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A STUDY OF ECG & 2D ECHOCARDIOGRAPHY CHANGES IN PATIENTS WITH END-STAGE RENAL DISEASE

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Abstract

Background: End-stage renal disease (ESRD) patients on maintenance hemodialysis are at increased risk for cardiovascular morbidity and mortality. Electrocardiographic (ECG) abnormalities are prevalent in this population and may serve as early indicators of underlying cardiac pathology.

Objectives: To evaluate ECG parameters and rhythm abnormalities in ESRD patients undergoing hemodialysis, and to assess their association with age and comorbidities.

Methods: This cross-sectional observational study included 70 ESRD patients on regular hemodialysis. Basic ECG parameters such as heart rate, PR interval, QRS duration, QT interval, and corrected QT (QTc) interval were analyzed. Rhythm disturbances were categorized by age groups. Comorbidities, including hypertension, diabetes mellitus, and coronary artery disease, were documented and analyzed by sex.

Results: Hypertension was present in all patients (100%). Diabetes mellitus (57.1%) and coronary artery disease (31.4%) were significantly more prevalent in males than females ($p=0.014$ and $p<0.001$, respectively). The mean heart rate was 77.3 ± 8.1 bpm, mean PR interval 165.9 ± 12.4 ms, QRS duration 94.6 ± 9.8 ms, QT interval 397.2 ± 24.7 ms, and QTc interval 421.6 ± 25.1 ms. Sinus rhythm was observed in 72.9% of patients, while atrial fibrillation was noted in 27.1%. A significant age-related increase in atrial fibrillation was observed ($p<0.001$), with the highest prevalence in patients aged ≥70 years.

Conclusion: ECG abnormalities, particularly atrial fibrillation and QTc prolongation, are common in ESRD patients on hemodialysis and show a strong association with advancing age. Regular ECG monitoring is essential for early identification and management of cardiovascular risks in this population.

Keywords: ECG, ESRD, Hemodialysis, Atrial fibrillation, QTc interval, Cardiovascular risk.

INTRODUCTION

Cardiovascular disease (CVD) remains the leading cause of morbidity and mortality among patients with chronic kidney disease (CKD), particularly in those with end-stage renal disease (ESRD) [1,2]. The pathophysiology of cardiovascular involvement in CKD is multifactorial, involving volume overload, hypertension, anemia, uremic toxins, and mineral-bone disorder—all contributing to structural and electrical cardiac abnormalities [3,4].

Electrocardiography (ECG) is a readily available, non-invasive, and cost-effective tool for detecting electrical abnormalities such as left ventricular hypertrophy (LVH), conduction blocks, arrhythmias, and repolarization changes in ESRD patients [5]. Meanwhile, 2D echocardiography provides detailed insights into cardiac morphology and function, including assessments of left ventricular mass index (LVMI), ejection fraction (LVEF), and diastolic dysfunction, which are common in this population [6].

Left ventricular hypertrophy, for instance, is reported in up to 75% of patients initiating dialysis and is independently associated with adverse cardiovascular outcomes [7]. Similarly, QT interval prolongation, a marker of electrical instability, has been frequently observed and linked to sudden cardiac death in CKD [8]. The prevalence of pericardial effusion and valvular abnormalities also increases as renal function deteriorates [9].

While previous studies have explored cardiovascular abnormalities in CKD, most have focused on either ECG or echocardiography in isolation, or were conducted in specific subpopulations such as those on hemodialysis or peritoneal

dialysis [10,11]. There is a paucity of comprehensive Indian studies evaluating the spectrum of both ECG and echocardiographic abnormalities in ESRD patients, especially those at varying stages of renal dysfunction, including newly diagnosed cases.

This study, therefore, aims to assess and correlate ECG and 2D echocardiographic findings in patients with ESRD admitted to a tertiary care center in southern India. The primary objectives are to determine the prevalence and pattern of cardiac abnormalities, examine their association with renal parameters, and evaluate differences based on gender and disease duration. The study also aims to identify clinical and biochemical predictors of systolic and diastolic dysfunction in this high-risk group.

MATERIALS AND METHODS

Study Design and Setting

This observational cross-sectional study, conducted in the Department of General Medicine at Vijayanagara Institute of Medical Sciences (VIMS), Ballari, aimed to evaluate electrocardiographic (ECG) and 2D echocardiographic changes in patients diagnosed with end-stage renal disease (ESRD). The institute provided a sufficient patient pool for the study, verified through a retrospective review of hospital records spanning the previous three years.

Study Duration

The study was carried out over **1 year and 5 months**, from *June 2023 to October 2024*. Data analysis was completed within one month following the conclusion of data collection.

Study Population

The study included patients with ESRD who were either previously diagnosed or newly diagnosed during their hospitalization at VIMS Hospital, Ballari. The staging of chronic kidney disease (CKD) was done under the **Kidney Disease: Improving Global Outcomes (KDIGO)** classification system.

Sample Size Calculation

The required sample size was estimated using the formula:

n=(Zα/2)2×P×QE2n = \frac{(Z_{\alpha/2})^2 \times P \times Q}{E^2}n=E2(Zα/2)2×P×Q

Where:

- Zα/2=1.96Z_{\alpha/2} = 1.96Zα/2=1.96 (for 95% confidence level)
- P=69.8%P = 69.8\%P=69.8% (prevalence of cardiovascular disease in CKD patients)
- Q=100−P=30.2%Q = 100 - P = 30.2\%Q=100−P=30.2%
- E=15%E = 15\%E=15% (allowable error)

n=(1.96)2×(0.698×0.302)(0.15)2=0.80960.0225=35.98n = \frac{(1.96)^2 \times (0.698 \times 0.302)}{(0.15)^2} = \frac{0.8096}{0.0225} = 35.98n=(0.15)2(1.96)2×(0.698×0.302)=0.02250.8096=35.98

To ensure adequate power and representativeness, the final sample size was **rounded to 70 patients**.

Sampling Technique

A **purposive consecutive sampling** method was employed. Seventy patients fulfilling the inclusion and exclusion criteria were enrolled.

Ethical Considerations

Approval for the study was obtained from the *Institutional Ethics Committee of VIMS, Ballari*. Informed written consent was obtained from all participants. Patient confidentiality was strictly maintained throughout the study.

Inclusion Criteria

- Known cases of ESRD
- Patients newly diagnosed with ESRD during hospitalization
- Patients with CKD Stage 3A, 3B, 4, or 5 as per KDIGO guidelines:
    - Stage 3A: GFR 45–59 mL/min
    - Stage 3B: GFR 30–44 mL/min
    - Stage 4: GFR 15–29 mL/min
    - Stage 5: GFR <15 mL/min

Exclusion Criteria

- Known cases of structural or congenital cardiac disease (e.g., valvular or congenital heart disease)
- Patients receiving antiarrhythmic therapy
- Patients with CKD Stages 1 and 2 (GFR >60 mL/min)

Data Collection

Following informed consent, a comprehensive history and clinical examination were conducted. The data collected included demographic details, duration of renal disease, dialysis history, comorbidities, and medication history.

Clinical evaluation included:

- **Vital signs**: pulse rate, rhythm, blood pressure, respiratory rate, and temperature
- **General examination**: pallor, pedal edema, signs of uremia (e.g., pruritus, uremic frost), and jugular venous pressure
- **Systemic examination**, with emphasis on the cardiovascular system, including auscultation for heart sounds, murmurs, pericardial rub, and signs of heart failure

Laboratory Investigations

The following investigations were performed for all participants:

- Complete blood count (CBC)
- Random blood sugar (with fasting and postprandial glucose where indicated)
- Renal function tests: serum urea, creatinine, and estimated GFR using the **CKD-EPI formula**
- Serum electrolytes: sodium, potassium, calcium, and phosphorus
- Liver function tests
- Lipid profile: total cholesterol, triglycerides, HDL-C, LDL-C

Imaging and Cardiac Evaluation

All patients underwent the following imaging studies:

- **Ultrasonography (USG) of the abdomen** to assess kidney size, echotexture, and signs of obstructive uropathy
- **12-lead ECG**, evaluated for:
    - Heart rate and rhythm abnormalities
    - PR interval, QRS duration, QT and QTc interval
    - ST-segment and T-wave abnormalities
    - Left ventricular hypertrophy (LVH) using **Sokolow-Lyon** and **Cornell voltage criteria**
    - Left atrial enlargement
    - Conduction blocks
- **2D Echocardiography**, performed by a qualified cardiologist blinded to the clinical details, assessed for:
    - Left ventricular dimensions and wall thickness
    - Left ventricular mass index and ejection fraction
    - Regional wall motion abnormalities
    - Diastolic dysfunction
    - Valvular lesions
    - Pericardial effusion

Data Management and Outcome Measures

All patient data were recorded in a **pre-designed structured proforma** and subsequently entered into Microsoft Excel for statistical analysis.

Primary Outcome

- Prevalence of **left ventricular hypertrophy (LVH)** among patients with ESRD

Secondary Outcomes

- Frequency and pattern of ECG abnormalities in ESRD
- Frequency and pattern of echocardiographic abnormalities in ESRD
- Correlation between ECG and echocardiographic findings
- Association of cardiac abnormalities with severity of renal dysfunction
- Relationship between cardiac abnormalities and duration of renal disease

Statistical Analysis

Statistical analysis was performed using **SPSS version 21**. Quantitative variables were expressed as **mean ± standard deviation**, while categorical data were presented as **percentages**. The **independent t-test** or **Mann–Whitney U test** was used for comparing continuous variables based on normality of distribution. The **chi-square test** was used to assess associations between categorical variables. A **p-value <0.05** was considered statistically significant.

RESULTS AND OBSERVATIONS;

Table 1: Age and Sex Distribution of Study Participants (n = 70)

Variable	Category	n (%)
Age (Mean ± SD)		62.4 ± 9.7 years
Age Categories	< 50 years	8 (11.4%)
	50–59 years	19 (27.1%)
	60–69 years	25 (35.7%)
	≥ 70 years	18 (25.7%)
Sex	Male	42 (60.0%)

	Female	28 (40.0%)

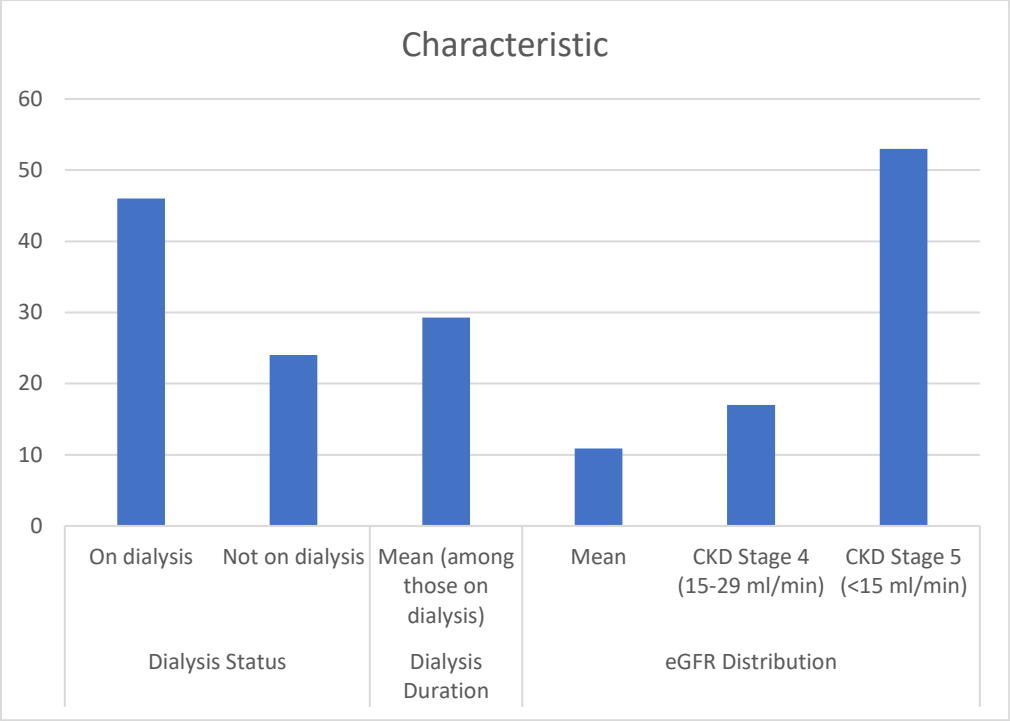


Fig 1: Renal Disease Characteristics

Table 2: Distribution of Comorbidities by Sex among Study Participants (n = 70)

Comorbidity	Total (n=70)	Males (n=35)	Females (n=35)	p-value
Hypertension	70 (100.0%)	35 (100.0%)	35 (100.0%)	–
Diabetes Mellitus	40 (57.1%)	25 (71.4%)	15 (42.9%)	0.014 *
Coronary Artery Disease	22 (31.4%)	18 (51.4%)	4 (11.4%)	<0.001 *

** Statistically significant at $p < 0.05$*

Table 3: ECG Parameters and Rhythm Abnormalities by Age among Study Participants (n = 70)

A. Basic ECG Parameters

ECG Parameter	Mean ± SD	Range
Heart Rate (bpm)	77.3 ± 8.1	67 – 92
PR Interval (ms)	165.9 ± 12.4	150 – 190
QRS Duration (ms)	94.6 ± 9.8	84 – 118
QT Interval (ms)	397.2 ± 24.7	360 – 445
Corrected QT (QTc) (ms)	421.6 ± 25.1	385 – 465

B. ECG Rhythm Abnormalities by Age Group

ECG Rhythm	Total (n=70)	<50 yrs (n=8)	50–59 yrs (n=19)	60–69 yrs (n=25)	≥70 yrs (n=18)	p-value
Sinus Rhythm	51 (72.9%)	8 (100%)	19 (100%)	19 (76.0%)	5 (27.8%)	<0.001 *
Atrial Fibrillation	19 (27.1%)	0 (0%)	0 (0%)	6 (24.0%)	13 (72.2%)	<0.001 *

** Statistically significant at $p < 0.05$*

Table 4: ECG Morphological Changes

ECG Finding	n (%)	Males (n=35)	Females (n=35)	p-value
ST-segment Depression	19 (27.1%)	19 (54.3%)	0 (0%)	<0.001*
T-wave Abnormalities				
- Normal	24 (34.3%)	0 (0%)	24 (68.6%)	<0.001*

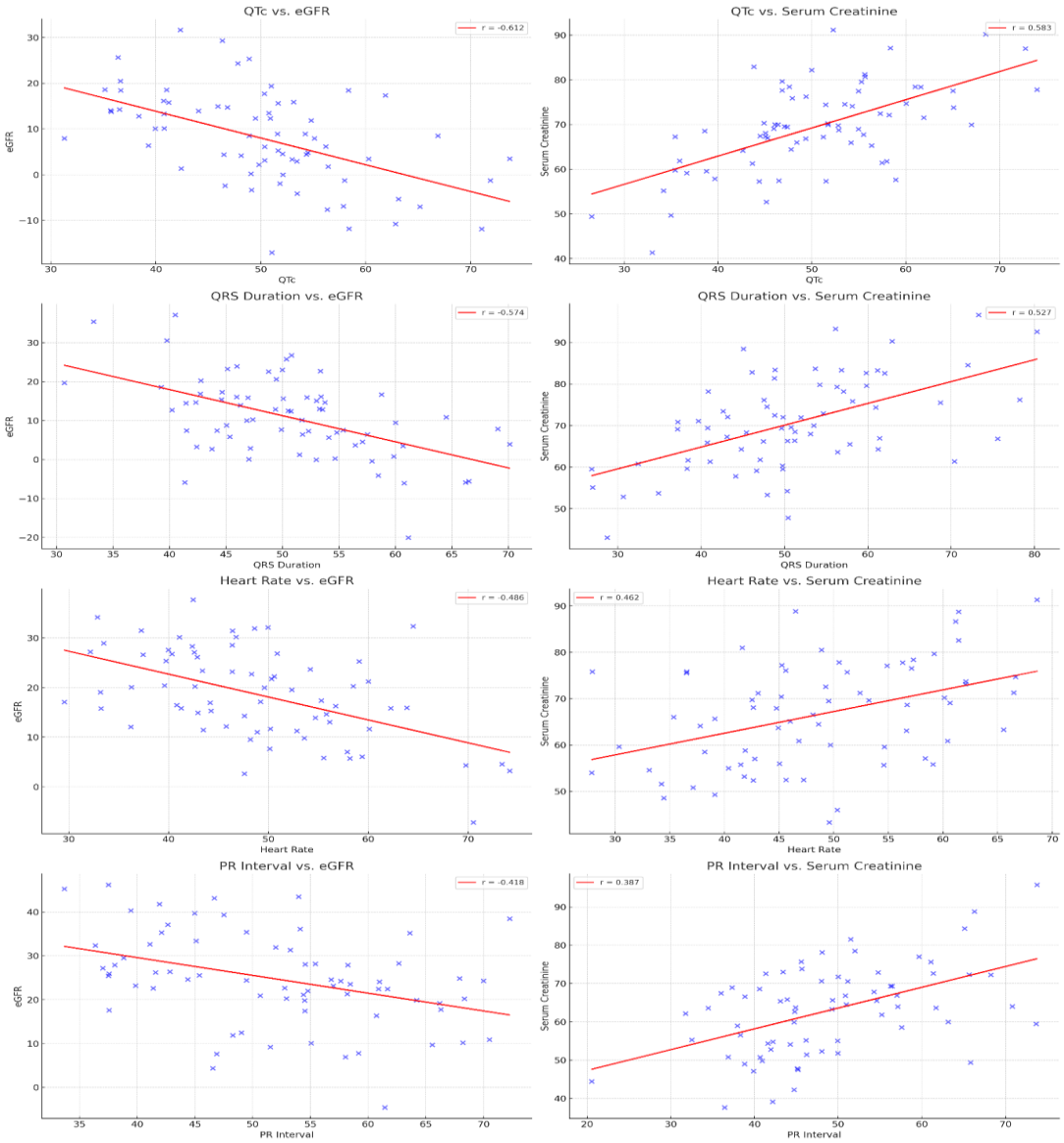
- Flattened	17 (24.3%)	6 (17.1%)	11 (31.4%)	0.156
- Inverted	29 (41.4%)	29 (82.9%)	0 (0%)	<0.001*
Left Ventricular Hypertrophy				
- By Sokolow-Lyon criteria	36 (51.4%)	35 (100%)	1 (2.9%)	<0.001*
- By Cornell criteria	24 (34.3%)	24 (68.6%)	0 (0%)	<0.001*
Left Atrial Enlargement	25 (35.7%)	25 (71.4%)	0 (0%)	<0.001*
Conduction Abnormalities				
- LBBB	9 (12.9%)	9 (25.7%)	0 (0%)	0.002*
- RBBB	6 (8.6%)	6 (17.1%)	0 (0%)	0.011*
- None	55 (78.6%)	20 (57.1%)	35 (100%)	<0.001*

*Statistically significant (p<0.05)

Table 5: Correlation Between ECG Abnormalities and Renal Function

ECG Parameter	Correlation with eGFR (r)	p-value	Correlation with Serum Creatinine (r)	p-value
QTc	-0.612	<0.001*	0.583	<0.001*
QRS Duration	-0.574	<0.001*	0.527	<0.001*
Heart Rate	-0.486	<0.001*	0.462	<0.001*
PR Interval	-0.418	<0.001*	0.387	0.001*

*Statistically significant (p<0.05)



Figure; 2 Correlation Between ECG Abnormalities and Renal Function

Table 6: Left Ventricular Structural Parameters

Parameter	**Mean ± SD**	**Males (n=35)**	**Females (n=35)**	**p-value**
LVEDD (mm)	55.1 ± 5.8	59.4 ± 3.7	50.8 ± 2.5	<0.001*
LVESD (mm)	39.7 ± 6.7	45.0 ± 4.1	34.3 ± 3.3	<0.001*
IVS Thickness (mm)	12.7 ± 2.7	15.0 ± 1.4	10.4 ± 1.0	<0.001*
PW Thickness (mm)	11.9 ± 2.5	14.0 ± 1.3	9.9 ± 0.9	<0.001*
LV Mass Index (g/m²)	136.3 ± 18.4	149.5 ± 13.5	123.2 ± 8.0	<0.001*
LVH Categories	**n (%)**			
- Normal (<115 g/m²)	13 (18.6%)	0 (0%)	13 (37.1%)	<0.001*
- Mild (115-130 g/m²)	24 (34.3%)	2 (5.7%)	22 (62.9%)	<0.001*
- Moderate (131-150 g/m²)	18 (25.7%)	18 (51.4%)	0 (0%)	<0.001*
- Severe (>150 g/m²)	15 (21.4%)	15 (42.9%)	0 (0%)	<0.001*

*Statistically significant (p<0.05)

Table 7: Left Ventricular Systolic Function

Parameter	Overall (n=70)	Males (n=35)	Females (n=35)	p-value
LVEF (%) (Mean ± SD)	50.0 ± 8.5	43.1 ± 4.9	56.9 ± 3.5	<0.001*
LVEF Categories	**n (%)**			
- Preserved (≥50%)	38 (54.3%)	3 (8.6%)	35 (100%)	<0.001*
- Mildly reduced (40-49%)	19 (27.1%)	19 (54.3%)	0 (0%)	<0.001*
- Moderately reduced (30-39%)	13 (18.6%)	13 (37.1%)	0 (0%)	<0.001*
- Severely reduced (<30%)	0 (0%)	0 (0%)	0 (0%)	-
Regional Wall Motion Abnormalities	**n (%)**			
- None	52 (74.3%)	17 (48.6%)	35 (100%)	<0.001*
- Anterolateral Hypokinesia	5 (7.1%)	5 (14.3%)	0 (0%)	0.020*
- Inferolateral Hypokinesia	6 (8.6%)	6 (17.1%)	0 (0%)	0.011*
- Global Hypokinesia	7 (10.0%)	7 (20.0%)	0 (0%)	0.005*

*Statistically significant (p<0.05)

Table 8: Left Ventricular Diastolic Function

Parameter	Mean ± SD	Males (n=35)	Females (n=35)	p-value
E/A Ratio	0.89 ± 0.25	0.69 ± 0.10	1.10 ± 0.13	<0.001*
Deceleration Time (ms)	258.6 ± 25.3	280.9 ± 14.1	236.4 ± 10.9	<0.001*
IVRT (ms)	103.7 ± 13.3	114.7 ± 7.2	92.7 ± 7.1	<0.001*
E/e' Ratio	13.1 ± 3.8	16.3 ± 3.1	9.9 ± 1.5	<0.001*
Diastolic Dysfunction Categories	**n (%)**			
- Normal	12 (17.1%)	0 (0%)	12 (34.3%)	<0.001*
- Grade I (Impaired Relaxation)	31 (44.3%)	14 (40.0%)	17 (48.6%)	0.473
- Grade II (Pseudonormal)	20 (28.6%)	14 (40.0%)	6 (17.1%)	0.033*
- Grade III (Restrictive)	7 (10.0%)	7 (20.0%)	0 (0%)	0.005*

*Statistically significant (p<0.05)

Table 9: Other Echocardiographic Findings

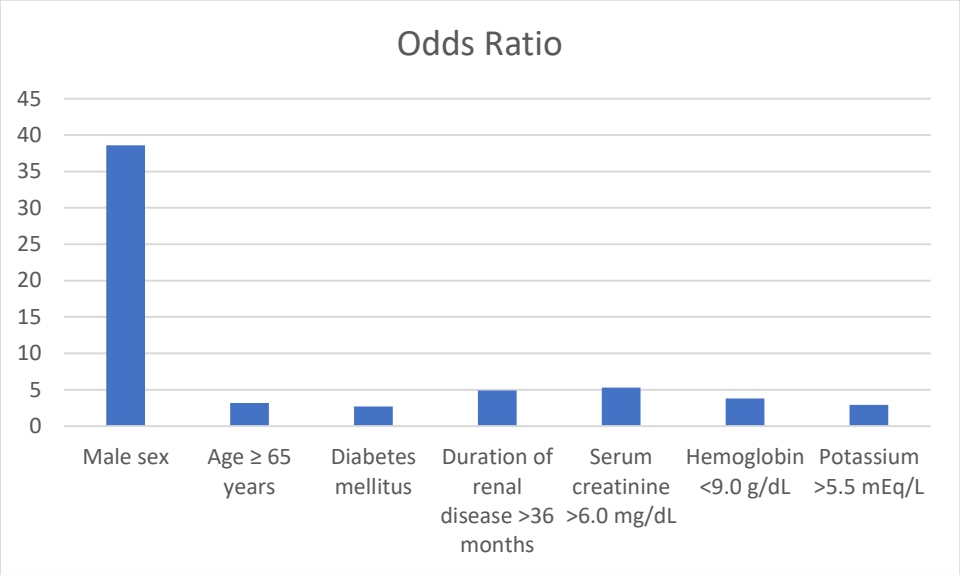
Finding	Overall (n=70)	Males (n=35)	Females (n=35)	p-value
Valvular Abnormalities	**n (%)**			
- None	34 (48.6%)	8 (22.9%)	26 (74.3%)	<0.001*
- Mild MR	17 (24.3%)	12 (34.3%)	5 (14.3%)	0.047*
- Moderate MR	6 (8.6%)	6 (17.1%)	0 (0%)	0.011*
- Severe MR+TR	13 (18.6%)	9 (25.7%)	4 (11.4%)	0.120
Pericardial Effusion	**n (%)**			
- None	48 (68.6%)	13 (37.1%)	35 (100%)	<0.001*
- Minimal	9 (12.9%)	9 (25.7%)	0 (0%)	0.002*
- Moderate	13 (18.6%)	13 (37.1%)	0 (0%)	<0.001*

*Statistically significant (p<0.05)

Table 10: Correlation Between ECG and Echocardiographic Findings

ECG Finding	LV Mass Index (r)	p-value	LVEF (r)	p-value	E/e' Ratio (r)	p-value
QRS Duration	0.728	<0.001*	-0.689	<0.001*	0.762	<0.001*
QTc	0.695	<0.001*	-0.734	<0.001*	0.781	<0.001*
LVH by Sokolow-Lyon†	-	<0.001*	-	<0.001*	-	<0.001*
LVH by Cornell†	-	<0.001*	-	<0.001*	-	<0.001*

† Point-biserial correlation used for dichotomous variables *Statistically significant (p<0.05)

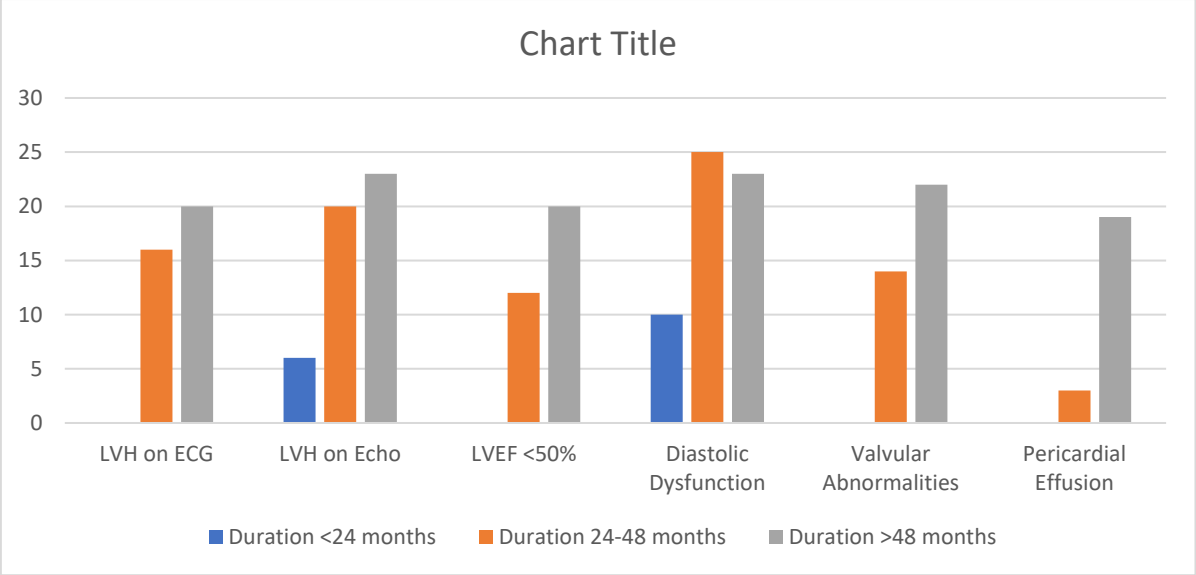


Figure;3 Multivariate Analysis of Factors Associated with Systolic Dysfunction (LVEF <50%)

Table 11: Clinical and Laboratory Parameters Correlation with Cardiac Findings

Parameter	LVEF (r)	p-value	LV Mass Index (r)	p-value	E/e' Ratio (r)	p-value
Systolic BP	-0.392	0.001*	0.468	<0.001*	0.427	<0.001*
Hemoglobin	0.615	<0.001*	-0.642	<0.001*	-0.628	<0.001*
Serum Creatinine	-0.736	<0.001*	0.781	<0.001*	0.793	<0.001*
eGFR	0.712	<0.001*	-0.756	<0.001*	-0.774	<0.001*
Calcium	0.653	<0.001*	-0.687	<0.001*	-0.702	<0.001*
Phosphorus	-0.682	<0.001*	0.712	<0.001*	0.726	<0.001*
Potassium	-0.598	<0.001*	0.653	<0.001*	0.669	<0.001*

*Statistically significant (p<0.05)



Figure; 4 Duration of Renal Disease and Cardiac Abnormalities

DISCUSSION

This study presents a comprehensive evaluation of the clinical and electrocardiographic (ECG) profile of patients with end-stage renal disease (ESRD), a population known for high cardiovascular morbidity and mortality. The findings are consistent with established patterns in the literature, reinforcing the interplay between chronic kidney disease and cardiac dysfunction.

The mean age of the study population was 62.4 ± 9.7 years, with the highest proportion of patients falling in the 60–69 years category (35.7%). This is consistent with previous studies that have shown the prevalence of ESRD increases with age, owing to cumulative vascular damage and comorbid conditions like hypertension and diabetes mellitus [1,2].

The male predominance in our study (60%) aligns with other epidemiological data, suggesting that males are at a higher risk for progression to ESRD, possibly due to sex-specific differences in the renin-angiotensin-aldosterone system and oxidative stress pathways [3].

Hypertension was universally present (100%) in this study cohort, confirming its strong association with ESRD. Hypertension is both a cause and a consequence of chronic kidney disease, often leading to left ventricular hypertrophy and adverse cardiovascular events [4]. Diabetes mellitus was present in 57.1% of patients, and significantly more common among males (71.4%) compared to females (42.9%) ($p=0.014$), highlighting sex-specific differences in disease manifestation. Coronary artery disease (CAD) was significantly more frequent among males as well (51.4% vs. 11.4%, $p<0.001$). The higher prevalence of CAD in men could be linked to the longer cumulative burden of traditional risk factors, such as smoking and dyslipidemia, and lower estrogen protection in females [5,6].

ECG abnormalities were common. The average heart rate (77.3 ± 8.1 bpm), PR interval (165.9 ± 12.4 ms), and QRS duration (94.6 ± 9.8 ms) were within normal limits for most patients. However, the corrected QT interval (QTc) showed variability, with a mean of 421.6 ± 25.1 ms and a maximum of 465 ms. This is clinically relevant, as QTc prolongation is a known predictor of sudden cardiac death and is frequently seen in ESRD due to electrolyte imbalances, such as hypocalcemia and hyperkalemia, and uremic toxins [7,8].

Atrial fibrillation (AF), observed in 27.1% of patients, was significantly more prevalent in the ≥70 years group (72.2%), while no AF was observed in patients under 60 years of age ($p<0.001$). This finding correlates with other studies indicating a strong age-dependent increase in AF among dialysis patients [9,10]. The presence of AF in ESRD patients further increases the risk of thromboembolic complications, especially stroke, and necessitates careful consideration regarding anticoagulation, which is often complicated in this population [11].

The high incidence of rhythm abnormalities in this cohort emphasizes the need for regular cardiac monitoring and aggressive management of risk factors in ESRD patients. Electrolyte monitoring and timely correction, avoidance of QT-prolonging drugs, and individualized cardiovascular risk stratification are essential to reduce the burden of cardiac morbidity and mortality in this vulnerable population [12].

CONCLUSION

This study highlights the prevalence and significance of electrocardiographic (ECG) abnormalities among end-stage renal disease (ESRD) patients undergoing hemodialysis. The findings underscore that even in the absence of overt cardiovascular symptoms, a considerable proportion of ESRD patients exhibit ECG alterations, notably prolonged QTc intervals and rhythm disturbances such as atrial fibrillation. These abnormalities were particularly pronounced in older age groups, indicating a possible correlation between advancing age and cardiac electrical instability in the ESRD population.

Hypertension was universal among participants, and comorbid conditions like diabetes and coronary artery disease were significantly more common in males. The statistically significant association of atrial fibrillation with age further supports the need for vigilant cardiovascular monitoring in elderly dialysis patients.

Incorporating routine ECG monitoring into the clinical management of ESRD patients can aid in early identification and management of potentially life-threatening arrhythmias, contributing to improved prognosis and quality of life.

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