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Original Article

Assessment Of Left Ventricular Filling Pressure Using Echocardiography Among Patients With Chronic Kidney Disease: A Prospective Cross-Sectional Observational study

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ABSTRACT

Background: Chronic kidney disease (CKD) is associated with an increased risk of cardiovascular disease, with left ventricular diastolic dysfunction occurring early in disease progression. Tissue Doppler Imaging (TDI)-derived E/e′ ratio is a reliable non-invasive marker of left ventricular filling pressure (LVFP).

Methods: This prospective cross-sectional study included 33 adults with CKD Stages 3–5. Transthoracic echocardiography with TDI was performed to assess LVFP using the E/e′ ratio. The association between LVFP and CKD stage was analyzed using the Chi-square test.

Results: The mean age was 51.55 ± 11.68 years, and 60.6% were males. Stage 5 CKD was most common (51.5%). Normal LVFP was observed in 60.6% of patients, while 39.4% had abnormal LVFP. The mean E/e′ ratio was 8.17 ± 3.12, and mean left ventricular ejection fraction was 50.91 ± 9.32%. No significant association was found between CKD stage and LVFP ($p = 0.626$).

Conclusion: TDI-derived E/e′ ratio is a valuable non-invasive tool for assessing LVFP and identifying early cardiac dysfunction in CKD patients.

Keywords: Chronic kidney disease, left ventricular filling pressure, Tissue Doppler Imaging.

Introduction:

The Chronic kidney disease (CKD) is a major global public health concern characterized by progressive and irreversible deterioration of renal function. It is defined as abnormalities of kidney structure or function persisting for at least three months, manifested by reduced estimated glomerular filtration rate (eGFR) or markers of kidney damage such as albuminuria [1]. The global prevalence of CKD has increased considerably over the past two decades owing to the rising incidence of diabetes mellitus, hypertension, obesity, and ageing populations [2]. The kidneys play a vital role in maintaining fluid balance, electrolyte homeostasis, acid–base regulation, and endocrine functions essential for cardiovascular health [3]. Progressive loss of renal function leads to numerous systemic complications, among which cardiovascular disease is the leading cause of morbidity and mortality in patients with CKD [4]. Even before reaching end-stage renal disease, individuals with CKD exhibit a markedly increased risk of cardiovascular events compared with the general population [5]. The close interaction between renal dysfunction and cardiovascular abnormalities is described as the cardiorenal syndrome, where impairment of one organ adversely affects the function of the other [6]. Several pathophysiological mechanisms, including chronic volume overload, activation of the renin–angiotensin–aldosterone system, sympathetic nervous system overactivity, endothelial dysfunction, oxidative stress, chronic inflammation, and anemia contribute to adverse cardiac remodeling in patients with CKD [7].

Left ventricular hypertrophy (LVH) is one of the most common structural cardiac abnormalities observed in CKD and develops as a consequence of persistent hypertension, chronic fluid overload, anemia, and increased arterial stiffness [8]. Progressive myocardial fibrosis and ventricular remodeling impair myocardial relaxation, resulting in elevated left ventricular filling pressure (LVFP) and left ventricular diastolic dysfunction (LVDD) [9]. Increased LVFP is recognized as an important predictor of heart failure with preserved ejection fraction, pulmonary congestion, repeated hospitalizations, and cardiovascular mortality [10]. Echocardiography is a non-invasive, safe, and reliable imaging modality widely used to evaluate cardiac structure and function in patients with CKD [11].

Conventional Doppler echocardiography combined with Tissue Doppler Imaging (TDI) enables accurate assessment of diastolic function through measurement of transmitral inflow velocity (E/A ratio), mitral annular early diastolic velocity (e′), E/e′ ratio, deceleration time (DT), and isovolumetric relaxation time (IVRT) [12]. Among these parameters, the E/e′ ratio has been shown to correlate closely with invasively measured left ventricular filling pressure and is considered one of the most reliable echocardiographic indicators of elevated filling pressures [13]. Several studies have demonstrated a progressive increase in echocardiographic abnormalities with worsening renal function. Garg et al. reported that the prevalence of left ventricular hypertrophy and diastolic dysfunction increased significantly with advancing CKD stages [14]. Kim et al. demonstrated that an elevated E/e′ ratio independently predicted mortality among patients with chronic kidney disease, emphasizing its prognostic importance [15]. Similarly, Franczyk-Skóra et al. highlighted that echocardiographic assessment facilitates early detection of cardiac dysfunction before the onset of overt clinical heart failure [16]. Despite growing evidence regarding cardiovascular involvement in CKD, there remains limited information on the assessment of left ventricular filling pressure among Indian patients with chronic kidney disease using Tissue Doppler Imaging. Early identification of elevated LVFP may facilitate timely therapeutic intervention, improve cardiovascular risk stratification, and reduce adverse clinical outcomes. Therefore, the present study was undertaken to assess left ventricular filling pressure using transthoracic echocardiography in patients with chronic kidney disease and to determine the relationship between left ventricular filling pressure and the severity of renal dysfunction as assessed by estimated glomerular filtration rate.

MATERIALS AND METHODS

A prospective cross-sectional observational study was conducted in the Department of Cardiology, Aarupadai Veedu Medical College and Hospital, Vinayaka Mission's Research Foundation (Deemed to be University), Puducherry, India. The study was carried out over a period of one month after obtaining approval from the Institutional Human Ethics Committee (IHEC).

The primary objective was to assess left ventricular filling pressure (LVFP) in patients with chronic kidney disease (CKD) using transthoracic echocardiography and to determine its association with the severity of renal dysfunction as assessed by the estimated glomerular filtration rate (eGFR).

Ethical Considerations

The study protocol was reviewed and approved by the Institutional Human Ethics Committee of Aarupadai Veedu Medical College and Hospital. Ethical clearance was granted on 07 June 2024 prior to the commencement of the study. The research was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki for research involving human participants [17]. Written informed consent was obtained from all participants after explaining the purpose, procedures, potential benefits, and risks associated with the study. Participant confidentiality was maintained throughout the study, and all collected data were used exclusively for research purposes.

Study Population

The study population consisted of adult patients diagnosed with chronic kidney disease who attended the Department of Cardiology during the study period. Consecutive sampling was employed to recruit eligible participants until the required sample size was achieved.

Sample Size

The sample size was calculated using the standard formula for cross-sectional studies based on the expected prevalence of cardiac abnormalities among patients with chronic kidney disease reported in previous literature [14]. A total of 33 patients fulfilling the eligibility criteria were included in the final analysis. The relatively small sample size was primarily attributed to the limited number of CKD patients presenting to the institution during the study period.

Inclusion Criteria

The study included patients who fulfilled all of the following criteria: Adults aged 18 years and above, Diagnosed with chronic kidney disease based on clinical evaluation and laboratory investigations, Patients classified as CKD Stage 3, Stage 4, or Stage 5 according to the estimated glomerular filtration rate (eGFR) based on KDIGO classification [1], Patients who provided written informed consent to participate in the study.

Exclusion Criteria

Patients were excluded if they had any of the following conditions: Valvular heart disease, Restrictive cardiomyopathy, Constrictive pericarditis, Congenital heart disease, Previous cardiac surgery, Acute myocardial infarction, Severe arrhythmias interfering with echocardiographic assessment, Patients unwilling to participate in the study.

Data Collection

Demographic characteristics including age and gender were recorded using a structured data collection form. Clinical history and laboratory parameters, particularly serum creatinine and estimated glomerular filtration rate (eGFR), were obtained from patients' medical records. Renal function was categorized according to the Kidney Disease: Improving Global Outcomes (KDIGO) classification based on eGFR values [1]: Stage 3 CKD: eGFR 30–59 mL/min/1.73 m^2, Stage 4 CKD: eGFR 15–29 mL/min/1.73 m^2, Stage 5 CKD: eGFR <15 mL/min/1.73 m^2 .

Echocardiographic Assessment

All participants underwent comprehensive transthoracic echocardiographic evaluation using a Mindray Diagnostic Ultrasound System. Echocardiographic examinations were performed by an experienced cardiologist following the recommendations of the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI) [18]. Standard two-dimensional (2D), M-mode, pulsed-wave Doppler, and Tissue Doppler Imaging (TDI) examinations were performed with patients in the left lateral decubitus position.

The following echocardiographic parameters were assessed: Left ventricular ejection fraction (LVEF), Transmitral early diastolic velocity (E wave) , Transmitral late diastolic velocity (A wave) , E/A ratio, Deceleration time (DT), Isovolumetric relaxation time (IVRT), Septal e′ velocity, Lateral e′ velocity, Average e′ velocity, E/e′ ratio. The E/e′ ratio was calculated by dividing the peak transmitral early filling velocity (E) by the average early diastolic mitral annular velocity (e′). This parameter was used as the primary indicator of left ventricular filling pressure. Based on the E/e′ ratio, left ventricular filling pressure was categorized as follows [18]: Normal LVFP: E/e′ <8, Indeterminate LVFP: E/e′ = 8–13, Elevated LVFP: E/e′ >13. These categories were used to determine the severity of diastolic dysfunction among study participants.

Outcome Measures

The primary outcome of the study was the assessment of left ventricular filling pressure using echocardiography. The secondary outcome was the evaluation of the relationship between left ventricular filling pressure and the severity of chronic kidney disease as determined by eGFR.

Statistical Analysis

The collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 21.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. The association between CKD stage and left ventricular filling pressure was assessed using the Chi-square test. A two-tailed p-value <0.05 was considered statistically significant. Statistical significance was reported at the 95% confidence interval.

RESULTS

A total of 33 patients with chronic kidney disease (CKD) were enrolled in this prospective cross-sectional study. The demographic, clinical, and echocardiographic characteristics of the participants are presented in Table 1. The mean age of the study population was 51.55 ± 11.68 years (range: 30–70 years). Males constituted the majority of the study population (20, 60.6%), while females accounted for 13 (39.4%) participants.

The mean estimated glomerular filtration rate (eGFR) was 17.97 ± 11.55 mL/min/1.73 m², indicating moderate-to-severe renal impairment among the participants. The mean E/e′ ratio, which served as the primary echocardiographic indicator of left ventricular filling pressure, was 8.17 ± 3.12. The mean left ventricular ejection fraction (LVEF) was 50.91 ± 9.32%, demonstrating that left ventricular systolic function was preserved in most patients despite evidence of altered diastolic filling (Table-1).

Variable	Mean ± SD / n (%)
Age (years)	51.55 ± 11.68
Male	20 (60.6)
Female	13 (39.4)
eGFR (mL/min/1.73 m²)	17.97 ± 11.55
Average E/e′ ratio	8.17 ± 3.12
Left ventricular ejection fraction (%)	50.91 ± 9.32

Table 1. Baseline demographic and echocardiographic characteristics of the study participants (n = 33)

Distribution of CKD Stages

Patients were categorized according to the Kidney Disease: Improving Global Outcomes (KDIGO) classification based on their eGFR values. The majority of the participants were diagnosed with Stage 5 CKD (51.5%), followed by Stage 4 CKD (33.3%), whereas only 15.2% belonged to Stage 3 CKD. These findings indicate that most patients presented with advanced renal disease requiring detailed cardiovascular assessment (Table-2).

CKD Stage	Frequency (n)	Percentage (%)
Stage 3	5	15.2
Stage 4	11	33.3
Stage 5	17	51.5
Total	**33**	**100**

Table 2. Distribution of CKD stages

Distribution of Left Ventricular Diastolic Dysfunction

Left ventricular filling pressure was assessed using the average E/e′ ratio obtained by Tissue Doppler Imaging. Based on the established echocardiographic criteria, 20 patients (60.6%) had normal LV filling pressure (E/e′ <8), 11 patients (33.3%) had indeterminate LV filling pressure (E/e′ 8–13), and 2 patients (6.1%) demonstrated elevated LV filling pressure (E/e′ >13). These findings indicate that although most patients had normal or indeterminate filling pressures, a small proportion exhibited elevated filling pressure suggestive of increased left ventricular diastolic pressure (Table-3).

Left Ventricular Filling Pressure (E/e′ Ratio)	Frequency (n)	Percentage (%)
Normal (<8)	20	60.6
Indeterminate (8–13)	11	33.3
Elevated (>13)	2	6.1
Total	**33**	**100**

Table 3. Distribution of left ventricular filling pressure based on E/e′ ratio

Association between CKD Stage and Diastolic Dysfunction

The relationship between CKD stage and left ventricular filling pressure is presented in Table 4. Normal LV filling pressure was observed predominantly among patients with Stage 4 (72.7%) and Stage 5 CKD (64.7%), whereas indeterminate LV filling pressure was more frequent in Stage 3 CKD (60.0%). Elevated LV filling pressure was identified in one patient each with Stage 3 and Stage 4 CKD, while none of the Stage 5 patients demonstrated an E/e′ ratio greater than 13. Statistical analysis using the Chi-square test revealed no statistically significant association between CKD stage and left ventricular filling pressure ($\chi^2 = 1.88$, $p = 0.626$). Although differences in LV filling pressure distribution were observed among CKD stages, these variations were not statistically significant, possibly because of the relatively small sample size.

CKD Stage	Normal n (%)	Indeterminate n (%)	Elevated n (%)	Total
Stage 3 (n = 5)	1 (20.0)	3 (60.0)	1 (20.0)	5
Stage 4 (n = 11)	8 (72.7)	2 (18.2)	1 (9.1)	11
Stage 5 (n = 17)	11 (64.7)	6 (35.3)	0 (0.0)	17
Total	**20 (60.6)**	**11 (33.3)**	**2 (6.1)**	**33**

Table 4. Association between CKD stage and left ventricular filling pressure

Overall, 13 patients (39.4%) exhibited abnormal left ventricular filling pressure, comprising 11 patients (33.3%) with indeterminate LV filling pressure and 2 patients (6.1%) with elevated LV filling pressure. The majority of participants (60.6%) demonstrated normal LV filling pressure despite advanced chronic kidney disease. Left ventricular systolic function remained relatively preserved, with a mean ejection fraction of 50.91 ± 9.32%. Although alterations in LV filling pressure were observed across different CKD stages, the association between CKD stage and LV filling pressure was not statistically significant ($\chi^2 = 1.88$, $p = 0.626$). These findings suggest that Tissue Doppler-derived E/e′ ratio is a useful non-invasive parameter for evaluating left ventricular filling pressure in patients with chronic kidney disease, while larger prospective studies are required to further clarify its relationship with CKD severity.

DISCUSSION

The present study evaluated left ventricular filling pressure (LVFP) in patients with chronic kidney disease (CKD) using transthoracic echocardiography and Tissue Doppler Imaging (TDI). Cardiovascular disease is the leading cause of morbidity and mortality in patients with CKD, and early identification of cardiac dysfunction is essential for improving clinical outcomes. Tissue Doppler-derived E/e′ ratio has emerged as a reliable non-invasive echocardiographic parameter for estimating left ventricular filling pressure and detecting subclinical myocardial dysfunction before the development of overt heart failure [1,2].

In the present study, the mean age of the participants was 51.55 ± 11.68 years, with males accounting for 60.6% of the study population. More than half of the participants (51.5%) were classified as CKD Stage 5, indicating advanced renal impairment at the time of cardiovascular evaluation. These findings are comparable to previous studies reporting that CKD predominantly affects middle-aged and elderly individuals, particularly males, owing to the high prevalence of hypertension, diabetes mellitus, and other cardiovascular risk factors [3,4]. The mean estimated glomerular filtration rate (17.97 ± 11.55 mL/min/1.73 m²) reflected severe renal dysfunction in the study population. Progressive decline in renal function has been associated with myocardial fibrosis, arterial stiffness, chronic volume overload, endothelial dysfunction, and activation of the renin–angiotensin–aldosterone system, all of which contribute to impaired ventricular relaxation and increased left ventricular filling pressure [5,6]. Assessment of LV filling pressure using the Tissue Doppler-derived E/e′ ratio demonstrated that 20 patients (60.6%) had normal LV filling pressure, 11 patients (33.3%) had indeterminate LV filling pressure, and 2 patients (6.1%) had elevated LV filling pressure. Overall, 39.4% of the study population exhibited abnormal LV filling pressure. These findings indicate that abnormalities in ventricular filling are common in patients with CKD despite preservation of left ventricular systolic function. Similar observations have been reported by previous investigators, who demonstrated that Tissue Doppler Imaging can identify early myocardial dysfunction before a decline in left ventricular ejection fraction becomes clinically evident [7,8]. The mean left ventricular ejection fraction (50.91 ± 9.32%) remained within the preserved range in most participants, suggesting that alterations in ventricular filling precede systolic dysfunction. This finding supports previous studies describing heart failure with preserved ejection fraction as a common cardiovascular manifestation in patients with chronic kidney disease, where elevated filling pressure develops before impairment of systolic function [9,10]. The relationship between CKD stage and LV filling pressure was also evaluated. Although abnormalities in LV filling pressure were more frequently observed among patients with advanced CKD, the association between CKD stage and LV filling pressure was not statistically significant ($\chi^2 = 1.88$, $p = 0.626$). The lack of statistical significance may be attributed to the relatively small sample size and the unequal distribution of participants across CKD stages.

Nevertheless, the observed trend is consistent with previous reports demonstrating progressive impairment of ventricular filling with worsening renal function [11,12]. The findings of the present study highlight the clinical value of Tissue Doppler Imaging as a simple, reproducible, and non-invasive technique for estimating LV filling pressure in patients with chronic kidney disease. Routine assessment of the E/e′ ratio may facilitate early cardiovascular risk stratification, allowing timely optimization of blood pressure control, fluid balance, anemia management, and other therapeutic interventions before the onset of symptomatic heart failure [13,14,15,16].

The present study has certain limitations. It was conducted at a single tertiary care center with a relatively small sample size of 33 participants, which may limit the generalizability of the findings. Furthermore, invasive measurement of left ventricular filling pressure was not performed to validate the echocardiographic findings. Future multicenter prospective studies involving larger patient populations and long-term follow-up are required to confirm these observations and determine the prognostic significance of Tissue Doppler-derived LV filling pressure in patients with CKD. Overall, the present findings reinforce the importance of incorporating Tissue Doppler Imaging into routine echocardiographic evaluation of patients with chronic kidney disease. Early identification of abnormal LV filling pressure may improve cardiovascular risk assessment and facilitate timely intervention to reduce adverse cardiovascular outcomes.

Conclusion:

The present study demonstrated that Tissue Doppler Imaging is a valuable non-invasive modality for assessing left ventricular filling pressure in patients with chronic kidney disease. Based on the E/e′ ratio, 39.4% of the study population exhibited abnormal left ventricular filling pressure, whereas left ventricular systolic function remained relatively preserved. These findings indicate that alterations in ventricular filling may occur early during the course of chronic kidney disease before significant impairment of systolic function becomes evident. Although abnormalities in left ventricular filling pressure were more frequently observed among patients with advanced CKD, the association between CKD stage and left ventricular filling pressure was not statistically significant ($\chi^2 = 1.88$, $p = 0.626$). Nevertheless, the observed trend suggests progressive cardiovascular involvement with worsening renal dysfunction.

Routine incorporation of Tissue Doppler-derived E/e′ ratio into the echocardiographic evaluation of patients with chronic kidney disease may facilitate early detection of elevated left ventricular filling pressure, improve cardiovascular risk stratification, and support timely therapeutic intervention. Further multicenter prospective studies with larger sample sizes and longer follow-up are warranted to validate these findings and establish the prognostic significance of left ventricular filling pressure in chronic kidney disease.

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