Section: General Medicine

Original Research Article

ELECTROCARDIOGRAPHIC CHANGES IN CHRONIC KIDNEY DISEASE PATIENTS: A CROSS SECTIONAL STUDY

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ABSTRACT

Background: Chronic kidney disease (CKD) is a significant global health burden and affects approximately 10-15% of the adult population. Cardiovascular complications are the leading cause of morbidity and mortality in CKD patients. Electrocardiographic (ECG) abnormalities are commonly observed due to electrolyte imbalances, myocardial remodeling and autonomic dysfunction. Despite this, routine ECG screening is often underutilized in CKD patients. This study aims to evaluate the prevalence and spectrum of ECG changes in CKD patients and their clinical significance.

Materials and Methods: This cross-sectional study was conducted over a year at Adichunchanagiri Hospital and Research Center. A total of 94 adult patients with diagnosed CKD were included based on predefined inclusion and exclusion criteria. A detailed clinical history, physical examination and laboratory investigation (including serum electrolytes, renal function tests, and hemoglobin levels) were performed. A standard 12-lead ECG was recorded and parameters such as QTc interval, PR interval, QRS duration and ST-T changes were analyzing. Data was statistically analyzed using SPSS v23.0 software with a p-value <0.05 considered significant.

Results: Among 94 CKD patients there was a male preponderance with M:F ratio of 1:0.34. Mean age of studied cases was found to be 51.43 ± 15.06 years. Most of the patients belonged to stage 5 CKD (59.57%). Anemia was seen in 38 patients (40.43%) whereas hypocalcemia and hyperphosphatemia was seen in 29 (30.85%) and 16 (17.02%) patients each. Diabetes and hypertension were the most frequent risk factors (43.62%). Common ECG abnormalities included left ventricular hypertrophy changes (27.66%) followed by Q waves (19.15%), ST segment elevation/depression (17.02%), and prolonged QRS duration (12.77%).

Conclusion: A high prevalence of ECG abnormalities in CKD patients highlights the need for routine ECG screening to detect high-risk individuals early. Given its affordability and accessibility ECG should be integrated into standard CKD management to improve cardiovascular risk stratification and patient outcomes.

Keywords: Chronic kidney disease, ECG abnormalities, left ventricular hypertrophy, arrhythmias, cardiovascular risk.

INTRODUCTION

Chronic kidney disease (CKD) is a condition in which there is a persistent reduction in kidney function. It is characterized by a glomerular filtration rate (GFR) of less than 60 mL/min/1.73 m² and/or the presence of kidney damage for at least three months.[1] CKD has emerged as a significant global health problem which affects approximately 10-15% of the adult population worldwide. The increasing

prevalence of CKD is caused by the rising incidence of diabetes mellitus, hypertension and obesity. The burden of CKD extends beyond renal impairment and is responsible for increased morbidity, mortality as well as healthcare costs. One of the important aspects of this disease is CKD remains underdiagnosed and undertreated in many cases for quite considerable time leading to adverse systemic consequences. These complications include, amongst other things, cardiovascular complications which account for the majority of deaths in CKD patients.[2]

The development and progression of CKD is influenced by genetic as well as environmental factors. Established risk factors include advanced age, male gender, African or South Asian ethnicity and a family history of kidney disease. Metabolic conditions such as diabetes mellitus and hypertension are the most common aetiologies contributing to nearly two-thirds of CKD cases.[3] Other important risk factors include obesity, dyslipidemia, smoking and metabolic syndrome. Additionally, diseases such as glomerulonephritis, polycystic kidney disease and interstitial nephritis also contribute to progression to CKD. Environmental and socioeconomic factors such as dietary habits and prolonged intake of nephrotoxic drugs may also increase the burden of CKD.[4]

CKD is a significantly impacts cardiovascular, metabolic, hematopoietic and endocrine systems and their haemostasis. The progressive decline in kidney function causes accumulation of uremic toxins and chronic inflammation which collectively contribute to systemic dysfunction.[5] Cardiovascular complications including hypertension, heart failure and arrhythmias are the leading cause of mortality in CKD patients. Metabolic disturbances such as dyslipidemia, insulin resistance and reduced bone mineral metabolism further exacerbate disease progression. Erythropoietin deficiency and iron dysregulation in CKD causes anemia which contributes to fatigue and reduced oxygen delivery worsening cardiovascular outcomes. In addition to these changes hormonal imbalances such as hypothyroidism ae also commonly seen in patients with CKD.[6]

Cardiovascular disease (CVD) is the most common cause of mortality in CKD patients. With decline in renal functions there is a steady increase in risk of cardiovascular complications. The pathophysiological mechanisms underlying CKD-associated cardiovascular disease is multifactorial. Endothelial dysfunction, vascular calcification, myocardial fibrosis and left ventricular hypertrophy are major contributing factors. Uremic toxins, inflammation, and oxidative stress accelerate atherosclerosis and arterial stiffness thereby predisposing CKD patients to ischemic heart disease, heart failure and sudden cardiac death. Additionally, volume overload and anemia contribute to hemodynamic stress, leading to adverse cardiac remodeling.[7]

Electrocardiographic (ECG) abnormalities are frequently present in CKD patients. In many instances routine ECG in asymptomatic CKD patients have reported to be having various abnormalities.[8] Common ECG findings in CKD patients include prolonged QT interval, left ventricular hypertrophy (LVH) patterns, peaked T waves (suggesting hyperkalemia) and ST-segment depression. Uremic cardiomyopathy and myocardial fibrosis contribute to increased QRS duration and bundle branch blocks. Electrolyte disturbances such as hyperkalemia can cause widened QRS complexes and sine-wave patterns. Whereas hypocalcemia may lead to QT prolongation and increased risk of torsades de pointes. Frequent premature ventricular contractions (PVCs), atrial ectopics and atrial fibrillation are also observed.[9]

This study was undertaken to assess ECG changes in diagnosed cases of CKD irrespective of duration and stage of CKD.

MATERIALS AND METHODS

This was a cross sectional study comprising of adult patients diagnosed with any stage of chronic kidney disease (CKD). Duration of the study was a year from January 2024 to December 2025. The institutional ethical committee approved the study and informed and written consent was obtained from all the participants of the study. 94 diagnosed cases of CKD were included in this study on the basis of a predefined inclusion and exclusion criteria. The patients were recruited from individuals attending outpatient and inpatients department of medicine at Adichunchanagiri hospital and research center. The sample size was calculated by formula n= Z2 P (1-P)/d2 using OPENEPI software version 3 on the basis of pilot studies done on the topic of ECG changes in CKD assuming 90% power and 95% confidence interval 90 patients were sufficient for this study .

A detailed history was taken with respect to duration of renal disease, presence of risk factors such as diabetes mellitus, hypertension or family history of chronic kidney disease. Presenting complaints such as shortness of breath, edema, urine output and presence of fatigue was also documented. A thorough clinical examination was conducted including cardiovascular and nervous system examination. Investigations such as complete blood count, differential leukocyte counts, blood urea and serum creatinine, random blood sugar level, serum electrolytes (Na, K, Cl and Ca) were done in all cases. Presence of abnormalities such as hypocalcemia, hyperphosphatemia, hyperkalemia and anemia were looked for and noted. Chronic kidney disease was classified into various stages based on estimated glomerular filtration rate (eGFR). Stage 1 included patients with an eGFR greater than 90 mL/min, accompanied by other renal abnormalities such as proteinuria. Stage 2 was defined by an eGFR between 60 and 90 mL/min and stage 3 included those with an

eGFR ranging from 30 to 60 mL/min. Patients were categorised into Stage 4 and Stage 5 if eGFR was between 15–30 mL/min and below 15 mL/min respectively.

Ultrasound abdomen was reviewed to look for structural changes in kidneys. Standard 12-leads ECG was performed in each patient, with a focus on analyzing ST and T changes, QTc interval, PR interval, and QRS duration.

Data were entered into Microsoft Excel, and statistical analysis was performed using SPSS software (version 23.0). Quantitative variables, including blood urea, serum creatinine, serum electrolytes (Na, K, Cl, Ca), QTc interval, PR interval, QRS duration, and other ECG parameters, were expressed as mean ± standard deviation (SD). Qualitative variables, such as the presence and type of arrhythmias, comorbid conditions (diabetes mellitus, hypertension), were presented as frequencies and percentages. A p-value of <0.05 was considered statistically significant.

Inclusion Criteria

- Individuals diagnosed to be having CKD defined as kidney damage for 3 months or more, as confirmed by kidney damage markers, with or without documented reduction in glomerular filtration rate (GFR) or GFR<60 mL/min/1.73 m² for ≥3 months with or without kidney damage.
- Age more than 18 years.
- Those who gave informed and written consent to be part of study.

Exclusion Criteria

- Those who refused consent to be part of study.
- Age less than 18 years.
- Patients having conditions such as ischemic heart disease, thyroid function abnormalities, chronic liver disease or metabolic conditions known to predispose for development of arrhythmia.
- Patients with cognitive impairment and psychiatric illnesses.
- Patients on pro-arrhythmic drugs such as quinidine, flecainide and disopyramide etc.

RESULTS

The analysis of gender distribution of the studied cases showed that out of 94 cases of CKD there were 70 (74.47 %) males and 24 (25.53 %) females. There was a significant male preponderance in cases of CKD with a M:F ratio of 1:0.34 (Figure 1).

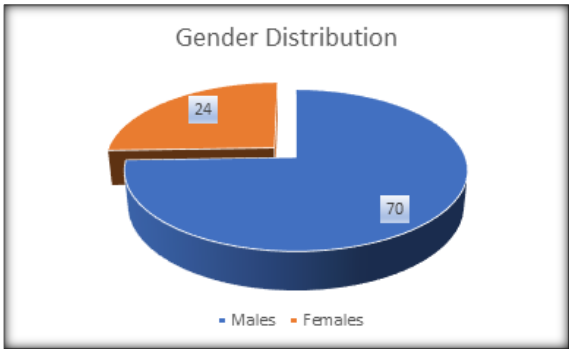

Figure 1: Gender Distribution of Studied cases.

The analysis of the age distribution of the studied cases showed that the majority of individuals were in the 41-60 years age group, accounting for 44 cases (46.81%). This was followed by those above 60 years, comprising 28 cases (29.79%), while the 18-40 years age group had the least representation with 22 cases (23.40%). Mean age of the studied population was 51.43 +/- 15.06 years (Table 1).

The analysis of the distribution of chronic kidney disease (CKD) stages among the studied cases showed that the majority of patients were in Stage 5, accounting for 56 cases (59.57%). This was followed by Stage 4, with 22 cases (23.40%), and Stage 3, which included 9 cases (9.57%). Stage 2 had 7 cases (7.45%), while Stage 1 had no cases (0%). The findings indicate that most patients were in the advanced stages of CKD, with a significant proportion in Stage 5 (Figure 2).

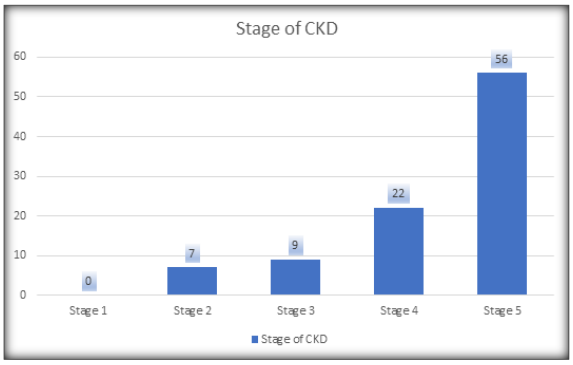

Figure 2:- Distribution of cases on the basis of stage of the disease.

The analysis of biochemical parameters among the studied cases showed that anemia was the most common abnormality, observed in 38 patients (40.43%). This was followed by hypocalcemia, which was present in 29 patients (30.85%), while hyperphosphatemia was noted in 16 patients (17.02%). The least common biochemical abnormality was hyperkalemia, affecting 11 patients (11.70%) (Table 2).

The analysis of comorbidities among the studied cases showed that the most common condition was the combination of diabetes mellitus and hypertension, affecting 41 patients (43.62%). This was followed by diabetes mellitus alone, which was

present in 27 patients (28.72%), while hypertension alone was observed in 26 patients (27.66%) (Table 3). The analysis of ECG findings among the studied cases showed that left ventricular hypertrophy was the most common abnormality, observed in 26 patients (27.66%). This was followed by the presence of Q waves in 18 patients (19.15%) and ST segment elevation or depression in 16 patients (17.02%). Prolonged QRS duration was noted in 12 patients (12.77%), while both tachycardia and left & right atrial enlargement were found in 11 patients (11.70%) each (Table 4).

Table 1: Age Distribution of studied cases

	No of cases	Percentage
18-40 years	22	23.40%
41-60 years	44	46.81%
Above 60 years	28	29.79%
Mean Age:- 51.43 +/- 15.06		

Table 2: Biochemical Parameters in studied cases

Biochemical Parameter	No. of Patients	Percentage
Anemia	38	40.43%
Hypocalcemia	29	30.85%
Hyperphosphatemia	16	17.02%
Hyperkalemia	11	11.70%

Table 3: Co-Morbidities in studied cases

Comorbidity	No. of Patients	Percentage
Diabetes Mellitus + Hypertension	41	43.62%
Hypertension	26	27.66%
Diabetes Mellitus	27	28.72%

Table 4: ECG findings in cases of chronic kidney disease

ECG Finding	No. of Patients	Percentage
Left Ventricular Hypertrophy	26	27.66%
Q Waves	18	19.15%
ST Segment Elevation or Depression	16	17.02%
Prolonged QRS Duration	12	12.77%
Tachycardia	11	11.70%
Left & Right Atrial Enlargement	11	11.70%

DISCUSSIONS

In this study of 94 cases of CKD there were 70 (74.47 %) males and 24 (25.53 %) females. There was a significant male preponderance in cases of CKD with a M:F ratio of 1:0.34. Mean age of the studied population was 51.43 +/- 15.06 years. Ghosh A et al conducted a study to evaluate the correlation between chronic kidney disease (CKD), dyslipidemia, and dysglycemia.10 Cases were defined as patients over 20 years of age diagnosed with CKD (non-oedematous), while controls were age- and gender-matched individuals attending the medicine outpatient department or indoor facility without a CKD diagnosis. This study also reported a male preponderance in cases of CKD with M:F ratio of 3:2. Go Alen S et al. conducted a cohort study to evaluate the association between reduced estimated glomerular filtration rate (GFR) and the risks of death, cardiovascular events, and hospitalization. For this purpose, the authors undertook a study comprising 1,120,295 adults who had serum creatinine measured between 1996 and 2000 and had not undergone dialysis or kidney transplantation.[11] The mean age of participants was 52 years, and 55% of the study population were women. The risk of cardiovascular events increased inversely with GFR. Moreover, lower GFR levels were associated with higher hospitalization rates. The mean age of CKD cases in this study was similar to our study.

In our study Anemia was the most common biochemical abnormality, observed in 40.43% of cases, followed by hypocalcemia (30.85%) and hyperphosphatemia (17.02%). Hyperkalemia was the least frequent, affecting 11.70% of patients. Adi Lukas Kurniawan et al conducted a cross-sectional study to explore the association between metabolic parameters and the risks of anemia and electrolyte disturbances among chronic kidney disease (CKD) patients in Taiwan.[12] For this purpose, the authors undertook a study comprising 2176 CKD stages 3–5 patients The study found that elevated diastolic blood pressure, fasting blood glucose, and glycated hemoglobin A1c (HbA1c) were associated with the presence of anemia. Additionally, elevated fasting blood glucose and HbA1c were linked to hyponatremia (OR = 1.59 and 1.58, $P < 0.01$) and hypercalcemia (OR = 1.38 and 1.33, $P < 0.05$). No significant association was found between serum lipid levels and anemia. However, total triglycerides, total cholesterol, and low-density lipoprotein-cholesterol were associated with hypercalcemia (OR = 1.43, 1.95, and 3.08, respectively, $P < 0.05$).On the basis of these findings, the authors concluded that elevated diastolic blood pressure, fasting blood glucose, HbA1c, and blood lipids are associated with

anemia and electrolyte or mineral disorders in CKD patients. Similar Metabolic disturbances in cases of CKD were also reported by the authors such as Cibulka R et al,[13] and Slee AD et al.[14]

In this study the most common systemic condition was the combination of diabetes mellitus and hypertension, affecting 41 patients (43.62%). This was followed by diabetes mellitus alone, which was present in 27 patients (28.72%), while hypertension alone was observed in 26 patients (27.66%). Rinku Joshi et al conducted a cross-sectional study to estimate the prevalence of chronic kidney disease (CKD) among patients with type 2 diabetes mellitus (T2DM) and determine the associated sociodemographic and clinical risk factors.[15] For this purpose, the authors undertook a study comprising 201 patients with T2DM. Participants completed a questionnaire regarding their socioeconomic status and underwent relevant physical and haematological examinations. The primary and secondary outcome measures were the prevalence and risk factors of CKD among T2DM patients. The study found that the prevalence of CKD among T2DM patients was 86.6%. Univariable analysis showed that age (p=0.026), hypertension status (p=0.002), duration of diabetes (p=0.009), and hemoglobin levels (p=0.027) were significantly associated with CKD. On the basis of these findings, the authors concluded that advancing age, concomitant hypertension, increasing duration of T2DM, and the presence of anemia were important risk factors for CKD. Similar correlation between hypertension, diabetes mellitus and CKD has also been reported by the authors such as Newtonraj A et al,[16] and Van Buren PN et al.[17]

The analysis of ECG findings revealed that left ventricular hypertrophy was the most common abnormality (27.66%) followed by Q waves (19.15%), ST segment elevation or depression (17.02%) and prolonged QRS period (12.77%). Tachycardia and atrial enlargement (left & right) were each noted in 11.70% of patients. Salman Shafi et al conducted a cross-sectional study to assess the frequency of electrocardiographic (ECG) abnormalities in patients with chronic kidney disease (CKD).[18] For this purpose, the authors undertook a study comprising 124 CKD patients aged 20-80 years who were not previously on renal replacement therapy and were admitted to the nephrology ward at a tertiary care facility over a 6-month period. The study found that 78.4% of CKD patients had one or more ECG abnormalities. The most common abnormality was left ventricular hypertrophy (40%) followed by Q waves (27.2%) ST segment elevation or depression (23.4%), prolonged QRS duration (19.2%), tachycardia (17.6%) and left and right atrial enlargement (17.6%).On the basis of these findings, the authors concluded that ECG abnormalities are highly prevalent in hospitalized CKD patients. Similar ECG changes in cases of CKD has also been reported by the authors such as Shapira OM et al,[19] and Park S et al.[20]

CONCLUSION

Chronic kidney disease (CKD) patients have a high prevalence of electrocardiographic (ECG) abnormalities. This makes it important to assess ECG of all known cases of CKD irrespective of their symptomatology. Regular ECG screening can facilitate early identification of patients at risk for adverse cardiac events thereby enabling timely intervention.

Conflict of Interest: None.

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