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Original Article

Echocardiographic Assessment of Left Ventricular Hypertrophy in Chronic Kidney Disease Patients: Association with Renal Dysfunction Severity and Cardiac Remodeling

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ABSTRACT

Background: Chronic kidney disease (CKD) is strongly associated with cardiovascular complications, particularly left ventricular hypertrophy (LVH), which is an important predictor of cardiovascular morbidity and mortality. This study evaluated the prevalence of LVH among CKD patients using echocardiography.

Methods: This cross-sectional observational study included 100 CKD patients aged 18–70 years with estimated glomerular filtration rate (eGFR) <60 ml/min/1.73 m². Echocardiographic assessment was performed using two-dimensional and M-mode echocardiography to evaluate ventricular wall thickness, left ventricular dimensions, and ejection fraction.

Results: Among the participants, 58% were male and 42% were female, with a mean age of 53.4 ± 11.2 years. LVH was present in 66% of patients and increased progressively with CKD severity, reaching 83% in Stage V CKD patients. Left ventricular systolic dysfunction was observed in 52% of patients.

Conclusion: LVH is highly prevalent among CKD patients and is significantly associated with worsening renal dysfunction. Echocardiography is an effective non-invasive modality for early detection of cardiovascular abnormalities in CKD patients.

Keywords: Chronic kidney disease; Left ventricular hypertrophy; Echocardiography; Cardiac remodeling; Cardiovascular risk; eGFR

Introduction:

Chronic kidney disease (CKD) is a progressive and irreversible deterioration of renal function characterized by structural or functional kidney abnormalities persisting for more than three months [1]. CKD has emerged as a major public health concern worldwide because of its increasing prevalence, high healthcare burden, and association with adverse cardiovascular outcomes. According to global epidemiological estimates, approximately 10–13% of the adult population is affected by CKD, with prevalence continuing to rise due to increasing rates of diabetes mellitus, hypertension, obesity, and aging populations [2]. Cardiovascular disease remains the leading cause of morbidity and mortality among CKD patients, accounting for nearly half of all deaths in advanced renal disease [3]. The risk of cardiovascular mortality in CKD patients is substantially higher than that of progression to end-stage renal disease (ESRD), particularly in elderly individuals and patients with multiple comorbidities [4]. The pathophysiological relationship between renal dysfunction and cardiovascular abnormalities has resulted in the concept of cardiorenal syndrome, wherein impairment of one organ system adversely affects the other [5].

Left ventricular hypertrophy (LVH) is one of the most common structural cardiac abnormalities observed in CKD patients [6]. LVH represents an adaptive myocardial response to chronic pressure and volume overload. Persistent systemic hypertension increases afterload and contributes to concentric hypertrophy, while anemia, fluid retention, and arteriovenous shunting increase preload and promote eccentric hypertrophy [7]. Additional mechanisms such as oxidative stress, chronic inflammation, endothelial dysfunction, activation of the renin–angiotensin–aldosterone system (RAAS), sympathetic overactivity, and vascular calcification contribute to myocardial fibrosis and ventricular remodeling [8].

The prevalence of LVH increases progressively with worsening renal dysfunction and is particularly high among patients receiving dialysis therapy [9]. Previous studies have demonstrated that LVH is an independent predictor of cardiovascular morbidity and mortality in CKD patients, contributing to heart failure, arrhythmias, ischemic heart disease, and sudden cardiac death [10].

Echocardiography is widely regarded as the cornerstone imaging modality for evaluating cardiac morphology and function in CKD patients because of its accessibility, reproducibility, and non-invasive nature [11]. Two-dimensional and M-mode echocardiography provide accurate assessment of ventricular wall thickness, chamber dimensions, left ventricular mass, and systolic function. Early identification of structural cardiac abnormalities may facilitate timely intervention and improve long-term clinical outcomes.

Despite the increasing burden of CKD-associated cardiovascular disease, limited data are available regarding the prevalence and severity of LVH among CKD patients in the Indian population. Therefore, the present study was conducted to evaluate echocardiographic evidence of LVH among CKD patients and determine its association with CKD severity.

Materials and Methods

Study Design and Setting: This hospital-based cross-sectional observational study was conducted in the Department of Cardiology of a tertiary care teaching hospital between January 2025 and April 2026.

Study Population: A total of 100 patients diagnosed with chronic kidney disease were enrolled in the study using convenience sampling.

Inclusion Criteria

1. Patients aged between 18 and 70 years
2. Diagnosed cases of chronic kidney disease with eGFR <60 ml/min/1.73 m² for more than three months
3. Patients willing to provide informed consent

Exclusion Criteria

1. Congenital heart disease
2. Significant valvular heart disease
3. Acute myocardial infarction or acute coronary syndrome
4. Severe chronic pulmonary disease
5. Chronic liver disease or malignancy
6. Patients with inadequate echocardiographic windows

Clinical Evaluation:

Detailed demographic and clinical information including age, sex, duration of CKD, hypertension, diabetes mellitus, smoking history, and medication use were recorded using a structured proforma. Blood pressure was measured according to standard clinical guidelines.

Laboratory Investigations:

Laboratory investigations included: Serum creatinine, Blood urea, Hemoglobin, Serum electrolytes, Estimated glomerular filtration rate (eGFR). CKD staging was performed according to Kidney Disease Improving Global Outcomes (KDIGO) guidelines [1].

Echocardiographic Assessment:

Two-dimensional and M-mode transthoracic echocardiography was performed using a standardized echocardiography machine by an experienced cardiologist. Measurements were obtained according to American Society of Echocardiography recommendations [12]. Measurements taken were averaged over 3 cardiac cycles, and the LV measurements taken include inter ventricular septal thickness at end diastole (IVSTd), posterior wall thickness at end diastole (PWTd), the left ventricular internal diameter in diastole (LVIDD), and left ventricular internal diameter in systole (LVIDS). Teichholz's formula was used to calculate LV systolic function. Left ventricular mass (LVM) was calculated using the formula: LVM = 0.8 [1.04 (IVSTd + LVIDD + PWTd) 3 − (LVIDd)3] + 0.6g.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 21. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. Associations between CKD stages and echocardiographic findings were assessed using Chi-square test and one-way ANOVA where appropriate. A p-value <0.05 was considered statistically significant.

Results

Demographic Characteristics:

A total of 100 patients diagnosed with chronic kidney disease (CKD) were included in the present study. Among the study participants, 58 (58%) were male and 42 (42%) were female, demonstrating a slight male predominance. The mean age of the study population was 53.4 ± 11.2 years, with the majority of patients belonging to the 49–58 years age group, indicating a higher burden of CKD and cardiovascular involvement among middle-aged and elderly individuals. Comorbid conditions commonly associated with CKD were highly prevalent in the study population. Hypertension was observed in 72% of patients and represented the most common associated risk factor. Diabetes mellitus was present in 46% of cases, while anemia was identified in 68% of patients. The high prevalence of anemia and hypertension may have contributed significantly to adverse cardiac remodeling and development of left ventricular hypertrophy (LVH) (Table-1).

Variable	Frequency (%)
Male	58 (58%)
Female	42 (42%)
Mean age	53.4 ± 11.2 years
Hypertension	72 (72%)
Diabetes mellitus	46 (46%)
Anemia	68 (68%)

Table 1. Demographic Characteristics of Study Population

Distribution of CKD Stages:

Based on Kidney Disease Improving Global Outcomes (KDIGO) classification, 28% of patients were categorized as Stage III CKD, 42% as Stage IV CKD, and 30% as Stage V CKD. Stage IV CKD constituted the largest proportion of the study population, indicating that most patients presented with advanced renal dysfunction at the time of cardiovascular evaluation.

The increasing proportion of patients in advanced CKD stages highlights the progressive burden of cardiovascular complications associated with worsening renal impairment (Table-2).

CKD Stage	Number of Patients	Percentage
Stage III	28	28%
Stage IV	42	42%
Stage V	30	30%

Table 2. Distribution of CKD Stages

Echocardiographic Findings

Echocardiographic assessment demonstrated a high prevalence of structural cardiac abnormalities among CKD patients. Left ventricular hypertrophy was identified in 66% of the overall study population. The prevalence of LVH progressively increased with worsening CKD stage, suggesting a strong association between declining renal function and myocardial remodeling. Among Stage III CKD patients, LVH was observed in 36% of cases. In contrast, the prevalence increased markedly among Stage IV patients, where 71% demonstrated echocardiographic evidence of LVH. The highest prevalence was observed among Stage V CKD patients, in whom LVH was present in 83% of individuals. These findings indicate that advanced renal dysfunction is associated with significant increases in left ventricular mass and ventricular wall thickness. Progressive pressure overload due to uncontrolled hypertension, chronic anemia, fluid retention, arterial stiffness, and neurohormonal activation may contribute to worsening myocardial hypertrophy in advanced CKD stages (Table-3).

CKD Stage	LVH Present	Percentage
Stage III	10	36%
Stage IV	30	71%
Stage V	25	83%

Table 3. Prevalence of LVH According to CKD Stage

Left Ventricular Systolic Function

Left ventricular systolic dysfunction was identified in 52% of the study population and was predominantly observed among patients with Stage IV and Stage V CKD. Reduced left ventricular ejection fraction (LVEF) in advanced CKD stages may reflect progressive myocardial fibrosis, ventricular dilation, and impaired myocardial contractility resulting from chronic uremic and hemodynamic stress. Mean echocardiographic measurements revealed increased interventricular septal thickness and posterior wall thickness, further supporting the high burden of ventricular hypertrophy among CKD patients.

Parameter	Mean ± SD
IVSd	12.6 ± 2.1 mm
PWTd	11.9 ± 1.8 mm
LVIDd	5.4 ± 0.7 cm
LVEF	48.2 ± 8.6%

Table 4. Echocardiographic Parameters Among CKD Patients

The mean interventricular septal thickness (12.6 ± 2.1 mm) and posterior wall thickness (11.9 ± 1.8 mm) were elevated compared to normal reference ranges, indicating significant myocardial hypertrophy among the study population. Additionally, the mean left ventricular ejection fraction was mildly reduced (48.2 ± 8.6%), suggesting early systolic dysfunction in a substantial proportion of CKD patients. Overall, the echocardiographic findings of the present study demonstrate a strong relationship between CKD progression and cardiovascular structural abnormalities, particularly LVH and impaired systolic function (Table-4).

Discussion

The present study demonstrated a high prevalence of left ventricular hypertrophy among patients with chronic kidney disease. LVH was identified in 66% of the study population and showed a progressive increase with worsening renal dysfunction. These findings emphasize the close relationship between CKD progression and cardiovascular remodeling. The prevalence of LVH observed in the present study is consistent with previous reports among CKD populations. Foley et al. demonstrated that structural cardiac abnormalities develop early during renal impairment and progressively worsen with declining kidney function [9]. Similarly, London et al. reported that approximately 70–80% of dialysis patients exhibit echocardiographic evidence of LVH [6].

The pathogenesis of LVH in CKD patients is multifactorial. Persistent hypertension contributes to chronic pressure overload and concentric hypertrophy, whereas anemia and fluid overload lead to increased preload and eccentric ventricular remodeling [13]. Chronic activation of the RAAS system, endothelial dysfunction, oxidative stress, and inflammation further contribute to myocardial fibrosis and ventricular stiffness [14]. The present study also observed left ventricular systolic dysfunction in more than half of the study population. Progressive myocardial remodeling and fibrosis may impair ventricular contractility and contribute to reduced systolic performance in advanced CKD stages [15]. These abnormalities significantly increase the risk of heart failure, arrhythmias, and sudden cardiac death.

Echocardiography remains an indispensable tool for cardiovascular evaluation in CKD patients because it enables early identification of subclinical structural and functional abnormalities [11, 16, 17]. Routine echocardiographic screening in CKD patients may facilitate timely initiation of cardioprotective strategies including blood pressure optimization, anemia correction, fluid management, and RAAS inhibition.

The present study has certain limitations. The sample size was relatively small and the study was conducted at a single center, which may limit external generalizability. Longitudinal follow-up was not performed to assess progression of cardiac abnormalities or cardiovascular outcomes over time. Future multicentric prospective studies with larger populations are recommended.

Conclusion

Left ventricular hypertrophy is highly prevalent among patients with chronic kidney disease and demonstrates a strong association with worsening renal dysfunction. Advanced CKD stages are associated with increased ventricular wall thickness and impaired systolic function, reflecting progressive cardiac remodeling. Echocardiography serves as a reliable and clinically valuable non-invasive modality for early cardiovascular assessment and risk stratification in CKD patients. Early identification and management of LVH may help reduce cardiovascular morbidity and improve long-term clinical outcomes in this high-risk population.

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