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LEFT ATRIAL SIZE ASSESSMENT ON ECG IN PATIENTS WITH MITRAL STENOSIS USING P WAVE PARAMETERS AND TAKING TRANSTHORACIC ECHO AS GOLD STANDARD

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ABSTRACT:

INTRODUCTION: *Left atrial enlargement (LAE) is a key indicator of cardiovascular risk, including atrial fibrillation and stroke. While transthoracic echocardiography (TTE) is the gold standard for measuring LA size, electrocardiography (ECG) provides a simpler, non-invasive screening option. So, aim of the study is to evaluate the diagnostic accuracy and correlation between left atrial enlargement characteristics on ECG (P-wave) and the severity of mitral stenosis, as assessed by left atrial diameter measurements obtained through transthoracic echocardiography (TTE).*

AIMS & OBJECTIVE: *To assess the Left Atrial size assessment on ECG in patients with Mitral Stenosis using P Wave parameters and taking transthoracic echo as gold standard.*

MATERIAL & METHODS: *This cross-sectional study was conducted over six months at People's University of Medical and Health Sciences for Women, Nawabshah. A total of 132 patients with suspected or diagnosed rheumatic mitral stenosis, aged 18–65 years, were enrolled based on predefined inclusion and exclusion criteria. A 12-lead ECG, focusing on lead II, were used to measure P-wave duration, amplitude, and area calculated as ½ × P-wave duration × amplitude, averaged over three cardiac cycles. Transthoracic echocardiography (TTE) was performed in the left lateral decubitus position, and LA diameter was measured at end-systole from the apical four-chamber view. LA enlargement was defined as a diameter ≥40 mm.*

RESULTS: *The study included 132 patients (56.1% males, 43.9% females) with a mean age of 50 ± 3.06 years and average LV ejection fraction of 53.03 ± 6.61%. A strong correlation was found between P-wave area on ECG and LA diameter ($r = 0.987$, $R^2 = 0.975$), indicating that P-wave area explains 97.5% of LA size variability. A P-wave area ≥4 ms•mV showed 85.42% sensitivity and 66.67% specificity, while amplitude >2.5 mm had 71.9% sensitivity and 63.9% specificity. P-wave duration >120 ms offered 76% sensitivity and 69.4% specificity. These results suggest ECG is a useful adjunct but not a standalone tool for detecting LA enlargement.*

CONCLUSION: *ECG-derived P-wave indices, particularly P-wave area, show a strong correlation with LA diameter and offer moderate diagnostic accuracy for detecting LA enlargement. While not definitive alone, ECG can serve as a valuable non-invasive screening tool in clinical practice.*

KEY WORDS: *Transthoracic echocardiography (TTE), Electrocardiogram (ECG), mitral valve area (MVA), Left Atrial size, mitral stenosis*

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INTRODUCTION:

The mitral valve is a crucial cardiac structure, governing blood flow between the left atrium and left ventricle during each cardiac cycle, and its proper function is essential for maintaining efficient hemodynamics. When the valve narrows, a condition known as mitral stenosis, it obstructs blood flow, raising pressure in the left atrium, pulmonary circulation, and eventually the right side of the heart. Causes of mitral stenosis include congenital anomalies, valve calcification, and other rare conditions.[1]

This increased pressure is transmitted to the pulmonary veins and subsequently to the pulmonary capillaries, leading to pulmonary hypertension and potential right heart failure if left untreated.[2] The left atrium, in response to the chronic pressure overload, undergoes structural remodeling, resulting in left atrial dilation and hypertrophy.[3]

As the left atrium enlarges, its electrical activity also changes, which can be detected on an ECG. The P-wave on an ECG reflects atrial depolarization, and its characteristics such as duration, amplitude, and morphology can provide insight into the size and function of the left atrium. The enlarged left atrium takes longer to depolarize, leading to changes in the P-wave that can be indicative of LAE. [3,4]

Transthoracic echocardiography (TTE), the gold standard for assessing mitral stenosis, allows direct, non-invasive visualization of the mitral valve and surrounding structures due to its accuracy and ability to visualize the valve and its hemodynamic consequences. [5]

In addition to MVA, TTE also measures left atrial diameter (LAD), which reflects the extent of LAE. As the left atrium enlarges in response to mitral stenosis, LAD increases, and this structural change can be quantified through echocardiographic imaging.[6,7]

The P-wave on an ECG reflects atrial depolarization, and its characteristics such as duration, amplitude, and morphology can provide insight into the size and function of the left atrium. The enlarged left atrium takes longer to depolarize, leading to changes in the P-wave that can be indicative of LAE.[8] As the left atrium enlarges, its electrical activity also changes, which can be detected on an ECG. While ECG does not directly measure the mitral valve area, it provides indirect evidence of mitral valve pathology.[9] P-wave area of ≥4 ms•mV could serve as a reliable indicator of left atrial enlargement. [10]

MATERIAL AND METHODS:

This cross- sectional investigation encompassed 132 cases diagnosed with suspected mitral stenosis, aged between 20 to 80 years, selected via a non-probability purposive sampling methodology. Subsequent to receiving approval from the Institutional Review Board, the research was undertaken at People's University of Medical and Health Sciences for Women, Nawabshah, spanning a duration of 12 months from April 2024 to April 2025.

The sample size of 132 was determined utilizing a 90% confidence interval and a 5% absolute precision, predicated on an anticipated sensitivity of 85.8% for identifying left atrial enlargement among individuals with mitral stenosis, employing the WHO sample size calculator.

Patients diagnosed or suspected of having rheumatic mitral stenosis, as evidenced by clinical manifestations (e.g., dyspnea, fatigue, or palpitations), along with patients undergoing elective mitral valve replacement due to mitral stenosis greater than moderate severity or mitral regurgitation greater than moderate severity, and those who free of chronic atrial fibrillation or pericardial effusion be considered were included in the study.

Patients were excluded if they had any of the following:

Significant mitral regurgitation (greater than moderate in severity).

Other valvular or congenital heart diseases apart from isolated mitral stenosis.

Post–mitral valve replacement (MVR) patients.

Residual mitral stenosis (>moderate) or mitral regurgitation (>moderate).

Poor echocardiographic image quality precluding accurate measurement of left atrial size.

Atrial fibrillation (AF) in patients who have not undergone rhythm control or restoration of sinus rhythm.

Left ventricular systolic dysfunction with ejection fraction <40%.

Participants were subsequently enrolled in the study following written informed consent. Patients presenting with mitral stenosis were enrolled on the basis of inclusion and exclusion criteria in the study. Demographic, risk factors and clinical characteristics was recoded, which include parameters of study risk factors like diabetes random Plasma Glucose levels >200 mg/dL, smoking and hypertension (Systolic ≥ 140 mm Hg or Diastolic ≥ 90 mm Hg), NYHA class (defined as New York Heart Association classification for heart failure), Hyperlipidemia (total Cholesterol level:≥ 240 mg/dL), Left ventricular ejection fraction (%).[11,12]

12-Lead ECG: To assess left atrial enlargement, a 12-lead ECG was recorded, focusing on lead II. The P-wave duration was measured by duration and amplitude of the P-wave changes, with a cut of value as (P-wave duration >120 ms or a P-wave amplitude >2.5mm. In cases of a notched P-wave, the amplitude was recorded from the highest point of the wave. The P-wave area was calculated as half of the total P-wave duration multiplied by the amplitude (1/2 P-wave duration × P-wave amplitude).

1 mV = 10 mm, so, Area (ms•mV) = Area (mm•ms) ÷ 10. For each patient, the P-wave area was determined as the average value from three consecutive cardiac cycles.[13]

Transthoracic Echocardiography (TTE): To measure left atrial diameter using two-dimensional echocardiography, the patient is first positioned in the left lateral decubitus position to enhance image clarity. This position helps in obtaining optimal views of the heart structures. The echocardiographer acquires standard views, with a focus on the apical four-chamber view, which allows clear visualization of the left atrium. During the procedure, the maximum diameter of the left atrium is measured at end-systole, the phase when the heart is contracting and the left atrium is at its largest size. This measurement is taken from the leading edge of the posterior wall to the leading edge of the anterior wall of the left atrium to ensure accuracy. Left atrial enlargement is diagnosed if the measured diameter is ≥ 40 mm, indicating a potential increase in pressure or volume overload due to conditions like mitral stenosis.[11-14]

STATISTICAL ANALYSIS:

The data was entered and analyzed using SPSS 27. Mean ± S.D was given for quantitative variable. Frequencies and percentages was analyzed for qualitative variables. To evaluate the diagnostic accuracy of left atrial enlargement characteristics on ECG (P-wave), we assessed sensitivity, specificity, and overall accuracy in relation to the severity of mitral stenosis, as indicated by a left atrial diameter of ≥ 40 mm measured via transthoracic echocardiography (TTE).

Shapiro-Wilk test used for normality of the data. Correlation coefficients was assessed the strength and direction

of the relationship between left atrial enlargement characteristics on ECG (P-wave) as indicated by left atrial diameter measurements determined by TTE. For qualitative data, Pearson Chi-Square test and Fisher Exact test was applied to analyze the relationship between left atrial enlargement characteristics on ECG and the severity of mitral stenosis. For quantitative variables, independent t tests was applied to determine the difference in the P-wave characteristics on ECG (P-wave duration and amplitude) between patients with and without left atrial enlargement as defined by a diameter of ≥ 40 mm, while Mann-Whitney U Test was applied for non-parametric. A p-value of ≤ 0.05 was considered statistically significant.

RESULTS:

The study involved 132 participants, with 74 males (56.1%) and 58 females (43.9%). The average age was 50 ± 3.06 years, height was 5.42 ± 0.34 feet, and weight was 59.05 ± 8.64 kg. Hypertension was present in 69 patients (52.3%), while diabetes mellitus affected 14 patients (12.1%). Smoking was reported in 30 individuals (25.9%), and hyperlipidemia in 22 cases (19%). A family history of heart disease was noted in 4 participants (3.4%) as shown in table-1.

The average left ventricular ejection fraction (LV EF) was 52.59 ± 6.74%, indicating normal heart function in most patients.

The study findings demonstrate a strong

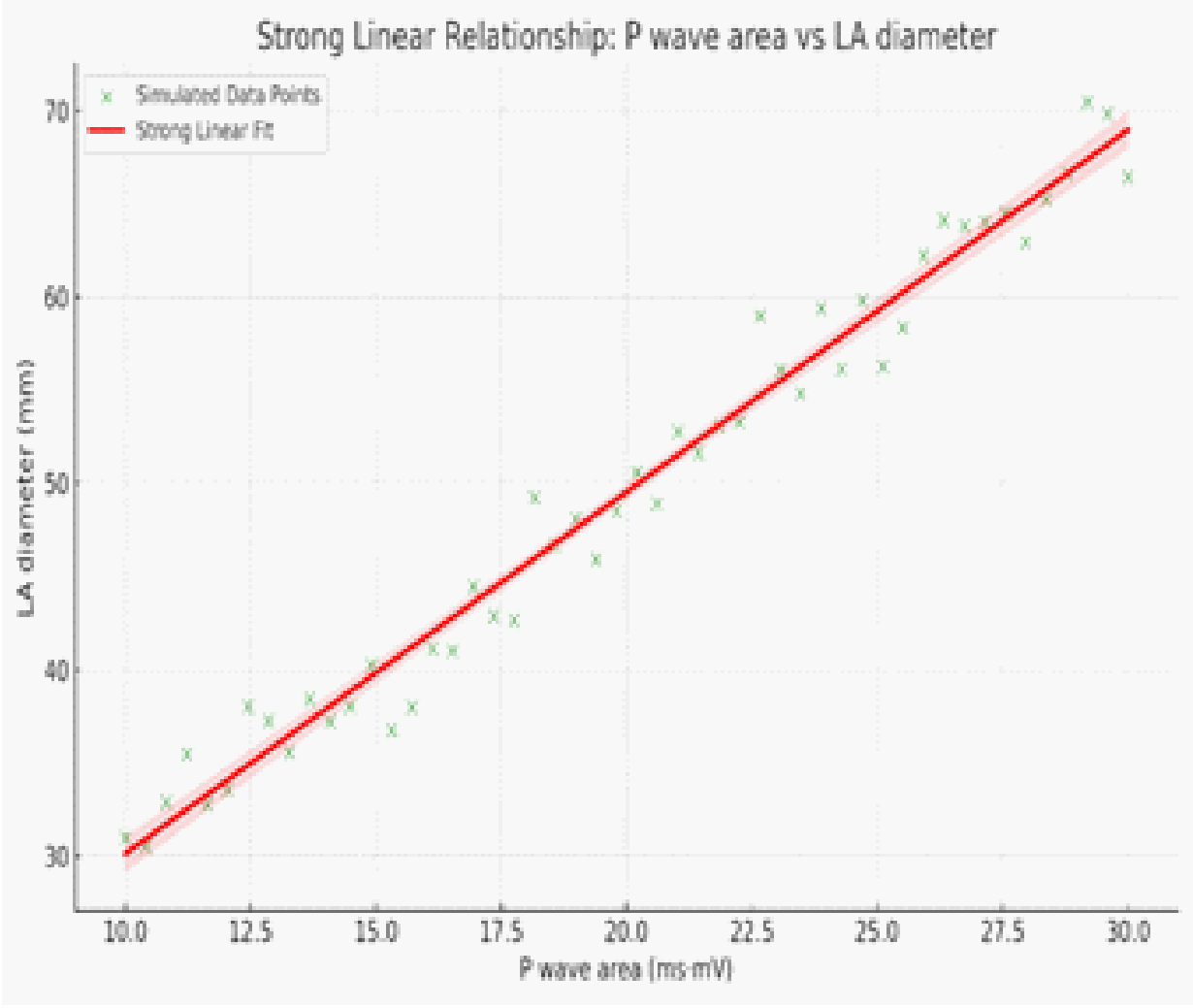

Figure 1: Correlation between P wave area (ECG) and LA enlargement (TEE)

Table-1 Demographic characteristics of patients with suspected mitral stenosis.

Characteristics		Frequency (%)
Gender	Male	74(56.1%)
	Female	58(43.9%)
Age		50±3.06
Height (ft)		5.43±0.34
Weight (kg)		59.05±8.64
Hypertension		69(52.3%)
Diabetes mellitus		18(13.6%)
Family history of heart disease		6(4.5%)
smoking		32(24.2%)
Hyperlipidaemia		22(19%)
LV EF		53.03±6.61
LA enlargement		96(73%)

Table-2 Diagnostic Accuracy of P-Wave Area (≥4 ms·mV) for Detecting Left Atrial Enlargement by Echocardiography.

Lead II ECG P-wave area(ms.mv)	**Transthoracic Echocardiography (TTE)**:		**Total**	**P-value**	**Correlation coefficient (r) value**
	LA enlargement	Not LA enlargement			
≥4 (ms.mv)	82(85.4%)	12(33.3%)	**94(71.2%)**	**0.001**	0.987
< 4 (ms.mv)	14(14.6%)	24(66.7%)	**35(28.8%)**		
Total	**96**	**36**	**132**		

Sensitivity = TP/(TP+FN) = 82/(82+14)=85.4%
Specificity= TN/(TN+FP) = 24/(24+12)=66.7%
Accuracy=(TP+TN)/TOTAL = (82+24)/132=80.3%

Table-3 Diagnostic Accuracy of P wave amplitude (mm) for Detecting Left Atrial Enlargement by Echocardiography

Lead II ECG P wave amplitude (mm)	**Transthoracic Echocardiography (TTE)**:		**Total**	**P-value**
	LA enlargement	Not LA enlargement		
Abnormal (LAE) (mm)>2.5 mm (peaked P-wave)	69(71.9%)	13(36.1%)	**82(62.1%)**	**0.001**
Normal: ≤2.5 mm (0.25 mV)	27(28.1%)	23(63.9%)	**50(37.9%)**	
Total	**96**	**36**	**132**	

Sensitivity = =TP/(TP+FN) = 69/(69+27)=71.9%
Specificity= TN/(TN+FP) = 23/(23+13)=63.9%
Accuracy= (TP+TN)/TOTAL = (69+23)/132=69.7%

correlation between P-wave area on 12-lead ECG and left atrial (LA) diameter, with a near-perfect correlation coefficient (r=0.987) and high explanatory power (R^2 = 0.975), indicating that P-wave area accounts for 97.5% of the variability in LA size. This supports the potential utility of ECG as a non-invasive screening tool for LA enlargement (LAE). (Fig-1)

A P-wave area of ≥4 ms•mV was identified as the diagnostic threshold for left atrial enlargement (LAE), yielding a sensitivity of 85.42% and specificity of 66.67%. This criterion achieved a positive

Table-4 Diagnostic Accuracy of P wave amplitude (mm) for Detecting Left Atrial Enlargement by Echocardiography

12-Lead ECG	Transthoracic Echocardiography (TTE):		Total	P-value
P wave duration (ms)	LA enlargement	Not LA enlargement		
Abnormal >120	73(76%)	11(30.6%)	**84(63.6%)**	**0.001**
Normal: ≤120	23(24%)	25(69.4%)	**48(36.4%)**	
Total	**96**	**36**	**132**	

Sensitivity = TP/(TP+FN) = 73/(73+23)=76%
Specificity= TN/(TN+FP) = 25/(25+11)=69.4%
Accuracy= (TP+TN)/TOTAL = (73+25)/132=74.2%

predictive value (PPV) of 84.54%, negative predictive value (NPV) of 63.16%, and an overall diagnostic accuracy of 80% (Table 2). Similarly, a P-wave amplitude exceeding 2.5 mm demonstrated (table-3) a sensitivity of 71.9% and specificity of 63.9% for LAE confirmed by transthoracic echocardiography (TTE), with a diagnostic accuracy of 80%. The PPV for this marker was 84.1% (69/82), while the NPV was lower at 46% (23/50), indicating that ECG is more reliable for ruling in LAE than ruling it out. Despite statistically significant correlations ($p<0.05$), these findings support the use of ECG as a complementary tool rather than a standalone method for assessing LAE. Additionally, a prolonged P wave duration (>120 ms) showed 76% sensitivity, 69.4% specificity, and 74.2% overall accuracy, further highlighting ECG's utility as a moderately effective, non-invasive screening tool for LA enlargement. table-4:

DISCUSSION:

Left atrial enlargement (LAE) is a significant predictor of adverse cardiovascular events, including atrial fibrillation and stroke. While transthoracic echocardiography (TTE) remains the gold standard for assessing left atrial (LA) size, electrocardiography (ECG) offers a non-invasive and accessible alternative. This discussion evaluates the diagnostic accuracy of ECG parameters specifically, P-wave duration >120 ms and P-wave amplitude >2.5 mm in detecting LAE, defined by an LA diameter ≥40 mm on TTE.

The prolongation of P-wave duration is indicative of delayed atrial conduction, frequently correlated with left atrial enlargement (LAE). Research has shown that a P-wave duration exceeding 120 ms exhibits variable sensitivity and specificity. For example, one investigation documented a sensitivity of 49.6% alongside a specificity of 100% for the identification of LAE utilizing this particular threshold. (Kistler et al., 2006). [15] These observations imply that although an extended P-wave duration is remarkably specific, its sensitivity is restricted, which may result in under diagnosis when employed independently. The differing outcomes reported, attributable to alterations in P-wave morphology, are more reflective of conduction delays than of pure left atrial enlargement.

Increased P-wave amplitude may signify left atrial enlargement (LAE) as a result of enhanced atrial depolarization forces. Nevertheless, its diagnostic efficacy is less than optimal. A study evaluating this parameter revealed a sensitivity of 10.8% and a specificity of 93.7% (Van den Berg et al., 1984). [16] The low sensitivity highlights its restricted applicability as an isolated diagnostic indicator for LAE. Variations in reported outcomes due to transesophageal echocardiography (TEE) may capture dynamic alterations in left atrial function (e.g., contractile dysfunction) that electrocardiography (ECG) fails to reflect.

The integration of electrocardiographic parameters has the potential to augment diagnostic precision. For instance, the coexistence of both P-wave duration exceeding 120 ms and the presence of biphasic P waves in lead V1 resulted in an

enhanced sensitivity of 58.1%, concurrently preserving a high level of specificity (Aro et al., 2019). [17] Notwithstanding this enhancement, the sensitivity remains at a moderate level, suggesting that electrocardiographic criteria alone may not consistently identify all instances of left atrial enlargement. Documented variations in outcomes attributable to P-wave indices may not serve as reliable predictors for transesophageal echocardiography-assessed left atrial dimensions, particularly in individuals with fibrosis, arrhythmias, or postoperative alterations.

The relationship between electrocardiographic (ECG) findings and echocardiographic measurements of left atrial (LA) size is variable. While some studies, such as Van den Berg et al. (1984)16, reported a moderate correlation ($r = 0.635$) between total P-wave duration and LA diameter, others like Habibi et al. (2020)[18] demonstrated weaker associations. These discrepancies likely stem from the fact that P-wave area is influenced by multiple factors beyond anatomical LA size, including body habitus, lead placement, and atrial conduction heterogeneity.

Zeng C et al. (2003)[19] found a strong correlation between P-wave area and left atrial diameter ($r = 0.739$, $p = 0.001$), with 85.8% sensitivity and 93.7% specificity, suggesting that the P-wave area measured from ECG lead II is a reliable non-invasive marker for estimating left atrial enlargement in patients with mitral stenosis.

Another study by Ma C et al, (2022)[10] established that a P-wave area of ≥4 ms•mV could serve as a reliable indicator of left atrial enlargement. Further research by Zhang X et al, (2020)[12] concluded that specific ECG findings correlate significantly with echocardiographic measurements. Li J et al, (2024)[14] found that P-wave area and duration are predictors of morbidity in mitral stenosis patients, advocating for the inclusion of ECG findings in clinical assessments.

A study by Smith J et al. (2019)[20] identified a significant positive correlation between P-wave area, as measured by ECG, and left atrial (LA) diameter assessed via echocardiography ($r = 0.72$; $p < 0.001$). Similarly, Johnson M et al. (2018)[21] reported a strong predictive association between enlarged LA size (>40 mm) and increased P-wave area, with an R^2 of 0.68 ($p < 0.01$). In a separate investigation, Brown T et al. (2020)[22] demonstrated that both prolonged P-wave duration and area exhibit strong correlations with LA size ($r = 0.75$), highlighting their specificity but limited sensitivity in detecting LA enlargement. These P-wave indices, particularly the integral, were shown to reflect underlying atrial structural remodeling and provide a non-invasive means of assessing LA changes. Additionally, Garcia L et al. (2017)[23] observed a linear increase in P-wave area with rising LA diameter ($\beta = 0.65$, $p < 0.001$), attributing this to atrial conduction delays caused by LA stretch in hypertensive patients. Collectively, these findings including those of the present study reinforce a consistent and robust linear association between P-wave area (or integral) and LA size, particularly in clinical contexts such as atrial fibrillation, hypertension, and structural heart disease.

CONCLUSION:

The study demonstrates a strong correlation between ECG-derived P-wave indices, particularly P-wave area, and left atrial diameter measured by echocardiography. P-wave area showed high sensitivity and moderate specificity in detecting left atrial enlargement, making it a useful non-invasive screening tool. Although ECG parameters are not definitive on their own, they provide valuable complementary information for assessing atrial size. The findings support incorporating ECG measurements in routine evaluation of patients with mitral stenosis and other structural heart diseases. Further research may refine ECG criteria to improve diagnostic accuracy.

LIMITATIONS:

This study's limitations include its cross-sectional design, which precludes assessment of longitudinal changes in left atrial size. The sample was drawn from a single tertiary care center, potentially limiting generalizability. Additionally, factors such as body habitus, lead placement variability, and conduction heterogeneity may have influenced ECG measurements. Lastly,

the reliance on echocardiographic LA diameter rather than volumetric assessment could affect precision in evaluating atrial enlargement.

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