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ORIGINAL RESEARCH

A Comparative Study of Electrocardiographic and Echocardiographic Evidence of Left Ventricular Hypertrophy

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ABSTRACT

Introduction: The increased risk of morbidity and mortality associated with left ventricular hypertrophy (LVH) diagnosed by electrocardiogram (ECG) or echocardiography is well known. The aim of the study was to evaluate ECG and echocardiography evidence of LVH in patients provisionally diagnosed to have LVH on clinical assessment and to determine the sensitivity and specificity of different criteria of LVH on ECG in comparison with echocardiography.

Materials and methods: Hundred patients provisionally diagnosed to have LVH based on clinical assessment were enrolled in this study. A standard 12-lead ECG was recorded. Left ventricular hypertrophy was measured on ECG by applying following criteria: Sokolow–Lyon, Cornell, Romhilt–Estes score. Using two-dimensional echocardiography as the gold standard, LVH was calculated. Sensitivity and specificity of different criteria of ECG were calculated in comparison with echocardiography.

Results: Out of 100 patients suspected to have LVH, 91 patients were found to have LVH on echocardiography. Indicating that echocardiography has sensitivity of 91% and diagnostic accuracy of 91%. On comparing different criteria, Sokolow criterion was found to have maximum sensitivity of 38.46%, while Cornell criterion was least sensitive, i.e., 14.29%, and sensitivity of Romhilt–Estes criterion was 19.78%. However, overall sensitivity of ECG can be increased by combining all the criteria, i.e., to 45.05%. Specificity of different criteria of ECG was high, i.e., as much as 100% in case of Romhilt–Estes criterion, while overall specificity of ECG was 77.778%.

Conclusion: Sensitivity and diagnostic accuracy of ECG were very low in comparison with echocardiography in detecting LVH; therefore, ECG cannot replace echocardiography in detecting LVH. Overall sensitivity of different criteria of ECG was low. However, sensitivity of ECG can be increased by combining Sokolow-Lyons voltage criteria and Cornell voltage criteria with Romhilt–Estes point score.

Keywords: Cornell, Echocardiography, Electrocardiogram, Romhilt–Estes score, Sokolow–Lyon.

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INTRODUCTION

Left ventricular hypertrophy is the thickening of the wall of left ventricle resulting in an increase in left ventricular mass. Left ventricular hypertrophy is a powerful independent risk factor for cardiovascular morbidity and mortality.[1] The increase in left ventricular mass represents a common final pathway toward the adverse effects on the cardiovascular system and higher vulnerability to complications.[2] Left ventricular hypertrophy may occur as a result of two basic hemodynamic abnormalities: Systolic overload and diastolic overload. Systolic overload is also known as pressure overload and occurs with conditions like aortic stenosis, systemic hypertension, hypertrophic cardiomyopathy, and coarctation of aorta. Diastolic overload is due to overfilling of left ventricle in diastole so that the left ventricle compromise occurs during diastole. Left ventricular diastolic overload is also known as volume overload, and occurs with mitral incompetence, aortic incompetence, and also with moderate left to right shunt. Echocardiography is considered as gold standard for LVH detection in clinical practice, but ECG remains widely used due to its simplicity, low cost, and easy accessibility. However, ECG criteria for LVH detection exhibit only limited accuracy (generally due to poor sensitivity).[3] The present study was designed to study various ECG criteria for detection of LVH by comparing it with the gold standard of echocardiography.

MATERIALS AND METHODS

Hundred patients of either sex more than 18 years of age admitted in emergency, intensive care unit, and medical wards of a tertiary care hospital at Amritsar who were provisionally diagnosed to have LVH based on clinical assessment were enrolled in the study. The patients were

subjected to ECG and echocardiography to confirm the diagnosis of LVH.

The patients with following etiologies were suspected to have LVH:

- Known cases of hypertension along with minimum of grade I hypertensive retinopathy changes (with or without antihypertensive drugs)[4]
- Atherosclerotic aortic sclerosis
- Rheumatic heart disease with mitral incompetence
- Ischemic cardiomyopathy with mitral incompetence
- Coronary artery disease

Following patients were excluded from the study:

- Obese [defined based on body mass index (BMI) >30 kg/m^2].[5]
- Smokers
- Patients with physical abnormalities of chest wall, such as kyphosis or scoliosis
- Chronic obstructive lung disease
- Patients manifesting ECG findings of bundle branch block, atrial fibrillation, or atrial flutter and Wolff–Parkinson–White syndrome.
- Patients on digitalis, class 1a antiarrhythmic drugs (i.e., procainamide, quinidine, disopyramide) and class 1c antiarrhythmic drugs (i.e., flecainide, propafenone) which alter ECG pattern

The study was carried out after approval from hospital ethical committee and after obtaining informed consent from the patient and the relatives. Detailed history was taken regarding the onset of symptoms and presence of risk factors. Detailed general physical examination along with systemic examination including body surface area (BSA) using Mosteller[6] formula: [BSA (m^2) = ([height (cm) × weight (kg)]/3600)^{½}] and BMI using the Quetelet index [weight (kg)/height (m^2)] was calculated.

A standard 12-lead ECG was recorded with subjects lying comfortably in supine position. The machine was calibrated before recording ECG with paper speed 25 mm/sec and amplitude of stylus deflection at 1 mV/cm. Left ventricular hypertrophy was measured on ECG by applying following criteria[7]:

Sokolow–Lyon criterion: S in VI and R in V5 and V6 (whichever is larger) > 35 mm

R in aVL > 11 mm

Cornell criteria: S in V3 and R in aVL > 28 mm (men)
S in V3 and R in aVL > 20 mm (women)

Romhilt–Estes score: diagnostic > 5, probable > 4

Voltage criteria: 3

R or S in limb leads: 20 mm

S in V1 or V2 > 30 mm

R in V5/V6 > 30 mm

ST/T wave abnormality:

ST/T wave vector opposite to QRS without digitalis: 3

ST/T wave vector opposite to QRS with digitalis: 1

Negative terminal P wave in V1 of 1 mm in depth and 0.04 seconds in duration indicate left atrial enlargement: 3

Left axis deviation of QRS of –30 or more: 2

QRS duration > 0.09 seconds: 1

Delayed intrinsicoid deflection in V5/V6 > 0.05 seconds: 1

Echocardiography was done with the help of Philips HD 11 XE echocardiogram machine using M-mode, as it has greater resolution due to higher frame rate.[8] Borders were defined according to proposed criteria given by the American Society of Echocardiography (ASE).[9] Left ventricular mass was calculated using Devereux's[10] anatomical validated formula:

$$\text{LV mass (gm)} = 0.8\{1.04([\text{LVID} + \text{PWT} + \text{IVST}]^3 - [\text{LVID}]^3)\} + 0.6\,\text{gm}$$

All measurements were made at the end of diastole in centimeters. Left ventricular hypertrophy cut points according to left ventricular mass were taken as 208 gm for men and 145 gm for females[11] (from Framingham cohort study). Left ventricular mass index (LVM/BSA) was calculated, and cut-off values for LVH for males and females were taken as 108 and 100 gm/m^2 respectively[12] as in Indian Subcontinent. Sensitivity was calculated by dividing true positive by sum of true positive and false negative and then multiplying by 100.

$$\text{Sensitivity} = \frac{\text{True positive}}{\text{True positive} + \text{False negative}}$$

Specificity was calculated by dividing true negative by true negative and false positive and then multiplying by 100.

$$\text{Specificity} = \frac{\text{True negative}}{\text{False positive} + \text{True negative}}$$

RESULTS

Overall in our study, 35% (n = 35) patients were in age group of 61 to 70 years, 33% (n = 33) were in age group 51 to 60 years, 18% (n = 18) were in age group 41 to 50 years, 9% (n = 9) in 71 to 80 years, 3% (n = 3) >81 years, while minimum of 2% (n = 2) in age group of 31 to 40 years. Also, 50% (n = 50) were male and 50% (n = 50) were female. When distributed according to etiology, 98% (n = 98) of them had hypertension, 14% (n = 14) had coronary artery disease along with hypertension, 3% (n = 3) had dilated cardiomyopathy with mitral regurgitation (MR), 3% (n = 3) had hypertension with aortic sclerosis, and 2% (n = 2) had rheumatic heart disease with MR. Out of the 100 suspected patients, only 43% (n = 43) patients showed LVH on ECG after applying all the

criteria, while 57% (n = 57) had no evidence of LVH on ECG. Out of 100 suspected cases, 38% (n = 38) had LVH on ECG after applying Sokolow criterion, 18% (n = 18) had LVH on ECG with Romhilt–Estes criterion, while 15% (n = 15) had LVH on ECG with Cornell criteria. Out of 100 patients suspected to have LVH, 91 patients were found to have LVH on echocardiography (Table 1). This indicates that echocardiography has sensitivity of 91% and diagnostic accuracy of 91% (Table 2). After statistical analysis, sensitivity of ECG (by combining all criteria) turned out to be 45.05%, while specificity of ECG was 77.78% with a positive predictive value (%) of 93.35% and a negative predictive value of 12.28% (Table 3). On comparing individual ECG criteria with echocardiography, sensitivity of Sokolow criterion came out to be 38.46%, and specificity was 66.76%, while positive predictive value was 92.11%, and negative predictive value was 9.68% (Tables 4 and 5). By comparing Romhilt–Estes criterion with echocardiography, sensitivity of Romhilt–Estes criterion in diagnosing LVH was 19.78%, and specificity was 100%. While positive predictive value was 100%, and negative predictive value was 10.98% (Tables 6 and 7). By comparing Cornell criterion with echocardiography, sensitivity of Cornell in diagnosing LVH was 14.29% and specificity was 77.778%, while positive predictive value was 86.67%, and negative predictive value was 8.24% (Tables 8 and 9). However, on comparing individual criterion with each other, Sokolow criterion had maximum sensitivity of 38.46%, while Cornell criterion was least sensitive, i.e., 14.29%, and sensitivity of Romhilt–Estes criterion was 19.78% (Graph 1);

Table 1: Distribution of patients showing LVH on echocardiography

Echocardiography	*Number of patients*	*Percent*
LVH	91	91
No LVH	9	9
Total	100	100

Table 2: Sensitivity and accuracy of echocardiography

Sensitivity	*Accuracy*
91%	91%

Table 3: Sensitivity and specificity of ECG with respect to echocardiography

	Sensitivity (%)	*Specificity (%)*	*Positive predictive value (%)*	*Negative predictive value (%)*
ECG	45.05	77.778	95.35	12.28

Table 4: Correlation of Sokolow criterion on ECG with echocardiography

	ECHO	
Sokolow criterion	*LVH*	*No LVH*
LVH	35 True positive	3 False positive
No LVH	56 False negative	6 True negative

Table 5: Sensitivity and specificity of Sokolow criterion with respect to echocardiography

	Sensitivity (%)	*Specificity (%)*	*Positive predictive value (%)*	*Negative predictive value (%)*
Sokolow criterion	38.46	66.67	92.11	9.68

Table 6: Correlation of Romhilt–Estes criterion with echocardiography

	ECHO	
Romhilt–Estes criterion	*LVH*	*No LVH*
LVH	18 True positive	0 False positive
No LVH	73 False negative	9 True negative

Table 7: Sensitivity and specificity of Romhilt–Estes criterion with respect to echocardiography

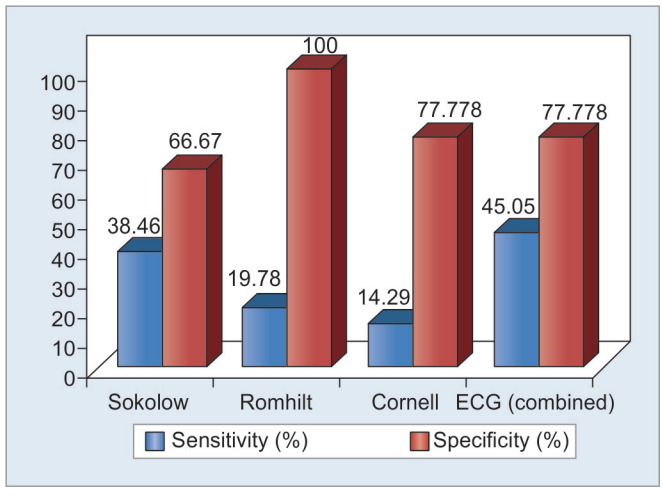
	Sensitivity (%)	*Specificity (%)*	*Positive predictive value (%)*	*Negative predictive value (%)*
Romhilt–Estes criterion	19.78	100.000	100.00	10.98

Table 8: Correlation of Cornell criterion on ECG with echocardiography

	ECHO	
Cornell criterion	*LVH*	*No LVH*
LVH	13 True positive	2 False positive
No LVH	78 False negative	7 True negative

Table 9: Sensitivity and specificity of Cornell criterion with respect to echocardiography

	Sensitivity (%)	*Specificity (%)*	*Positive predictive value (%)*	*Negative predictive value (%)*
Cornell criterion	14.29	77.778	86.67	8.24



Graph 1: Comparison of sensitivity and specificity of different criteria of ECG

Table 10: Comparing sensitivity and specificity of different criteria of ECG

	Sensitivity (%)	*Specificity (%)*	*Positive predictive value (%)*	*Negative predictive value (%)*
Sokolow	38.46	66.67	92.11	9.68
Romhilt–Estes	19.78	100	100	10.98
Cornell	14.29	77.778	86.67	8.24
ECG (combined criteria)	45.05	77.778	95.35	12.28

however, overall sensitivity of ECG can be increased by combining all the criteria, i.e., to 45.05%. Specificity of individual criterion of ECG is high, i.e., as much as 100% in case of Romhilt–Estes criterion (Table 10). The overall specificity of ECG was 77.78%.

Statistical Analysis

After statistical analysis of different criteria, it is found that Sokolow criterion is better than Cornell and Romhilt–Estes criteria in diagnosing LVH with a p-value of 0.001 against Cornell criterion and 0.037 against Romhilt–Estes criterion, which is statistically significant, while no difference was found between Cornell and Romhilt–Estes criteria (Table 11).

DISCUSSION

In the present study, out of 100 suspected patients echocardiography detected LVH in 91% of patients with a diagnostic accuracy of 91%, which is consistent with study done by Woythaler et al.[13] The study showed that echocardiographic left ventricular mass is similar to necropsy obtained left ventricular mass with a correlation coefficient of 0.81 for echocardiography and 0.83 for necropsy data.

In the present study, sensitivity of ECG to diagnose LVH comes out to be 45.05% and specificity as 77.78%, indicating that ECG is less sensitive in diagnosing LVH which is consistent with many previous studies[14-16] showing that ECG recognizes LVH poorly with test sensitivity generally ranging from 20% to below 50%. The study done by Pewsner et al[17] also favors present study and found that median sensitivity of ECG to diagnose LVH ranges from 10.5 to 21% with specificity from 89 to 99%.

In our study, sensitivity of Sokolow criterion to diagnose LVH came out to be 38.46%, which is consistent with the original study done by Sokolow and Lyon[18] and Casale et al,[19] which shows sensitivity of Sokolow criterion to be 32 and 33% respectively. Specificity of Sokolow criterion in our study was 92.11%, which is consistent with the work done by Sokolow and Lyon[18] and Casale et al,[19] which show the specificities of 100 and 93% respectively. This indicates that Sokolow criterion is less sensitive in diagnosing LVH.

Table 11: Statistical analysis of individual ECG criteria for LVH in comparison with each other

	Sokolow vs Cornell	*Sokolow vs Romhilt–Estes*	*Cornell vs Romhilt–Estes*
p-value	0.001	0.037	0.243
S	S	S	NS

S: Significant; NS: Nonsignificant

In the present study, sensitivity of Romhilt–Estes criterion to diagnose LVH was 19.78%, which is consistent with the studies done by Dada et al[20] and Okin et al,[21] which show sensitivities of 18 and 12% respectively. Specificity of Romhilt–Estes criterion in our study is 100%, which is consistent with the work done by Dada et al[20] and Okin et al,[21] which show the specificities of 92.80 and 100% respectively. The study done by Hameed et al[22] observed sensitivity and specificity to be 35 and 90% respectively, indicating that Romhilt–Estes criterion is less sensitive in diagnosing LVH but very specific in diagnosing LVH.

However, sensitivity of Cornell criterion to diagnose LVH is 14.29%, which is consistent with the studies done by Okin et al,[21] Domingos et al,[23] and Dada et al[20] in which sensitivities were 22, 12, and 22% respectively. Our study shows that specificity of Cornell criterion to find LVH is 77.78%, which is consistent with the studies done by Okin et al,[21] Domingos et al,[23] and Dada et al[20] showing specificities of 87, 100, and 80% respectively.

In this study, after comparing LVH on ECG in males and females it is found that ECG is more sensitive in males (51.06%) *vs* females (38.63%) with a diagnostic accuracy of 52% in males as compared with diagnostic accuracy of 44% in females. This finding is consistent with the studies done by Levy et al,[11] Colossimo et al,[24] and Hameed et al[22] that ECG is more sensitive in diagnosing LVH, which is perhaps a reflection of higher QRS expression in males.

In the present study, sensitivities of different criteria, Sokolow, Cornell, and Romhilt–Estes, in females were 31.88, 11.36, and 20.45% respectively. The sensitivities of these criteria in the study done by Casiglia et al[25] in females were 12.7, 14.6, and 10.1% respectively. As sensitivity of Sokolow criterion is maximum, it is better in judging LVH in females, which is consistent with the finding of Alfakih et al showing that Sokolow criterion is better in diagnosing LVH in females.[26]

In the present study, sensitivities of different criteria, i.e., Sokolow, Cornell, and Romhilt–Estes, in diagnosing LVH in males were 41.68, 17.02, and 19.94% respectively. The sensitivities of these criteria in the study done by Casiglia et al[25] in males were 16.7, 3.8, and 25.5% respectively.

CONCLUSION

So, after comparing all these criteria, our study shows that all criteria are very less sensitive in diagnosing LVH,

with Sokolow criterion showing maximum sensitivity of 38.46% and Cornell criterion showing minimum sensitivity of 14.29%. But sensitivity can be increased, i.e., up to 45.05% by using all the criteria to diagnose LVH in combination. These observations are consistent with the studies done by Dada et al,[20] VIIDA study group,[27] Hammed et al.[22]

After comparing the diagnostic accuracy of all the three criteria with each other, it is found that Sokolow criterion is comparatively better in diagnosing LVH as compared with Cornell and Romhilt–Estes criteria, which is consistent with the study done by Dada et al,[20] which also found Sokolow criterion better than other criteria.

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