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## Original Article

# *Diagnostic Utility of Electrocardiography and Transthoracic Echocardiography in the Diagnosis of Left Ventricular Hypertrophy in Patients With Known Hypertension*

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## ABSTRACT

***Background:*** Left ventricular hypertrophy (LVH) is a significant risk factor for cardiovascular events. The increase in LV mass is usually screened by electrocardiography (ECG), which is often insensitive. Despite being insensitive, ECG is cost-effective compared with echocardiography. Therefore, this study aimed to assess the diagnostic utility of ECG and echocardiography in the diagnosis of LVH among patients with hypertension.

***Methods:*** This comparative prospective study was carried out on 200 patients with hypertension. ECG and echocardiography were performed on all the patients to evaluate the presence of LVH. The Sokolow–Lyon index, the Romhilt–Estes point, and the Cornell voltage criteria were the ECG criteria used. For 2D echocardiography, interventricular septal thickness (IVST) and left ventricular posterior wall thickness (LVPWT) were considered. The $\chi^2$ test was employed to test the significance of the qualitative variables. A *P* value of less than 0.05 was considered statistically significant.

***Results:*** The specificity of the Cornell voltage criteria was high compared with that of the other criteria of ECG, although the sensitivity was low for all the other ECG criteria. The occurrence of LVH according to the IVST criteria of 2D echocardiography was significantly associated with the severity and duration of hypertension ($P = 0.042$). The majority of the patients with diastolic dysfunction were in Stage I hypertension.

***Conclusions:*** The diagnostic utility of ECG compared with echocardiography was found to be insensitive. Hence, echocardiography is the preferred method in the detection of LVH in patients with hypertension. However, improved ECG criteria can be adopted in the future for LVH detection due to its cost-effective nature. ***(Iranian Heart Journal 2021; 22(1): 74-83)***

**KEYWORDS:** Electrocardiography, Hypertension, Left ventricular hypertrophy, Ventricular septum

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Left ventricular hypertrophy (LVH) is common in patients with hypertension and increases the risk of heart failure, sudden cardiac death, cerebrovascular events, heart failure, arrhythmias, and death following myocardial infarction.[1-3] Considered a pathological adaptation to cardiovascular disease, LVH is a strong

independent predictor of cardiovascular morbidity and mortality.[4, 5] The prevalence of LVH is steadily increasing and is more alarming in developing nations. An increase is seen with age, severity, and hypertension duration. LVH has a significant prevalence in general, with rates of between 16% and 20% in population-based samples and up to 50% in individuals with hypertension.[6-8] It results in diastolic dysfunction and decreased coronary flow reserve.[9] LVH, measured by indexed LV mass on echocardiography, is associated with impaired diastolic function.[10] The principle mechanisms by which LVH adversely affects diastolic function were thought to be abnormalities in LV active relaxation and passive stiffness.[11] Long-term studies from Framingham show that patients detected with LVH by either echocardiography or electrocardiography (ECG) are at a substantially higher risk of cardiovascular events.[12, 13]

The early detection and accurate diagnosis of LVH are of paramount importance. Current screening methods usually confirm LVH by ECG, echocardiography, chest radiography, and magnetic resonance imaging. Nonetheless, in clinical practice, ECG and echocardiography are the most frequently used methods mainly for the prognostic relationship in the accurate prediction of an increased cardiovascular risk when LVH is observed.[14] The E/A ratio, which can be estimated by Doppler echocardiography, is a first-generation test for the diastolic performance of the heart.[15]

Electrocardiography is the simplest and most frequently used method for the detection of LVH. As a result of the endorsement of 37 various ECG criteria by the American Heart Association, there is substantial confusion among clinicians. Moreover, these criteria have high specificities but low sensitivities.[16, 17] Transthoracic echocardiography was considered the gold standard to assess LVH.[18, 19] In spite of the benefits of echocardiography as a noninvasive imaging modality for the efficient assessment of LVH, it is too expensive, time-consuming, and expert-dependent to be used as a screening method. Hence, it was important to study the reliability of ECG in the diagnosis of patients with hypertension. Therefore, this research was conducted to study the diagnostic utility of ECG and transthoracic echocardiography in the diagnosis of LVH among patients with hypertension.

## METHODS

### Study Design

This comparative prospective study was performed on patients with hypertension at a tertiary hospital in India from October 2014 to March 2016. A total of 200 subjects aged above 40 years were selected after they provided written informed consent. The study was conducted after approval from the institutional ethics committee. Patients from both inpatient and outpatient departments were included. The exclusion criteria were hypertension with Type II diabetes mellitus, chronic kidney disease, thyroid and hepatic dysfunction, congenital heart diseases, poor echocardiography windows, LV systolic dysfunction, and non-provision of consent for 2D echocardiography.

All the patients underwent ECG and 2D echocardiography to investigate LVH. A standard 12-lead ECG (Scalar ECG) was used. For ECG, the Sokolow–Lyon index, the Romhilt–Estes point scoring system, and the Cornell voltage criteria were the criteria used. For 2D echocardiography, left ventricular posterior wall thickness (LVPWT) and interventricular septal thickness (IVST) were considered.

### ECG Criteria for LVH

In the Sokolow–Lyon index, S in V1 + R in $V_5$ or $V_6$ (whichever was larger) of 35 mm or more (≥ 7 large squares) and R in aVL of 11 mm or more were utilized.[12, 20] The Cornell

voltage criteria involve the measurement of the sum of the R wave in lead VL and the S wave in lead $V_3$. The Cornell criteria for LVH included S in $V_3$ + R in aVL of greater than 28 mm in men and S in $V_3$ + R in aVL of greater than 20 mm in women.[21] The Romhilt–Estes point scoring system interpreted the presence of LVH if the point score was greater than 5 points and interpreted the probability of LVH if the score was 4 points.

### Two-Dimensional Echocardiography Criteria for LVH

For the diagnosis of LVH, LV mass, and LV wall thickness were utilized using various recordings. IVST was measured from the leading edge of the right septal echocardiography to the leading edge of the left septal echocardiography, at end-diastole. The criterion employed to diagnose LVH in this study was greater than 13 mm in systole. LVPWT was measured as the distance between the anterior endocardial echocardiography and the anterior surface of the epicardial echocardiography, at end-diastole. A measurement of LVPWT of greater than 12 mm in diastole was the criterion followed in the present study. LV internal dimension was the distance between the left side of the interventricular septum and posterior LV endocardium at the level of the chordae tendineae. End-diastole was considered to be the onset of QRS. LV mass was calculated using 2 methods: the biplane area-length method and the truncated ellipsoid method. In both methods, LV wall volume was derived by subtracting intracavity LV volume from the entire epicardial LV volume including LV wall and ventricular septum.

### Statistical Analysis

The data were examined using SPSS software, version 20, and Epi Info software, version 7.2. The Levene test for the equality of variances was used, and equal variances were assumed within the groups. The independent sample test (unpaired *t*-test) was applied to test the equality of means. The $\chi^2$ test was applied to test the significance of the qualitative variables. A *P* value of less than 0.05 was considered significant.

## RESULTS

Age distribution based on gender is presented in Table 1. The majority (33.33%) of the cases were in the age group ranging from 60 to 69 years old with a mean age of 64.01 ± 12.16 years.

Patients with LVH were classified based on various ECG and 2D echocardiography criteria. Based on the ECG criteria, the occurrence of LVH was observed to be highest according to the Sokolow–Lyon criteria (41.5%). With regard to 2D echocardiography, LVH was observed to be highest in the IVST criteria (19%) (Table 2). The comparisons of various ECG criteria with the LVPWT and IVST criteria of 2D echocardiography are presented in Table 3. Among 200 subjects, the ECG of the Romhilt–Estes criteria diagnosed LVH in 45.5% of the subjects. According to the LVPWT criteria of 2D echocardiography, 13% of the study population had LVH and according to the IVST criteria of 2D echocardiography, 19% had LVH. The comparison between the ECG of the Romhilt–Estes criteria and the 2D echocardiography of the LVPWT criteria showed a sensitivity of 42.31%, a specificity of 54.02%, a positive predictive value of 12.09%, a negative predictive value of 86.24%, and an accuracy of 52.50%. Similarly, the comparison between the ECG of the Romhilt–Estes criteria and the 2D echocardiography of the IVST criteria demonstrated a sensitivity of 39.47%, a specificity of 53.09%, a positive predictive value of 16.48%, a negative predictive value of 78.9%, and an accuracy of 50.50%.

**Table 1:** Age distribution by gender

| Age Group (y) | Men | Women | Total |
|---|---|---|---|
| 40-49 | 19 | 13 | 32 |
| 50-59 | 17 | 10 | 27 |
| 60-69 | 40 | 29 | 69 |
| 70-79 | 26 | 22 | 48 |
| 80-89 | 14 | 7 | 21 |
| 90-99 | 2 | 1 | 3 |
| Total | 118 | 82 | 200 |

**Table 2:** Study population with LVH based on various ECG and 2D echocardiography criteria

| Variables | Frequency |
|---|---|
| **ECG Criteria** | |
| **Sokolow–Lyon** | |
| LVH present | 83 (41.5) |
| LVH absent | 117 (58.5) |
| **Romhilt–Estes** | |
| LVH present | 72 (36) |
| LVH absent | 109 (54.5) |
| LVH probable | 19 (9.5) |
| **Cornell Voltage** | |
| LVH present | 55 (27.50) |
| LVH absent | 145 (72.50) |
| **2D Echocardiography Criteria** | |
| **IVST** | |
| LVH present | 38(19) |
| LVH absent | 162(81) |
| **LVPWT** | |
| LVH present | 26(13) |
| LVH absent | 174(87) |

ECG, Electrocardiography; LVH, Left ventricular hypertrophy; IVST, Interventricular septal thickness; LVPWT, Left ventricular posterior wall thickness

**Table 3:** Comparisons of various ECG criteria with LVPWT and IVST

| ECG Criteria | LVPWT | | Total | IVST | | Total |
|---|---|---|---|---|---|---|
| | LVH Present (%) | LVH Absent (%) | | LVH Present (%) | LVH Absent (%) | |
| **Romhilt–Estes** | | | | | | |
| LVH present | 11(12.09) | 80(87.91) | 91(45.5) | 15(16.48) | 76(83.52) | 91(45.5) |
| LVH absent | 15(13.76) | 94(86.24) | 109(54.5) | 23(21.1) | 86(78.9) | 109(54.5) |
| Total | 26(13) | 174(87) | 200(100) | 38(19) | 162(81) | 200(100) |
| *P* value | 0.511 | | | 0.126 | | |
| **Sokolow–Lyon** | | | | | | |
| LVH present | 10(12.05) | 73(87.95) | 83(41.5) | 12(14.46) | 71(85.54) | 83(41.5) |
| LVH absent | 16(13.68) | 101(86.32) | 117(58.5) | 26(22.22) | 91(77.78) | 117(58.5) |
| Total | 26(13) | 174(87) | 200(100) | 38(19) | 162(81) | 200(100) |
| *P* value | 0.778 | | | 0.190 | | |
| **Cornell Voltage** | | | | | | |
| LVH present | 10(12.05) | 73(87.95) | 83(41.5) | 9(16.36) | 46(83.63) | 55(27.5) |
| LVH absent | 16(13.68) | 101(86.32) | 117(58.5) | 29(20) | 116(80) | 145(72.5) |
| Total | 26 (13) | 174 (87) | 200 | 38(19) | 162(81) | 200(100) |
| *P* value | 0.138 | | | 0.558 | | |

ECG, Electrocardiography; LVH, Left ventricular hypertrophy; IVST, Interventricular septal thickness; LVPWT, Left ventricular posterior wall thickness

* $P < 0.05$ was considered statistically significant.

Considering the Sokolow–Lyon criteria, 41.5% of the study population had LVH compared with 13% and 19% of the subjects diagnosed with the LVPWT and IVST criteria of 2D echocardiography. The comparison between the ECG of the Sokolow–Lyon criteria and the 2D echocardiography of LVPWT criteria showed a sensitivity of 38.46%, a specificity of 58.05%, a positive predictive value of 12.05%, a negative predictive value of 86.32%, and an accuracy of 55.50%. Likewise, the comparison between the ECG of the Sokolow–Lyon criteria and the 2D echocardiography of IVST yielded a sensitivity of 31.58%, a specificity of 56.17%, a positive predictive value of 14.46%, a negative predictive value of 77.78%, and an accuracy of 51.50%.

Considering the Cornell voltage criteria of ECG, 27.5% of the subjects had LVH, whereas those diagnosed based on the LVPWT criteria and IVST criteria of 2D echocardiography accounted for 13% and 19% of the patients with LVH, respectively. The comparison between the ECG of the Cornell voltage criteria and the 2D echocardiography of LVPWT criteria demonstrated a sensitivity of 15.38%, a specificity of 70.69%, a positive predictive value of 7.27%, a negative predictive value of 84.83%, and an accuracy of 63.50%. Similarly, the comparison between the ECG of the Cornell voltage criteria and the 2D echocardiography of IVST revealed a sensitivity of 23.68%, a specificity of 71.60%, a positive predictive value of 16.36%, a negative predictive value of 80.00%, and an accuracy of 62.50%.

There were no statistically significant differences between the diagnostic capability of the various criteria associated with ECG and 2D echocardiography ($P > 0.05$).

The distribution of the subjects with regard to the severity of hypertension among the study population showed that out of the 200 patients, 38.5% had prehypertension, 36.5% had Stage I hypertension, and 25% had Stage II hypertension.

Among 111 patients with hypertension of less than 3 years' duration, 8% had LVH. Out of 60 patients with hypertension of between 3 and 6 years' duration, 5% had LVH. Among those with hypertension of more than 6 years' duration, none had LVH according to the LVPWT criteria. Considering the IVST criteria, it was observed that 8.5% had LVH in the subjects who had hypertension of less than 3 years' duration, 8% had LVH in the subjects with hypertension of between 3 and 6 years' duration, and 2.5% had LVH in the subjects with hypertension of more than 6 years' duration.

In terms of the severity of hypertension, among 77 subjects with LVH, 4% had prehypertension, 6.5% had Stage I hypertension, and only 2.5% had Stage II hypertension according to the LVPWT criteria. Based on the IVST criteria, 4.5% had prehypertension, 8% had Stage I hypertension, and only 6.5% had Stage II hypertension. Nevertheless, the differences between the occurrence of LVH according to the LVPWT and IVST criteria on severity and duration were not found to be statistically significant (Table 4).

The association between the duration and severity of hypertension among the subjects who had LVH according to the LVPWT and IVST of 2D echocardiography showed that most of the patients had either prehypertension or Stage I hypertension of less than 3 years' duration. In contrast, among the subjects who had LVH according to the IVST of 2D echocardiography, the majority of the patients had either Stage I hypertension of less than 3 years' duration or hypertension of between 3 and 6 years' duration. In terms of the IVST criteria of 2D echocardiography, a significant association ($P = 0.042$) was observed between the

severity and duration of hypertension among the patients with LVH (Table 5).

The association between diastolic dysfunction and hypertension severity is depicted in Table 6.

Out of 24 subjects with Stage III and Stage IV diastolic dysfunction, only 3% had Stage II hypertension. There was no statistical significance with regard to diastolic dysfunction and hypertension severity.

**Table 4:** Occurrence of LVH according to the different criteria of 2D echocardiography in relation to the duration and severity of HTN

| HTN Variables | LVPWT | | Total | *P* value | IVST | | Total | *P* value |
|---|---|---|---|---|---|---|---|---|
| | LVH Present (%) | LVH Absent (%) | | | LVH Present (%) | LVH Absent (%) | | |
| **Duration of HTN** | | | | | | | | |
| <3 y | 16(8) | 95(47.5) | 111(55.5) | 0.08546[C] | 17(8.5) | 94(47) | 111(55.5) | 0.1893[C] |
| 3 to 6 y | 10(5) | 50(25) | 60(30) | | 16(8) | 44(22) | 60(30) | |
| >6 y | 0(0) | 29(14.5) | 29(14.5) | | 5(2.5) | 24(12) | 29(14.5) | |
| Total | 26(13) | 174(87) | 200(100) | | 38(19) | 162(81) | 200(100) | |
| **Severity of HTN** | | | | | | | | |
| Pre-HTN | 8(4) | 69(34.5) | 77(38.5) | 0.3082[C] | 9(4.5) | 68(34) | 77(38.5) | 0.09678[C] |
| Stage I HTN | 13(6.5) | 60(30) | 73(36.5) | | 16(8) | 57(28.5) | 73(36.5) | |
| Stage II HTN | 5(2.5) | 45(22.5) | 50(25) | | 13(6.5) | 37(18.5) | 50(25) | |
| Total | 26(13) | 174(87) | 200(100) | | 38(19) | 162(81) | 200(100) | |

HTN, Hypertension; IVST, Interventricular septal thickness; LVH, Left ventricular hypertrophy; LVPWT, Left ventricular posterior wall thickness

C, $\chi^2$ test

**P* < 0.05 was considered statistically significant.

**Table 5:** Association between the duration and severity of HTN among patients with LVH according to the LVPWT and IVST criteria of 2D echocardiography

| Criteria of 2D Echocardiography | Pre-HTN | Stage I HTN | Stage II HTN | Total | *P* value |
|---|---|---|---|---|---|
| **LVPWT: Duration/HTN** | | | | | |
| <3 y | 5(31.25) | 8(50) | 3(18.75) | 16 | 1[C] |
| 3 to 6 y | 3(30) | 5(50) | 2(20) | 10 | |
| Total | 8(30.76) | 13(50) | 5(19.23) | 26 | |
| **IVST: Duration/HTN** | | | | | |
| <3 y | 7(41.17) | 6(35.29) | 4(23.52) | 17 | 0.04248*[C] |
| 3 to 6 y | 2(12.5) | 9(56.25) | 5(31.25) | 16 | |
| >6 y | 0(0) | 1(20) | 4(80) | 5 | |
| Total | 9(23.68) | 16(42.10) | 13(34.21) | 38 | |

HTN, Hypertension; IVST, Interventricular septal thickness; LVH, Left ventricular hypertrophy; LVPWT, Left ventricular posterior wall thickness

C, $\chi^2$ test

**P* < 0.05 was considered statistically significant.

**Table 6:** Association between diastolic dysfunction and HTN severity

| E/A Ratio | Severity of HTN | | | Total | *P* value |
|---|---|---|---|---|---|
| | Pre-HTN (%) | Stage I HTN (%) | Stage II HTN (%) | | |
| <0.75 (Stage I DD) | 16 (8) | 13 (6.5) | 12 (6) | 41 (20.5) | 0.9176 [C] |
| 0.75-1.5 (Normal) | 51 (25.5) | 52 (26) | 32 (16) | 135 (67.5) | |
| >1.5 (Stages III & IV DD) | 10 (5) | 8 (4) | 6 (3) | 24 (12) | |
| Total | 77 (38.5) | 73 (36.5) | 50 (25) | 200 (100) | |

DD, Diastolic dysfunction; HTN, Hypertension

C, $\chi^2$ test

**P* < 0.05 was considered statistically significant.

## DISCUSSION

LVH is an independent predisposing factor associated with a high risk of cardiovascular outcomes, hence the importance of screening for diastolic dysfunction in patients with LVH, which could otherwise become a hazard for further cardiac dysfunction. Currently, LVH is diagnosed via either standard 12-lead ECG or different imaging methods such as cardiac magnetic resonance and echocardiography. Although ECG is widely used to diagnose LVH in clinical practice, the low sensitivity of ECG criteria restricts its use in the detection of LVH. Accordingly, we performed the present study specifically to evaluate the diagnostic utility of ECG and echocardiography in the diagnosis of LVH among patients with hypertension.

According to our results, the Cornell voltage criteria showed a mean sensitivity of 15.38% and a mean specificity of 70.69% with the LVPWT criteria according to 2D echocardiography. With IVST, the Cornell voltage criteria showed a sensitivity of 23.68% and a specificity of 71.60%. Sundstrom et al[22] reported a sensitivity of 16% and a specificity of 89% in their investigation. Various other studies have also reported similar results vis-à-vis sensitivity and specificity.[23-25] The results demonstrated a low sensitivity but a high specificity concerning the Cornell voltage criteria. Among the different ECG criteria, the Cornell voltage criteria showed a better specificity. Pewsner et al[26] revealed a low diagnostic value for ECG criteria in interpreting LVH and recommended that ECG criteria not be employed to rule out LVH in patients with hypertension. According to Levy et al,[6] the low sensitivity of ECG could be due to chest wall thickness, and as a result of low sensitivity, these methods will have limited use as screening modalities.

We observed a significant association between the severity and duration of hypertension among our patients with LVH in regard to IVST criteria. In a study performed by Antoniucci,[27] the incidence of LVH ranged between 11.8% and 14.5% among patients with hypertension as compared with those who were normotensive (2.7–3.2%) and those with borderline hypertension (1.6–6.1%). Additionally, the length of hypertension plays a significant role in the prevalence of LVH. Izzo et al[28] reported that longer hypertension duration has a significant association with the development of LVH. Thus, the association of the severity of hypertension could be attributed to the fact that the incidence of LVH rises with the severity of the hypertensive disease.[29]

In terms of diastolic dysfunction, 32.5% of our cases had diastolic dysfunction in terms of the E/A ratio, and the majority of these patients were in Stage I. This finding is in accordance with the result of a study by Avdic et al,[30] who reported 57 cases with diastolic dysfunction in 65% of patients with LVH. Similarly, Parrinello et al[31] reported a prevalence of altered diastolic dysfunction in 42% of cases and LVH in 55 patients. These findings indicate that echocardiography can diagnose diastolic dysfunction in patients with LVH in earlier stages.

In our study, the diagnostic utility of ECG for LVH in patients with hypertension showed less sensitivity, although the specificity was high in terms of the Cornell voltage criteria.

The results of the present study should be interpreted in light of its limitations. We estimated IVST and LVPWT by 2D echocardiography, although we could have attained better accuracy had we utilized cardiovascular magnetic resonance imaging. We enrolled subjects from a population that required echocardiography; our findings,

therefore, cannot be generalized to healthy or normal subjects. Furthermore, we only drew upon 3 criteria in ECG for comparison with 2D echocardiography. Studies on other criteria enjoying higher sensitivities should be conducted to determine the effectiveness of ECG over echocardiography.

The low sensitivity of ECG criteria implies that it has limited use as a screening test. Echocardiography should be the preferred choice in the identification of LVH in patients with hypertension. Still, in a developing country like India, echocardiography facilities are not accessible in all rural settings. Hence, upgraded ECG criteria such as QRS voltage can be considered to be standard investigations in the future for LVH on the strength of their cost-effectiveness and availability.

## CONCLUSIONS

ECG, as a baseline diagnostic utility for cardiac diseases, is less sensitive and more specific than echocardiography. Echocardiography is regarded as the preferred method in the identification of LVH in patients with hypertension. Further research is needed to outline the process of fundamental ECG more clearly and its capability toward the identification of LVH in more advanced hypertensive diseases.

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