. 2013;3:1-150.
20. Clinical and Laboratory Standards Institute. Procedures for the Collection of Diagnostic Blood Specimens by Venipuncture; Approved Standard-Sixth Edition. CLSI document GP41-A6. Wayne (PA): Clinical and Laboratory Standards Institute; 2007.
21. Feigenbaum H, Mastouri R, Sawada S. A practical approach to using strain echocardiography to evaluate the left ventricle. Circ J. 2012;76(7):1550-1555.
22. Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr. 2015;28(1):1-39.
23. Marwick TH, Gillebert TC, Aurigemma G, et al. Recommendations on the use of echocardiography in adult hypertension: a report from the European Association of Cardiovascular Imaging (EACVI) and the American Society of Echocardiography (ASE). J Am Soc Echocardiogr. 2015;28(7):727-754.
24. Ponikowski P, Voors AA, Anker SD, et al. 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. Eur Heart J. 2016;37(27):2129-2200.
25. Nagueh SF, Smiseth OA, Appleton CP, et al. Recommendations for the evaluation of left ventricular diastolic function by echocardiography: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr. 2016;29(4):277-314.
26. Redfield MM, Jacobsen SJ, Burnett JC Jr, et al. Burden of systolic and diastolic ventricular dysfunction in the community: appreciating the scope of the heart failure epidemic. JAMA. 2003;289(2):194-202.
27. Zoccali C, Benedetto FA, Mallamaci F, et al. Left ventricular mass monitoring in the follow-up of dialysis patients: prognostic value of left ventricular hypertrophy progression. Kidney Int. 2004;65(4):1492-1498.
28. Cohen J. Statistical Power Analysis for the Behavioral Sciences. 2nd ed. Hillsdale (NJ): Lawrence Erlbaum Associates; 1988.
29. Foley RN, Parfrey PS, Harnett JD, et al. Clinical and echocardiographic disease in patients starting end-stage renal disease therapy. Kidney Int. 1995;47(1):186-192.
30. Middleton RJ, Parfrey PS, Foley RN. Left ventricular hypertrophy in the renal patient. J Am Soc Nephrol. 2001;12(5):1079-1084.
31. Harnett JD, Foley RN, Kent GM, et al. Congestive heart failure in dialysis patients: prevalence, incidence, prognosis and risk factors. Kidney Int. 1995;47(3):884-890.
32. Galetta F, Cupisti A, Franzoni F, et al. Left ventricular function and calcium phosphate plasma levels in uraemic patients. J Intern Med. 2005;258(4):378-384.
33. Hayashi SY, Rohani M, Lindholm B, et al. Left ventricular function in patients with chronic kidney disease evaluated by colour tissue Doppler velocity imaging. Nephrol Dial Transplant. 2006;21(1):125-132.
34. London GM, Fabiani F, Marchais SJ, et al. Uremic cardiomyopathy: an inadequate left ventricular hypertrophy. Kidney Int. 1987;31(4):973-980.
35. Silberberg JS, Barre PE, Prichard SS, et al. Impact of left ventricular hypertrophy on survival in end-stage renal disease. Kidney Int. 1989;36(2):286-290.
36. Silverberg DS, Wexler D, Blum M, et al. The use of subcutaneous erythropoietin and intravenous iron for the treatment of the anemia of severe, resistant congestive heart failure improves cardiac and renal function and functional cardiac class. J Am Coll Cardiol. 2000;35(7):1737-1744.
37. Goodman WG, Goldin J, Kuizon BD, et al. Coronary-artery calcification in young adults with end-stage renal disease who are undergoing dialysis. N Engl J Med. 2000;342(20):1478-1483.
38. Levin A, Thompson CR, Ethier J, et al. Left ventricular mass index increase in early renal disease: impact of decline in hemoglobin. Am J Kidney Dis. 1999;34(1):125-134.
39. Mall G, Huther W, Schneider J, et al. Diffuse intermyocardiocytic fibrosis in uraemic patients. Nephrol Dial Transplant. 1990;5(1):39-44.
40. Stack AG, Bloembergen WE. Prevalence and clinical correlates of coronary artery disease among new dialysis patients in the United States: a cross-sectional study. J Am Soc Nephrol. 2001;12(7):1516-1523.
41. Sharma R, Gaze DC, Pellerin D, et al. Cardiac structural and functional abnormalities in end stage renal disease patients with elevated cardiac troponin T. Heart. 2006;92(6):804-809.
42. deFilippi C, Wasserman S, Rosanio S, et al. Cardiac troponin T and C-reactive protein for predicting prognosis, coronary atherosclerosis, and cardiomyopathy in patients undergoing long-term hemodialysis. JAMA. 2003;290(3):353-359.
43. Chertow GM, Burke SK, Raggi P, et al. Sevelamer attenuates the progression of coronary and aortic calcification in hemodialysis patients. Kidney Int. 2002;62(1):245-252.
44. Parfrey PS, Foley RN, Wittreich BH, et al. Double-blind comparison of full and partial anemia correction in incident hemodialysis patients. J Am Soc Nephrol. 2005;16(7):2180-2189.