

Comparison of Electrocardiographic Criteria With Echocardiographic Parameters For Detection of Left Ventricular Hypertrophy in Hypertensive And Non-Hypertensive Patients – A Cross Sectional Study

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ABSTRACT:

BACKGROUND: Left ventricular hypertrophy is an important marker of Cardiovascular risk and is commonly associated with hypertension. Electrocardiography (ECG) is widely available and inexpensive for screening LVH, but conventional ECG criteria may have limited sensitivity. Echocardiography Permits direct assessment of left ventricular structure and quantification of Left ventricular mass.

OBJECTIVE: To compare commonly used ECG criteria with echocardiographic parameters for detection of LVH and to evaluate the influence of hypertension on LVH detection.

METHODS: A prospective cross – sectional study was conducted among 138 adults at VELS Medical College and Hospital over 6 month period from september 2025 to February 2026. All participants underwent standard 12 – lead ECG and comprehensive transthoracic echocardiography. ECG evidence of LVH was assessed using Sokolow – Lyon, Cornell voltage, Romhilt – estes criteria. Echocardiographic assessment included interventricular septal thickness in diastole, left ventricular posterior wall thickness in diastole, left ventricular internal diameter in diastole, left ventricular mass, relative wall thickness, left ventricular ejection fraction diastolic parameters, left atrial size, and pulmonary artery systolic pressure. participants were classified according to echocardiographic LVH status and further compared according to hypertensive status. Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were calculated for the ECG criteria.

RESULTS: Of 138 participants, 99 had echocardiographic LVH and 39 were classified as controls. Mean age was significantly higher in the LVH group than in the control group (60.25±10.45 vs 50.00± 13.70 years; p < 0.001). hypertension was significantly more prevalent in participants with LVH than in controls (74.7% vs 43.6%; p < 0.001). LVM, IVSd, LVPWd, LVIDd, left atrial size, and pulmonary artery systolic pressure were higher in the LVH group, while LVEF and tissue Doppler E' velocity were lower. Among ECG criteria, sokolow-lyon showed the highest sensitivity (46.7%) and accuracy (57.2%), whereas Romhilt – Estes demonstrated the highest specificity (92.3%). Cornell criteria showed a sensitivity of 30.3%, specificity of 89.7%, and accuracy of 47.1%.

CONCLUSION: Hypertension was significantly associated with echocardiographic LVH. Conventional ECG criteria demonstrate relatively low sensitivity despite good specificity. Sokolow – Lyon showed the best sensitivity and overall accuracy, whereas Romhilt – Estes showed the highest specificity. Echocardiography remains more useful for identification and quantification of structural LV remodeling, while ECG can serve as an accessible screening tool.

KEYWORDS: Left Ventricular Hypertrophy; Hypertension; Electrocardiography; Echocardiography; Left Ventricular Mass; Diagnostic accuracy; Sokolow – Lyon.

INTRODUCTION:

Left Ventricular Hypertrophy is known as an increase in left ventricular mass. LVH may be adaptive and associated with increased left ventricular pressure or volume overload, or it may be associated with primary myocardial disease such as infiltrative, inflammatory, or sarcomeric disorders. LVH is more common in people with older age and is associated with an increased risk of death and cardiovascular events [1]. This typically manifests as thickening of the ventricular walls (concentric hypertrophy), chamber dilation with wall thickening (eccentric hypertrophy), or a combination of both, usually in response to chronic pressure or volume overload [2]. It is estimated that 10% to 20% of worldwide adults have LVH, while those with hypertension have a higher prevalence. LVH is present in about 40% of people with hypertension. The risk of cardiovascular disease is three times higher in hypertensive people with LVH. LVH has also been linked to older age, obesity, and ethnic origin [3]. The prevalence of LVH is comparable in men and women, with 15-20% of the general population. The most frequent causes of LVH are hypertension and aortic valve stenosis, both of which cause the heart to contract against an overload of pressure [4]. LVH, which is associated with a high incidence and risk of death from cardiovascular disease, is thought to affect over 30% of patients with hypertension.

globally. In order to prevent and treat CVD, early detection and intervention of LVH are crucial ^[5]. Increase in elevated blood pressure that cause increase in systemic pressure, volume overload and elevated workload on the LV and eventually causing the LVH. There are various types of LV of structural modifications to the anatomy of the heart that differ from concentric hypertrophy, eccentric remodeling, concentric remodeling and eccentric hypertrophy to a mixofeccentric and concentric hypertrophy. Hypertensive LVH is an established risk factor for arrhythmias, MI, HF, sudden cardiac death as well as stroke ^[6]. In healthy trained athletes, LVH can also develop as a reaction to work overload; this is known as physiological LVH ^[2,6]. In clinical practice, LVH can be identified using electrocardiography (ECG), echocardiography, and cardiac MRI. Echocardiography can visually measure all cardiac structure parameters in a non invasive manner; it should be used to diagnose LVH. Additionally it is the gold standard for detecting LVH, due to its high sensitivity and specificity ^[7].

Echo can determine its underlying causes. It is indispensable for accurately quantifying LV mass and geometry, as well as for the early detection of structural abnormalities in the left ventricle across a range of cardiovascular diseases ^[8]. On the other hand, another non invasive technique for identifying LVH is the Electrocardiogram, which is more practical, affordable and appropriate for widespread screening ^[8,10]. Patients with any cause have been able to predict the presence of LVH using standard 12-lead electrocardiogram (ECG). For this purpose, many different ECG parameters have been proposed ^[9]. According to current guidelines, there is no preference among dozens of ECG criteria for detecting LVH. These criteria include limb-lead voltage criteria (such as R aVL greater than 11mm Sokolow) and precordial-voltage criteria (such as S in V1 greater than 23mm), a mix of voltage and non-voltage criteria (Romhilt-Estes), and limb and precordial voltage criteria (eg: total 12-lead voltage greater than 175mm, Siegel) ^[10]. These criteria generally offer high specificity (typically 85%–90%) but low sensitivity (often less than 50%), with performance varying widely across different criteria in terms of sensitivity, specificity, and overall accuracy (Hancock et al., 2009) ^[11].

Numerous studies have evaluated the diagnostic accuracy of ECG criteria by comparing them with echocardiographic findings. Although ECG demonstrates high specificity, its limited sensitivity restricts its ability to detect early or mild LVH. The diagnostic performance of individual ECG criteria may also vary between hypertensive and non-hypertensive individuals because of differences in ventricular remodeling and myocardial mass ^[12,13].

Comparing ECG criteria with echocardiographic parameters in hypertensive and non-hypertensive patients is clinically important for identifying the most reliable ECG criteria for screening LVH. Such comparisons may improve early diagnosis, facilitate appropriate cardiovascular risk assessment, and optimize patient management, particularly in resource-limited settings where echocardiography may not be universally available.

METHODS AND MATERIALS:

1. **Study design:** Cross-sectional study.
2. **Sample Size:** 138 (91 Hypertensive, 47 Non-Hypertensive)
3. **Study place:** VELS Medical College and Hospital.
4. **Study period:** 6 Months (September– February) 2025–2026.

INCLUSION CRITERIA

- Age > 18 years, both male and Female.
 - Patients with LVH.
 - Hypertension, Diabetes Mellitus.
 - Valvular Heart Disease.
 - Hypertrophic cardiomyopathy, if mild
 - Willingness to participate
- ### EXCLUSION CRITERIA
- Bundle Branch Block
 - Right Ventricular Hypertrophy.
 - Cardiomyopathy
 - Pregnancy.
 - Poor echowindow

ELECTROCARDIOGRAPHY:

A standard 12 – lead electrocardiogram (ECG) was recorded using a Mindray BeneHeart R 12 model computerized ECG machine to assess the electrical activity of the heart in patient With hypertensive and non-hypertensive. The ECG was

recorded in patients with supine position after proper placement of limb and precordial electrodes. The recording were obtained at a standard paper speed of 25mm/sec and calibration of 10 mm/mV. The AHA/ACCF/HRS recommendations and the European society of cardiology were followed for left ventricular hypertrophy criteria.

ECG criteria For Left ventricular hypertrophy evaluated:

- Sokolow-Lyon voltage: S in $V1+R$ in $V5$ or $V6 \geq 35$ mm
- Cornell voltage: R in $aVL+S$ in $V3 \geq 28$ mm(men) or ≥ 20 mm(women).
- Romhilt –Estes point score ≥ 5 points for definite LVH (points for high voltage, ST-T changes, Left atrial enlargement, axis deviation, QRS prolongation, etc).

ECHOCARDIOGRAPHY: Ultrasound evaluation was conducted using a GE logic P9 ultrasound system to assess the Cardiac function in hypertensive and non hypertensive patients. The frame rate was set between 50 and 70 frames per second for 2D acquisition and between 135 and 145 frames per second for tissue Doppler imaging (TDI) approaches for three cardiac cycles. To obtain the best images, the patients should be in supine position and turn to left lateral position and the settings were manually changed. The American Society of Echocardiography (ASE) recommendations were followed for all two – dimensional (2D) and standard Doppler measures.

ECHOCARDIOGRAPHIC PARAMETERS:

- Interventricular Septal Diameter in diastole
- LV posterior wall thickness in diastole
- Left ventricular end diastolic diameter
- Left ventricular mass.
- Relative wall thickness.
- DT
- E/é Ratio
- E/A
- Pulmonary artery systolic pressure
- LA size
- Ejection Fraction

STATISTICAL ANALYSIS: statistical analysis was performed using statistical package for the social sciences. Continuous variables were expressed as mean $\pm$ standard deviation, and categorical variables were expressed as frequencies and percentages. Where appropriate, medians and interquartile ranges were also reported. Diagnostic performance of ECG criteria was evaluated using sensitivity, specificity, positive predictive value, negative predictive value, and accuracy. spearman correlation was used to evaluate relationship between ECG / echocardiographic parameters and left ventricular mass. A P value < 0.05 was considered statistically significant.

RESULTS:

BASELINE CHARACTERISTICS

A total of 138 participants were included, of whom 99 had echocardiographic LVH and 39 were classified as controls. The mean age was significantly higher in the LVH group than in the control group (60.25 ± 10.45 vs 50.00 ± 13.70 years; $P < 0.001$). within the LVH group, the largest proportion of participants were aged 56-65 years (39.4%), the followed by those aged > 6 years (29.3%). There was no statistically significant difference in sex distribution between the LVH and control groups. Males constituted 54.5% of the LVH group and 41.0% of the control group ($p = 0.15$). Table 1. Baseline Characteristics of participants according to echocardiographic LVH status

Variable	LVH (n=99)	Control (n=39)	P value
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Age, years	60.25±10.45	50.00±13.70	<0.001
Male, n(%)	54(54.5)	16(41.0)	0.150
Female, n(%)	45(45.5)	23(59.0)	0.150
Hypertension, n(%)	74(74.7)	17(43.6)	<0.001
Hypertension duration, years	6.41±5.15	4.83±4.32	0.244

HYPERTENSION and LVH:

Hypertension was present in 74 of 99 participants (74.7%) in the LVH group compared with 17 of 39 participants (43.6%) in the control group. This difference was statistically significant ($P < 0.001$). Among the 91 hypertensive participants, 45 participants in the LVH group and 12 in the control group had a duration of hypertension <6 years, while 29 participants in the LVH group and 5 in the control group had hypertension for >6 years. The difference in duration was not statistically significant ($P = 0.45$). Mean duration of hypertension was 6.41 ± 5.15 years in the LVH group and 4.83 ± 4.32 years in the control group.

ECHOCARDIOGRAPHIC PARAMETERS:

LVM was significantly higher in participants with LVH than in controls (217.00 ± 55.75 vs 164.41 ± 21.92 g; $P < 0.001$). IVS was significantly greater in the LVH group (12.24 ± 1.38 vs 10.77 ± 0.43 mm; $P < 0.001$), as was LVPWd (12.20 ± 1.25 vs 10.79 ± 0.52 mm; $p < 0.001$). LVIDd was also significantly higher in participants with LVH (46.26 ± 5.07 vs 43.77 ± 2.95 mm; $P = 0.005$).

LVEF was lower in the LVH group than in the control group ($59.0 \pm 6.9\%$ vs $62.4 \pm 2.24\%$; $P = 0.003$). Tissue Doppler e' velocity was significantly larger in the LVH group (33.15 ± 5.17 vs 30.87 ± 4.72 mm/s; $P = 0.018$), while PASP was significantly higher (32.85 ± 6.44 vs 29.38 ± 5.97 mmHg; $P = 0.004$).

VARIABLE	LVH GROUP (N=99)	CONTROL GROUP (N=39)	P-VALUE
LEFT VENTRICULAR MASS(g)	217.00±55.75	164.41±21.92	<0.001
RELATIVE WALL THICKNESS(RWT)	0.532±0.070	1.891±8.728*	0.121
IVSd	12.24±1.38	10.77±0.43	<0.001
LVPWd	12.20±1.25	10.79±0.52	<0.001
LVIDd	46.26±5.07	43.77±2.95	0.005
LVEF(%)	59±6.9	62.4±2.24	0.003
Evalue	0.723±0.209	0.715±0.186	0.838
Avalue	0.855±0.249	0.787±0.242	0.151
E/Avalue	0.91±0.42	1.02±0.38	0.154

E/E'	13.09±5.29	11.56±4.14	0.108
E'	0.062±0.024	0.073±0.023	0.022
DT	160.45±40.33	155.95±36.24	0.545
PASP	32.85±6.44	29.38±5.97	0.004
LAsize	33.15±5.17	30.87±4.72	0.018
Heartrate	75.75±16.05	78.31±13.76,	0.382

ECG LVH CRITERIA: Sokolow – lyon criteria were positive in 52 participants (37.7%), cornell criteria in 34 participants (24.6%), and romhilt – estes criteria in 13 participants (9.4%). Sokolow – lyon demonstrated the highest sensitivity (46.7%) and accuracy (57.2%). cornell criteria demonstrated a sensitivity of 30.3%, specificity of 89.4% and accuracy of 47.1%. romhilt – estes demonstrated the highest specificity (92.3%) but the lowest sensitivity (10.1%) and accuracy (33.3%).

Performance of criteria in the assessment of left ventricular hypertrophy

CRITERIA	SENSIBILITY (%)	SPECIFICITY (%)	PPV (%)	NPV (%)	ACCURACY (%)
SOKOLOW-LYON	46.7	84.6	88.5	38.4	57.2
CORNELL	30.3	89.7	88.2	33.7	47.1
ROMHILT-ESTES	10.1	92.3	76.9	28.8	33.3

HYPERTENSIVE VERSUS NON HYPERTENSIVE PARTICIPANTS

There were 91 hypertensive and 47 non – hypertensive participants. There was no statistically significant difference in the proportion of participants meeting sokolow – lyon criteria between hypertensive and non – hypertensive groups ($p=0.79$). similarly, no significant differences were observed for cornell criteria ($P=0.51$) or romhilt – estes criteria ($P=0.79$). In contrast, echocardiographic LVH differed significantly between hypertensive and non – hypertensive participants ($P<0.001$).

DISCUSSION

The present study evaluated the diagnostic performance of three conventional ECG criteria against echocardiographic assessment of LVH in hypertensive and non-hypertensive adults. The principal finding was that hypertension was significantly associated with echocardiographic LVH, whereas the conventional ECG criteria demonstrated limited sensitivity. The LVH group was significantly older than the control group. The mean age was 60.25 years in the LVH group compared with 50.00 years in the control group. Increasing age is associated with cardiovascular remodeling and may contribute to increased left ventricular mass. Similar relationships between age and LVH have been described in population-based studies [3].

Hypertension showed a strong association with LVH in the present study. Echocardiographic LVH was present in 74.7%

of hypertensive participants in the LVH group compared with 43.6% of the control group. Chronic pressure overload associated with hypertension promotes increased myocardial wall thickness and left ventricular mass. These findings are consistent with previous studies demonstrating an association between hypertension and increased echocardiographic left ventricular mass [18,19].

The echocardiographic findings demonstrated significant structural differences between participants with and without LVH. LVM, IVSd, LVPWd, and LVIDD were significantly increased in the LVH group. These findings support the ability of echocardiography to identify structural remodeling that may not be detected by ECG. The LVH group also demonstrated a lower mean LVEF, although the mean value remained within a generally preserved systolic function range. Tissue Doppler E' velocity was significantly lower in the LVH group, suggesting altered myocardial relaxation. Left atrial size and PASP were also significantly higher in participants with LVH. These findings may reflect the hemodynamic consequences of ventricular remodeling and altered filling.

In the present study, Sokolow–Lyon was the most frequently positive ECG criterion, occurring in 37.7% of participants. Cornell criteria were positive in 24.6%, while Romhilt–Estes was positive in 9.4%. However, the diagnostic performance of the criteria was limited by relatively low sensitivity. Sokolow–Lyon demonstrated the highest sensitivity at 46.7% and the highest accuracy at 57.2%. Cornell criteria showed lower sensitivity at 30.3%, although specificity was 89.7%. Romhilt–Estes showed the highest specificity at 92.3% but very low sensitivity at 10.1%. Thus, a positive Romhilt–Estes result was relatively specific for LVH, but a negative result could not reliably exclude echocardiographic LVH. These findings are consistent with previous literature demonstrating that conventional ECG criteria generally have high specificity but limited sensitivity for echocardiographically defined LVH [9,10,14,20]. Marcato et al. reported low sensitivity for conventional ECG criteria when compared with echocardiography, while Bayram et al. similarly demonstrated poor sensitivity of Sokolow–Lyon, Cornell, and Romhilt–Estes criteria [14,20].

The present findings also support the results of Xie and Wang, who demonstrated only modest correlations between ECG variables and echocardiographic LV mass index in hypertensive patients [15]. The lack of significant correlation between the ECG criteria and LVM in the present study further emphasizes that ECG voltage abnormalities do not necessarily reflect the degree of anatomical LV hypertrophy. No significant difference was observed in the prevalence of individual ECG criteria between hypertensive and non-hypertensive participants. In contrast, echocardiographic LVH showed a significant difference between the two groups. This suggests that echocardiography may detect hypertension-associated structural remodeling more effectively than individual conventional ECG criteria.

Recent studies have also explored improved ECG-based methods, including computer-assisted and machine-learning approaches. Such approaches may improve sensitivity by incorporating multiple ECG features beyond conventional voltage criteria [16,17]. However, conventional ECG remains clinically valuable because of its low cost and wide availability, particularly where echocardiography is not readily accessible. Overall, the findings indicate that ECG and echocardiography should be viewed as complementary rather than competing diagnostic methods.

ECG can provide an accessible screening assessment, whereas echocardiography provides more comprehensive information regarding LV mass, wall thickness, geometry, systolic function, diastolic function, and associated structural remodeling.

Limitations:

This study has several limitations. First, the sample size was relatively small and was obtained from single tertiary – care institution, which may limit generalizability. Second, the cross – sectional design does not allow assessment of temporal changes in LV remodeling. Third, the study compared conventional ECG criteria with echocardiography and did not include cardiac magnetic resonance imaging as an independent reference standard. Fourth, the relatively small number of participants in some subgroup comparisons. Finally, the study did not evaluate newer ECG criteria or machine – learning – based approaches.

Conclusion:

The study demonstrated that patients with hypertension had a significantly higher incidence of LVH. Compared to ECG, echocardiography was better at identifying structural changes in the left ventricle. Romhilt – Estes showed the highest specificity among ECG criteria, while Sokolow – Lyon demonstrated the best sensitivity and accuracy. The study demonstrates that ECG LVH criteria showed a stronger association with echocardiographic LVH in hypertensive patients, particularly with the Romhilt – Estes and Sokolow criteria due to smaller sample size. Echocardiography is more sensitive for detecting and quantifying LVH and structural cardiac remodeling, while ECG is useful as a simple and

accessible screening method.

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