Comparison of Various ECG Criteria in the Diagnosis of Left Ventricular Hypertrophy Using Echocardiography as Gold Standard

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ABSTRACT

BACKGROUND
Left ventricular hypertrophy (LVH) is a progressive structural change characterized by thickening of left ventricular wall with or without enlargement. We wanted to evaluate different electrocardiography (ECG) criteria for the assessment of left ventricular hypertrophy (LVH) using echocardiography as gold standard.

METHODS
A total of 102 patients with hypertension were included in the study. Presence of LVH was assessed by Sokolow-Lyon criteria (SLC), Cornell Voltage criteria (CVC), and Romhilt - Estes Point Score (REPSS). Echocardiography was used to calculate the left ventricular mass index (LVMI) for the subjects. The sensitivity, specificity, accuracy, positive and negative predictive values of the three criteria were determined using LVMI calculated by Echo.

RESULTS
The study included 80 (78.4%) males and 22 (21.6%) females, aged between 30 and 80 years. LVH by echocardiography was present in 69 (86%) males and 16 (72%) females. The sensitivity and specificity of the ECG criteria for LVH in males were 57% and 33% (SLC), 40% and 67% (CVC) and 37% and 58% (REPSS) respectively. Sensitivity and specificity of the ECG criteria in females were 65% and 60% (SLC), 60% and 100% (CVC) and 20% and 100% (REPSS) respectively.

CONCLUSIONS
None of the 3 ECG criteria namely Sokolow-Lyon, Cornell Voltage, and Romhilt - Estes Point Score criteria could qualify as the initial screening test for LVH in a predominantly male hypertensive population. The Sokolow-Lyon criteria had higher sensitivity in both males and females, and the Cornell criteria had higher specificity in both groups. There was no correlation between LVMI by echo and amplitude of QRS voltage calculated as per SLC and CVC. Combining different criteria could improve the diagnostic accuracy of ECG.

KEYWORDS
Echocardiography, Electrocardiography, Left Ventricular Hypertrophy

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BACKGROUND

Left ventricular hypertrophy (LVH) is a progressive structural change characterized by thickening of left ventricular wall with or without enlargement.[1] LVH is associated with an increased risk of cardiovascular events.[2] LVH is implicated in the aetiopathogenesis of cardiac arrhythmias, myocardial ischemia, coronary heart disease, and congestive heart failure[3,4] and presence of LVH is associated with higher incidence of chronic kidney disease.[5-7] LVH has a significant prevalence among the general population and hypertensive patients.[8] Electrocardiography (ECG) and echocardiography are commonly used to detect the presence of LVH.[9,10] Echocardiography is considered the gold standard for assessment of LVH and calculation of left ventricular mass (LVM).[11] ECG diagnosis of LVH is based primarily on the QRS voltage and is used commonly as a screening tool.[11] Different ECG criteria are used to diagnose LVH. The commonly used criteria are the Sokolow-Lyon,[12] Cornell Voltage[13] and Romhilt - Estes Point Score criteria.[14] Sokolow-Lyon criteria (SLC) described by Sokolow and Lyon in 1949 is the oldest and the simplest.[12] Using SLC, LVH is diagnosed if the amplitude of the S wave in lead V_1 plus R wave in lead V_5-V_6 (whichever is more) is ≥35 mm or 3.5 mV (≥7 large squares).[1,12] The Cornell voltage criterion (CVC) was devised by Casale in 1985. In this criterion, LVH is diagnosed if the sum of the R wave in lead aVL and S wave in V_3 is >28 mm in males and >20 mm in females.[11,13,15] The Romhilt-Estes point score system (REPSS) proposed by Romhilt and Estes in 1968, uses two thresholds for detection of LVH.[14] The REPSS assigns point values to six variables in ECG and probable LVH is diagnosed if the score equals 4 and definite LVH is diagnosed if the score equals 5 points. Although the specificities of these criteria are typically high (80-90%), sensitivities are low (20-50%). Studies that have examined the performance of ECG for the detection of LVH have largely been limited to select groups of mostly white patients and were subject to selection bias. Furthermore there are several extracardiac factors which have an adverse impact on the ECG sensitivity of LVH presumably by altering QRS voltage.[16] It is in this context that the present study was carried out to evaluate three commonly used ECG criteria to assess their predictive power to diagnose LVH among south Indian population.

METHODS

This cross-sectional study was conducted on 102 subjects mostly those with Systemic hypertension. The study was conducted from January 2019 to March 2019 in Government Medical College, Kannur, India. Ethical clearance for the study was obtained from the institutional ethical committee. Detailed history, clinical examination, 12 lead half standardized ECG and echocardiography were performed. Left ventricular mass (LVM) was calculated by simplified cubed formula.[17]

$$LVM = 1.05 ((LVIDd + IVSTd + PWTd)^3 - (LVIDd)^3)$$

Where, LVIDd= left ventricle internal dimension in diastole, PWTd = posterior wall thickness in diastole, IVSTd = interventricular septum thickness in diastole, 1.05 = specific gravity of the myocardium.

Left ventricular mass index (LVMI) was calculated by indexing LVM to body surface area, and normal cut offs were <130 g/m^2 for males and <100 g/m^2 for females.[18] Concentric LVH was diagnosed if the LVMI was above the specified cut off with a relative wall thickness (RWT) of more than 0.45 by Echo which is calculated as,

$$RWT = (IVSd + LVPWd)/ LVIDd$$

Where, IVSd = thickness of interventricular septum in diastole and LVPWd = thickness of LV posterior wall in diastole.

Sensitivity, specificity, accuracy, positive and negative predictive values were calculated for each of the three ECG criteria for males and females separately using echo diagnosis of LVH as a gold standard. The criteria for diagnosing LVH were; 1) SLC: - S V_1 + R V_5 / V_6 >35mm and R aVL >11mm 2) CVC: - R aVL + S V_3 >28 mm in males and >20 mm in females 3) REPSS: - 5 points or more indicates LVH. Correlation of the different criteria with LVMI was also assessed.

Statistical Analysis

Statistical analysis was performed using Student's t-test for paired samples using SPSS v.21.0. Values were expressed as mean± standard deviation or as percentages. A p value <0.05 was considered statistically significant.

RESULTS

The age of the patients ranged between 30 and 80 years. Among 102 patients, 80 (78.4%) were males, and 22 (21.6%) were females. The mean ages for males were 52.5 years, and females were 47.5 years. The risk factors in the study subjects were systemic hypertension 68 (66.6%), diabetes mellitus 11 (10.78%) and chronic kidney disease 39 (38.2%). 13 (16.2%) males had aortic valve disease (Table 1). The mean LVM was 237 g in males and 160 g in females. The mean LVMI was 141 g/m^2 in males and 102 g/m^2 in females. 86% (69 out of 80) of men and 72% (16 out of 22) of women had true LVH by echo criteria.

The sensitivity and specificity of the ECG criteria in males were 57% and 33% (SLC), 40% and 67% (CVC) and 37% and 58% (REPSS) respectively. Sensitivity and specificity of the ECG criteria in females were 65% and 60% (SLC), 60% and 100% (CVC) and 20% and 100% (REPSS) respectively. The accuracy of the criteria were 53% (SLC), 44% (CVC) and 40% (REPSS) in men and 68% (SLC), 68% (CVC) and 36% (REPSS) in women. (Table 2).

Variable	N (%)			p value
Age (Years)	**Male**	**Female**	**Total**	
<30 years	6(5.8%)	0	6(5.8%)	0.33
30-40 years	8(7.8%)	4(3.9%)	12(11.7%)	0.28
40-50 years	19(18.6%)	9(8.8%)	28(27.4%)	0.18
50-60 years	20(19.6%)	6(5.8%)	26(25.4%)	0.79
60-70 years	18(17.6%)	3(2.9%)	21(20.5%)	0.55
70-80 years	9(8.8%)	0	9(8.8%)	0.20
Risk Factors				
Hypertension	52(65%)	16(72%)	68(66.6%)	0.61
Diabetes	7(8.7%)	4(18%)	11(10.78%)	0.24
Chronic kidney disease	33(41%)	6(27%)	39(38.2%)	0.32
Valvular heart disease	13(16.2%)	0	0	0.066
LVH	69(86%)	16(72%)	85(83.3%)	0.192

Table 1. Clinical Characteristics

Criteria	SLC		CVC		REPSS	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Sensitivity	57%	65%	40%	60%	37%	20%
Specificity	33%	60%	67%	100%	58%	100%
PPV	82%	85%	87%	100%	83%	100%
NPV	12%	60%	16%	40%	14%	25%
Accuracy	53%	68%	44%	68%	40%	36%

Table 2. ECG Criteria Used in the Diagnosis of Left Ventricular Hypertrophy

SLC-Sokolow-Lyon criteria, CVC-Cornell voltage criteria, REPSS- Romhilt-Estes point score system, PPV-Positive Predictive value, NPV-Negative Predicative value

DISCUSSION

In the present study, we evaluated the performance of three ECG criteria for diagnosing LVH using echocardiography as the gold standard. All these criteria assess the presence or absence of LVH as a binary function indicating that LVH is present or absent based on an empirically determined set of criteria.[19] As per the previous studies, sensitivities were lower (~10-30%) for SLC and REPSS and higher (~30-50%) for CVC. In contrast specificities were high for all the criteria (80-90%). The overall accuracy varied from one trial to another that no one criterion could be established as the preferred one. In our study, out of 102 patients 69 (86%) males and 16 (72%) females had echo evidence of LVH which is relatively higher compared to previously reported prevalence of LVH in south Indian population.[20] In our study, SLI and REPSS were the most and least sensitive criteria respectively for both sexes and this finding is in contrast to previous studies. CVC and SLI were the most and least specific criteria respectively for both sexes. CVC was the criterion with the highest sensitivity, specificity, accuracy, positive and negative predictive values in females. Gender-specific differences in the performance of ECG criteria were previously reported. One study from Brazil showed CVC to be more sensitive in women and SLC to be more sensitive in men[15,16] and such gender difference was not seen with our study. In another study by Rodrigues et al, subgroup analysis by gender revealed higher maximal sensitivity in males (REPSS) and higher maximal specificity in females (SLC).[21] In our study all except REPSS showed higher sensitivity in women and all criteria were more specific in women (50-100%), suggesting that all three tests could perform better in female population. However, overall diagnostic accuracy was low for all the three ECG criteria in both sexes even in the presence of higher prevalence of true LVH and so the tests could be expected to perform worse in an unselected population with less severe hypertension. There was no correlation between LVH based on LVMI and the amplitude of QRS in voltage based criteria (SLC and CVC). This could be attributed to change in QRS amplitude in relation to extracardiac factors like age, sex, body habitus and presence or absence of lung disease. New computing methods might improve the overall performance of ECG by incorporating factors like age, sex, obesity and presence of chronic obstructive pulmonary disease. In the absence of such diagnostic models, the overall low sensitivity and specificity renders ECG a relatively ineffective tool for the diagnosis of LVH.[17-20] Combining various criteria and using different criteria for men and women are other possible solutions to improve the performance of ECG as a diagnostic tool for LVH.

CONCLUSIONS

None of the 3 ECG criteria namely Sokolow-Lyon, Cornell Voltage, and Romhilt - Estes Point Score criteria qualify as good screening tests for LVH in a hypertensive male predominant population. The Sokolow-Lyon criteria had highest sensitivity and the Cornell criteria had highest specificity in both sexes. Overall accuracy was low in all the three criteria. There was no correlation between LVMI by echo and amplitude of QRS voltage calculated as per SLC and CVC. Combining different criteria could improve the diagnostic accuracy of ECG.

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