ORIGINAL ARTICLE e-ISSN: 2349-0659 p-ISSN; 2350-0964

Cardiovascular Profile of Patients with Chronic Kidney Disease: A Cross-Sectional Study

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Abstract

Background: Chronic kidney disease (CKD) carries a high risk of cardiovascular disease, the leading cause of mortality in these patients. Early detection improves risk stratification and clinical outcomes. **Objectives:** This study aimed to assess the cardiovascular profile, electrocardiography (ECG), echocardiographic, and carotid Doppler findings in CKD patients, evaluate associated risk factors, and determine the association between CKD stages and cardiovascular abnormalities. **Materials and Methods:** A hospital-based cross-sectional study of 320 CKD patients was conducted at ESIC Medical College and Hospital and Super Specialty Hospital, Hyderabad, from October 2024 to March 2026. Participants diagnosed with CKD using the Kidney Disease: Improving Global Outcomes 2012 guidelines were enrolled via consecutive sampling. Clinical evaluation, laboratory tests, ECG, 2D echocardiography, and carotid Doppler ultrasound were performed. Data analysis utilized IBM Statistical Package for the Social Sciences version 23, with $P < 0.05$ considered statistically significant. **Results:** The mean age was 55.4 ± 20.2 years, with 52.5% males. Stage 3 CKD was most prevalent (47.2%). ECG abnormalities occurred in 63.7% of patients, whereas echocardiographic and carotid Doppler abnormalities were present in 73.8% each. Left ventricular hypertrophy, reduced ejection fraction, carotid plaques, and carotid stenosis predominated. Significant associations were found between advanced CKD stages and ECG abnormalities ($P < 0.001$), echocardiographic abnormalities ($P = 0.001$), and carotid Doppler abnormalities ($P = 0.016$). **Conclusion:** Cardiovascular abnormalities are highly prevalent in CKD patients and increase significantly with advancing disease stages. Routine screening via ECG, echocardiography, and carotid Doppler enables early detection, precise risk stratification, and timely interventions to mitigate severe complications.

Keywords: Cardiovascular profile, Cardiovascular risk, Carotid Doppler, Chronic kidney disease, Echocardiography, Electrocardiography

Asian Pac. J. Health Sci., (2026); DOI: 10.21276/apjhs.2026.13.3.11

Introduction

Chronic kidney disease (CKD) is a major global public health concern, affecting approximately 10–15% of the adult population worldwide. It is characterized by persistent abnormalities of kidney structure or function, resulting in progressive impairment of renal function, reduced excretion of metabolic waste products, disturbances in fluid and electrolyte homeostasis, and multiple systemic complications. Among these complications, cardiovascular disease (CVD) represents the leading cause of morbidity and mortality in patients with CKD.[1,2]

The association between CKD and CVD is well established. Patients with CKD are at substantially increased risk of developing hypertension, left ventricular hypertrophy, coronary artery disease, heart failure, cardiac arrhythmias, and cerebrovascular disease. This increased cardiovascular risk is attributable not only to conventional risk factors such as diabetes mellitus, hypertension, dyslipidemia, obesity, and smoking, but also to several CKD-specific mechanisms. These include chronic inflammation, oxidative stress, endothelial dysfunction, activation of the renin–angiotensin–aldosterone system, anemia, abnormalities of mineral and bone metabolism, vascular calcification, and accumulation of uremic toxins.[2-5] Collectively, these factors contribute to progressive structural and functional abnormalities of both the myocardium and the vascular system.

Cardiovascular abnormalities may develop early during the course of CKD and may progress with deterioration of renal function. Early identification of such abnormalities is therefore important for appropriate risk stratification and timely intervention. Non-invasive investigations, including electrocardiography (ECG), two-dimensional echocardiography, and carotid Doppler ultrasonography, provide valuable information regarding electrical activity, cardiac structure and function, and subclinical atherosclerotic vascular disease, respectively.

Despite the well-recognized association between CKD and CVD, comprehensive assessment of cardiovascular abnormalities across different stages of CKD remains limited, particularly in the Indian population. Evaluation of cardiovascular involvement using multiple non-invasive modalities may therefore provide a more comprehensive understanding of the cardiovascular burden associated with progressive renal dysfunction.

This study was undertaken to evaluate the cardiovascular profile of patients with CKD. The objectives were to assess electrocardiographic, echocardiographic, and carotid Doppler abnormalities; evaluate common cardiovascular risk factors,

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How to cite this article: Nithisha A, Ramani SS, Aggarwal H, Rao SSP, Kumar KMN. Cardiovascular Profile of Patients with Chronic Kidney Disease: A Cross-Sectional Study. Asian Pac. J. Health Sci., 2026;13(3):45-49.

Source of support: Nil.

Conflicts of interest: None

Received: 18/06/2026 **Revised:** 27/06/2026 **Accepted:** 11/08/2026

including hypertension, diabetes mellitus, dyslipidemia, anemia, obesity, and smoking; and determine the association between CKD stage and cardiovascular abnormalities.

Materials and Methods

Study Design and Setting

This hospital-based cross-sectional study was conducted at ESIC Medical College and Hospital and Super Specialty Hospital, Hyderabad, over a period of 18 months from October 2024 to March 2026.

Study Population and Sample Size

The study included adult patients aged ≥18 years who had been diagnosed with CKD according to the Kidney Disease: Improving Global Outcomes (KDIGO) 2012 criteria.

The sample size was calculated using the standard formula for estimating a population proportion. A prevalence of CVD among patients with CKD of 25% was considered, with a 95% confidence level and 20% relative precision. The calculated minimum sample size was 288. Allowing for an additional 10% to account for possible non-response or incomplete data, the final sample size was increased to 320 participants. Consecutive sampling was used for participant recruitment.

Inclusion and Exclusion Criteria

Patients aged ≥18 years of either sex with established CKD who provided written informed consent were included in the study.

Patients with a history of liver failure, ischemic heart disease, peripheral vascular disease, nerve conduction abnormalities, or those who declined to participate were excluded from the study.

Data Collection

After obtaining approval from the Institutional Ethics Committee and written informed consent from each participant, demographic and clinical information was collected using a predesigned and structured proforma.

CKD was staged according to the KDIGO 2012 classification based primarily on estimated glomerular filtration rate (eGFR) and urine albumin-to-creatinine ratio. Clinical assessment included evaluation of cardiovascular risk factors and measurement of blood pressure, body mass index (BMI), and smoking history.

Laboratory investigations included hemoglobin, serum albumin, serum creatinine, blood urea, serum electrolytes, calcium, phosphorus, and lipid profile. eGFR was calculated using the appropriate standard equation.

Electrocardiographic Assessment

All participants underwent a standard 12-lead electrocardiogram. ECGs were evaluated for abnormalities including left ventricular hypertrophy, ST-segment and T-wave changes suggestive of myocardial ischemia, and cardiac arrhythmias.

Echocardiographic Assessment

Two-dimensional transthoracic echocardiography was performed in all participants to assess cardiac structure and function. Parameters evaluated included left ventricular dimensions, interventricular septal thickness, left ventricular posterior wall thickness, left ventricular mass, and left ventricular ejection fraction. Structural abnormalities such as left ventricular hypertrophy and left ventricular dilatation, as well as systolic dysfunction, were recorded.

Carotid Doppler Assessment

B-mode carotid ultrasonography with Doppler examination was performed bilaterally to assess carotid arterial structure and hemodynamics. Carotid intima-media thickness (CIMT), carotid plaques, stenotic lesions, peak systolic velocity, end-diastolic velocity, and the internal carotid artery/common carotid artery (ICA/CCA) peak systolic velocity ratio were recorded. Increased CIMT and the presence of carotid plaques or stenosis were considered indicators of subclinical atherosclerotic vascular disease.

Statistical Analysis

Data were entered into Microsoft Excel 2013 and subsequently analyzed using IBM Statistical Package for the Social Sciences Statistics, version 23. Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were presented as frequencies and percentages. Comparisons between groups were performed using the Chi-square test for categorical variables and one-way analysis of variance for continuous variables, as appropriate. A two-sided $P < 0.05$ was considered statistically significant.

Results

Baseline Characteristics

A total of 320 patients with CKD were included in the study. The mean age of the study population was 55.4 ± 20.2 years. There was a slight male predominance, with 168 (52.5%) male and 152 (47.5%) female participants.

Diabetes mellitus was present in 84 (26.3%) patients, whereas hypertension was documented in 75 (23.4%). Diabetes mellitus with coexisting hypertension was present in 77 (24.1%) patients. Obesity, defined as a BMI ≥25 kg/m^2, was observed in 213 (66.6%) participants. Regarding smoking status, 27 (8.4%) were current smokers and 109 (34.1%) were ex-smokers; therefore, 136 (42.5%) participants had a current or previous history of smoking [Table 1].

Clinical and Laboratory Profile

The mean systolic blood pressure of the study population was 141.5 ± 31.7 mmHg, whereas the mean diastolic blood pressure was 83.9 ± 20.3 mmHg.

The mean serum creatinine concentration was 5.3 ± 2.7 mg/dL, and the mean blood urea level was 104.8 ± 54.9 mg/dL. The mean creatinine clearance was 65.8 ± 36.4 mL/min, whereas the mean eGFR was 44.4 ± 27.4 mL/min/1.73 m^2.

The mean hemoglobin concentration was 12.1 ± 3.5 g/dL. The mean total cholesterol, triglyceride, low-density lipoprotein (LDL) cholesterol, and high-density lipoprotein (HDL) cholesterol levels were 202.4 ± 57.5 mg/dL, 219.1 ± 101.4 mg/dL, 120.4 ± 44.1 mg/dL, and 50.4 ± 17.3 mg/dL, respectively.

The mean serum potassium, calcium, and phosphorus levels were 4.4 ± 1.1 mEq/L, 9.5 ± 1.5 mg/dL, and 4.5 ± 1.4 mg/dL, respectively [Table 2].

Distribution According to CKD Stage

Among the 320 participants, 26 (8.1%) had Stage 1 CKD, 37 (11.6%) had Stage 2, 151 (47.2%) had Stage 3, 62 (19.4%) had Stage 4, and 44 (13.8%) had Stage 5 CKD. Thus, Stage 3 CKD constituted the largest proportion of the study population.

Electrocardiographic Findings

A normal ECG was observed in 116 (36.3%) participants, whereas 204 (63.7%) demonstrated one or more ECG abnormalities.

Left ventricular hypertrophy was the most frequent ECG abnormality, observed in 88 (27.5%) patients, followed by ischemic changes in 73 (22.8%) and cardiac arrhythmias in 43 (13.4%) patients.

Echocardiographic Findings

Two-dimensional echocardiography was normal in 84 (26.3%) patients, whereas 236 (73.8%) demonstrated one or more echocardiographic abnormalities.

Reduced left ventricular ejection fraction was observed in 84 (26.3%) patients and left ventricular dilatation in 81 (25.3%). Left ventricular hypertrophy was present in 71 (22.1%) participants.

The mean left ventricular internal diameter at end-diastole was 5.01 ± 0.56 cm, whereas the mean left ventricular posterior wall thickness at end-diastole was 1.09 ± 0.17 cm. The mean interventricular septal thickness at end-diastole was 1.12 ± 0.17 cm. The mean left ventricular mass was 246.42 ± 86.59 g.

Table 1: Baseline characteristics of the study participants

Variable	*n (%)/mean±SD*
Age (years)	55.4±20.2
Male	168 (52.5)
Female	152 (47.5)
Diabetes mellitus	84 (26.3)
Hypertension	75 (23.4)
Diabetes + hypertension	77 (24.1)
Obesity (BMI ≥25 kg/m^2)	213 (66.6)
Current smoker	27 (8.4)
Ex-smoker	109 (34.1)

BMI: Body mass index

Table 2: Clinical and laboratory profile of CKD patients

Variable	*Mean±SD*
Systolic BP (mmHg)	141.5±31.7
Diastolic BP (mmHg)	83.9±20.3
Serum creatinine (mg/dL)	5.3±2.7
Blood urea (mg/dL)	104.8±54.9
Creatinine clearance (mL/min)	65.8±36.4
Hemoglobin (g/dL)	12.1±3.5
Total cholesterol (mg/dL)	202.4±57.5
Triglycerides (mg/dL)	219.1±101.4
LDL cholesterol (mg/dL)	120.4±44.1
HDL cholesterol (mg/dL)	50.4±17.3
Serum potassium (mEq/L)	4.4±1.1
Serum calcium (mg/dL)	9.5±1.5
Serum phosphorus (mg/dL)	4.5±1.4
eGFR (mL/min/1.73 m^2)	44.4±27.4

CKD: Chronic kidney disease, SD: Standard deviation, BP: Blood pressure, LDL: Low-density lipoprotein, HDL: High-density lipoprotein, eGFR: Estimated glomerular filtration rate

Carotid Doppler Findings

Carotid Doppler examination was normal in 84 (26.3%) patients, whereas 236 (73.8%) demonstrated one or more abnormalities.

Carotid plaques were detected in 121 (37.8%) patients, whereas carotid stenosis was identified in 115 (35.9%).

The mean CIMT was 0.99 ± 0.28 mm. The mean peak systolic velocity was 153.97 ± 58.04 cm/s, and the mean end-diastolic velocity was 81.62 ± 40.00 cm/s. The mean ICA/CCA peak systolic velocity ratio was 2.58 ± 0.87.

Association between CKD Stage and Cardiovascular Abnormalities

A progressive increase in the prevalence of cardiovascular abnormalities was observed with advancing CKD stage.

The prevalence of ECG abnormalities increased from 26.9% in Stage 1 CKD to 59.5% in Stage 2, 63.6% in Stage 3, 67.7% in Stage 4, and 84.1% in Stage 5 CKD [Table 3]. This association between CKD stage and ECG abnormalities was statistically significant ($P < 0.001$).

Similarly, the prevalence of echocardiographic abnormalities increased from 42.3% in Stage 1 to 67.6% in Stage 2, 74.8% in Stage 3, 80.6% in Stage 4, and 84.1% in Stage 5 CKD. The association was statistically significant ($P = 0.001$).

Carotid Doppler abnormalities were observed in 65.4% of patients with Stage 1 CKD, 54.1% with Stage 2, 74.2% with Stage 3, 82.3% with Stage 4, and 81.8% with Stage 5 CKD. Although there was some variation between individual stages, an overall significant association was observed between CKD stage and carotid Doppler abnormalities ($P = 0.016$).

Overall, the findings demonstrate a substantial cardiovascular burden among patients with CKD, with cardiac and vascular abnormalities becoming increasingly prevalent as renal function deteriorates.

Table 3: Distribution of cardiovascular abnormalities among CKD patients

Variable	*n (%)/mean±SD*
CKD stage	
Stage 1	26 (8.1)
Stage 2	37 (11.6)
Stage 3	151 (47.2)
Stage 4	62 (19.4)
Stage 5	44 (13.8)
ECG findings	
Normal	116 (36.3)
LVH	88 (27.5)
Ischemic changes	73 (22.8)
Arrhythmia	43 (13.4)
2D Echocardiography	
Normal	84 (26.3)
Reduced EF	84 (26.3)
Dilated LV	81 (25.3)
LVH	71 (22.1)
Carotid Doppler	
Normal	84 (26.3)
Plaques	121 (37.8)
Stenosis	115 (35.9)

CKD: Chronic kidney disease, SD: Standard deviation, ECG: Electrocardiographic, LVH: Left ventricular hypertrophy, EF: Ejection fraction, LV: Left ventricle

Discussion

The present study evaluated the cardiovascular profile of patients with CKD using clinical, biochemical, electrocardiographic, echocardiographic, and carotid Doppler parameters. A substantial burden of cardiovascular abnormalities was observed, with an overall increase in abnormalities with advancing CKD stage. This supports the close association between progressive renal dysfunction and CVD, mediated by both conventional risk factors and CKD-specific mechanisms such as inflammation, oxidative stress, endothelial dysfunction, anemia, vascular calcification, and mineral metabolism abnormalities.

The mean age of the study population was 55.4 ± 20.2 years, with a slight male predominance (52.5%). This demographic profile was broadly comparable with previous Indian studies.[6] Diabetes mellitus and hypertension were common, whereas 66.6% of patients were overweight or obese and 42.5% had a current or previous history of smoking.[7] These findings highlight the coexistence of several modifiable cardiovascular risk factors in CKD. Mahishale *et al*.[8] similarly reported a high cardiovascular risk among CKD patients, particularly in the presence of obesity and other conventional risk factors.

Stage 3 CKD constituted the largest proportion of the study population (47.2%), followed by Stages 4 and 5. This pattern was comparable with observations reported by Mohanty *et al*.[9] and may reflect delayed recognition and diagnosis of CKD. The progressive deterioration in renal biochemical parameters and eGFR across CKD stages was consistent with the natural course of renal dysfunction.

Dyslipidemia was also frequently observed, with elevated total cholesterol, triglycerides, and LDL cholesterol. These abnormalities may contribute to the increased cardiovascular risk in CKD, particularly when combined with hypertension, diabetes, inflammation, endothelial dysfunction, and vascular calcification.[10]

Electrocardiographic Abnormalities

ECG abnormalities were present in 63.7% of patients, with LVH (27.5%) and ischemic changes (22.8%) being the most frequent findings. This was broadly consistent with the findings of Mahishale *et al*.,[8] who reported a high prevalence of ECG abnormalities among CKD patients. LVH may result from chronic pressure and volume overload and represents an important substrate for heart failure, arrhythmias, and cardiovascular mortality. The significant increase in ECG abnormalities from 26.9% in Stage 1–84.1% in Stage 5 CKD ($P < 0.001$) indicates increasing electrical and structural cardiac involvement with worsening renal function.

Echocardiographic Abnormalities

Echocardiographic abnormalities were identified in 73.8% of patients. Reduced ejection fraction (26.3%), left ventricular dilatation (25.3%), and LVH (22.1%) were the predominant abnormalities. The mean left ventricular mass was 246.42 ± 86.59 g, suggesting substantial structural cardiac involvement [Table 4]. Similar cardiac abnormalities have been reported in previous studies.[8,11] The prevalence of echocardiographic abnormalities increased from 42.3% in Stage 1 to 84.1% in Stage 5 CKD ($P = 0.001$), supporting a progressive relationship between renal dysfunction and cardiac remodeling.

Table 4: Echocardiographic and carotid Doppler parameters among CKD patients

Parameter	*Mean±SD*	*95% confidence interval*
2D echocardiographic parameters		
LV internal diameter (end diastole) (cm)	5.01±0.56	4.94–5.07
LV posterior wall (end diastole) (cm)	1.09±0.17	1.07–1.11
IVS Thickness (end diastole) (cm)	1.12±0.17	1.09–1.13
Left ventricular mass (g)	246.42±86.59	236.90–255.95
Carotid Doppler parameters		
Carotid intima-media thickness (mm)	0.99±0.28	0.96–1.02
Peak systolic velocity (cm/s)	153.97±58.04	147.58–160.35
End-diastolic velocity (cm/s)	81.62±40.00	77.22–86.02
ICA/CCA peak systolic velocity ratio	2.58±0.87	2.48–2.67

CKD: Chronic kidney disease, SD: Standard deviation, LV: Left ventricle, ICA: Internal carotid artery, CCA: Common carotid artery, IVS: Normal interventricular septum

Carotid Doppler and Subclinical Atherosclerosis

Carotid Doppler abnormalities were present in 73.8% of patients, including carotid plaques in 37.8% and stenosis in 35.9%. The mean CIMT was 0.99 ± 0.28 mm, indicating increased subclinical atherosclerotic burden.

These findings are consistent with observations by Babua *et al*.,[12] who reported a high prevalence of cardiovascular risk factors among CKD patients. Chaitanya *et al*.[13] demonstrated increased CIMT and carotid plaques across CKD stages in an Indian cohort, supporting the association between worsening renal dysfunction and subclinical atherosclerosis. Similarly, Sathi *et al*.[14] reported increased CIMT with advancing CKD and particularly high values among patients undergoing hemodialysis. Chhajed *et al*.[15] also demonstrated significantly greater CIMT in CKD patients compared with healthy controls and reported associations with age, BMI, total cholesterol, and triglycerides. These findings support the role of CKD and conventional cardiovascular risk factors in accelerating vascular disease.

Hinderliter *et al*.,[16] in the RRI-CKD study, further demonstrated that increased CIMT was associated with traditional cardiovascular risk factors, clinical CVD, and adverse cardiovascular outcomes, supporting carotid ultrasonography as a useful non-invasive marker of cardiovascular risk in CKD.

Relationship between CKD Stage and Cardiovascular Abnormalities

A significant association was observed between CKD stage and ECG, echocardiographic, and carotid Doppler abnormalities. ECG abnormalities increased from 26.9% in Stage 1 to 84.1% in Stage 5, whereas echocardiographic abnormalities increased from 42.3% to 84.1% over the same stages. Carotid Doppler abnormalities also showed a significant association with CKD stage ($P = 0.016$), although the distribution was not uniformly progressive across every individual stage.

The increasing cardiovascular burden with worsening CKD may be explained by persistent hypertension, fluid overload, anemia, activation of the renin–angiotensin–aldosterone and sympathetic nervous systems, chronic inflammation, oxidative stress, endothelial dysfunction, and abnormalities of calcium-phosphate metabolism. These mechanisms contribute to LVH, ventricular remodeling, arterial stiffness, vascular calcification, and accelerated atherosclerosis.

Table 5: Association between CKD stage and cardiovascular abnormalities

Cardiovascular abnormality	*Stage 1*	*Stage 2*	*Stage 3*	*Stage 4*	*Stage 5*	*P-value*
ECG abnormality (%)	26.9	59.5	63.6	67.7	84.1	<0.001
2D echo abnormality (%)	42.3	67.6	74.8	80.6	84.1	0.001
Carotid Doppler abnormality (%)	65.4	54.1	74.2	82.3	81.8	0.016

CKD: Chronic kidney disease, ECG: Electrocardiographic

The combined use of ECG, echocardiography, and carotid Doppler provided a comprehensive assessment of cardiovascular involvement in the present study. ECG identified electrical abnormalities, echocardiography demonstrated structural and functional cardiac changes, and carotid Doppler identified subclinical vascular disease.

Clinical Implications

The high prevalence of cardiovascular abnormalities observed in this study highlights the importance of cardiovascular assessment in patients with CKD, particularly those with advanced disease and additional risk factors such as diabetes, hypertension, obesity, dyslipidemia, and smoking. ECG, echocardiography, and carotid Doppler are non-invasive and complementary investigations that may facilitate early identification of cardiovascular involvement and appropriate risk stratification.

Overall, the findings indicate that CKD should be considered an important cardiovascular risk state, with cardiovascular abnormalities becoming increasingly prevalent as renal function declines [Table 5].

Conclusion

The present study demonstrated a high prevalence of cardiovascular abnormalities among patients with CKD, involving electrical, structural, functional, and vascular components. ECG abnormalities were observed in 63.7% of patients, whereas echocardiographic and carotid Doppler abnormalities were each present in 73.8%. LVH, reduced ejection fraction, left ventricular dilatation, carotid plaques, and stenotic lesions were the major abnormalities identified.

A significant association was observed between advancing CKD stage and ECG, echocardiographic, and carotid Doppler abnormalities. These findings indicate that cardiovascular involvement increases with worsening renal dysfunction. Comprehensive cardiovascular evaluation using ECG, echocardiography, and carotid Doppler may therefore facilitate early detection of CVD, improve risk stratification, and support timely preventive and therapeutic interventions in patients with CKD.

Statement

1. The authors hereby declare that there are no potential conflicts of interest with respect to research, authorship and/or publication of this article.
2. We confirm that the materials included in this chapter do not violate copyright laws. Where relevant, appropriate permissions have been obtained from the original copyright holder(s). All original sources have been appropriately acknowledged and/or referenced.

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