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Original Research Article

Comparative study of echocardiography and electrocardiography criteria for detecting left ventricular hypertrophy in hypertensive patients

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ABSTRACT

Background: The study aimed to compare seven different electrocardiogram (LVH) criteria for diagnosing left ventricular hypertrophy (LVH) with echocardiogram as diagnostic standard in hypertensive patients.
Methods: This was a hospital-based, cross-sectional study conducted in out-patient department and at medical wards of a tertiary care hospital at Bangalore. The study was carried out for a total duration of 12 months. All hypertensive patients underwent examination for prevalence of LVH using echocardiogram and ECG. Seven different ECG criteria were applied to diagnose the presence of LVH. Then the specificity, sensitivity, kappa measurement value, positive predictive value and negative predictive value for all criteria was calculated subsequently.
Results: Out of the 100 patients studied, 34 had LVH as diagnosed by echocardiography. Sokolow-Lyon criteria had a sensitivity of 35% and specificity of 94%. Cornell voltage had a sensitivity of 26% and specificity of 95%. Modified Cornell voltage had a sensitivity of32% and specificity of 94%. Framingham adjusted Cornell voltage, Minnesota code and Cornell product had a sensitivity of 23.5% and specificity of 98.4%. Framingham score had a sensitivity of 38% and specificity of 95.4%.
Conclusions: It can be concluded that among all the different criteria used in the study, Framingham score showed better sensitivity compared to others. In the evaluation of hypertensive patients for LVH, the role of ECG with all the commonly used criteria is of limited value and echocardiography is the method of choice.

Keywords: Echocardiography; Electrocardiography; Hypertension; Left ventricular hypertrophy

INTRODUCTION

Hypertension prevalence has been transpiring since decades, in spite of inclining lifestyle of people towards the healthier one. Hypertension is one of the leading cause of premature death worldwide, leading to 10.4 million deaths per year globally.[1] However, the prevalence of hypertension has majorly increased in low- and middle-income countries. Longstanding hypertension often leads to complications like stroke, renal failure, myocardial infarction, coronary events, left ventricular hypertrophy, peripheral arterial disease, and cardiovascular mortality. Left ventricular hypertrophy (LVH) is an uncharacteristic growth in left ventricular mass.[2] The mechanism underlying LVH remains under dilemma, however some evidences state that chronic haemodynamic overload is responsible for activating LV myocardial growth and non-haemodynamic variables are responsible for the extent of hypertrophic response.[3,4] Complications of LVH comprise atrial fibrillation, diastolic heart failure, systolic heart failure, and sudden death. Timely diagnosis and better understanding of

cardiac hypertrophy can result to more effective therapeutic strategies for managing this otherwise ruinous cardiovascular risk factor.[3] The LVH is mostly diagnosed using electrocardiography, echocardiography, and magnetic resonance imaging. The ECG diagnostics of LVH is based principally on the QRS voltage criteria. However, the diagnosis through ECG had been under controversy due to its sensitivity and specificity issues.[5,6] On the other hand, literature also states that the ECG criteria for LVH is a strong and independent predictor of cardiovascular morbidity and mortality in hypertensive patients and general population.[7] Therefore, this study aimed to compare seven different ECG criteria for diagnosing LVH with echocardiogram as diagnostic standard in hypertensive patients.

METHODS

This was a hospital-based, cross-sectional study conducted in out-patient department and at medical wards of a tertiary care hospital at Bangalore. The study was carried out for a total duration of 12 months (October 2015 to October 2015) and included hypertensive patients aged more than 18 years.

Exclusion criteria

Exclusion criteria were patients less than18 years of age; patients with valvular heart disease; patients with cardiomyopathy; patients with chronic kidney disease; patients with diabetes mellitus.

Data collection

Patients were assigned a case number and their name, age, sex, occupation were noted. All details regarding the present complaints and relevant past history was noted. Total duration of hypertension and the drugs taken for treatment of hypertension was recorded. Moreover, relevant general physical examination was done. Measurement of blood pressure was done as per standard procedure. Cardiovascular system examination was done. Other systems were examined for complications of hypertension. Additional investigations performed were: random blood glucose, blood urea, serum creatinine, ECG and echocardiogram.

Electrocardiographic criteria

Sokolow-Lyon voltage: Sv1+Rv5≥3.5 mV or Rv5/6≥2.6 mv; Cornell voltage: Ravl+Sv3 ≥2.8 mV (men), ≥2.0 mV (women); modified Cornell voltage: Ravl+Sv3 ≥2.4 mV (men), 2.0 mV (women); Framingham adjusted Cornell voltage: Ravl+Sv3+0.0174 × (age, 50) + 0.191 × (BMI, 26.5) ≥2.8 mV (men) and Ravl+Sv3+0.0387 × (age, 49) + 0.212 × (BMI, 24.9) ≥2.0 mV (women); Minnesota code 3.1: Rv5/v6≥2.6 mV, RI/II/IV/ avf≥2.0 mV or R avl >1.2 mV; Cornell product: (R avl+ S v3) × QRS duration 2436 mm×ms; Framingham score: R I + S III>2.5 mv<S v I/2+R v5/6 >3.5 mV.

Echocardiogram criteria

Combined M mode and two-dimensional echocardiographic studies were performed by single cardiologist (to minimize observer bias) using 2D ECHO with colour Doppler and continuous wave Doppler with a transducer of 2.5 MHz with VCR and a printer with an ECG gating facility. All patients were placed in 300 left lateral position with slight elevation of the head.

Comprehensive two-dimensional planes were employed with multiple parasternal views of the left ventricle in long and short axis and apical four chamber and long axis views and subcostal four chamber and short axis views. After positioning the cursor through the interventricular septum and posterior wall at the level of chordae tendinae simultaneous M mode and two-dimensional recordings were obtained from the posterior transducer position in both long axis and short axis of the ventricle.

The left ventricular posterior wall and the septum were measured at the time of atrial depolarization before the onset of the notch. The left ventricular internal dimension was measured at the level of chordae tendinae as the distance between the left side of interventricular septum and the posterior left ventricular endocardium. M mode measurements were taken by the leading edge-to-leading edge technique as recommended by American society of echocardiography. All the measurements were averaged to the closest 1 mm from three good quality cardiac cycles.

Determination of LVH

Various criteria/scoring systems have been used in determining LVH on surface ECG. This study compared different criteria like Sokolow-Lyon voltage (SLV), Cornell score, modified Cornell voltage, Framingham adjusted Cornell voltage, Cornell product, Minnesota code 3.1, Framingham score and compared with echocardiography.

Statistical analysis

After obtaining the results of the electrocardiogram and echocardiogram statistical tests were performed. The statistical tests are: diagnostic validity tests (sensitivity and specificity) and Kappa measurement of agreement.

Formulae used in the study

Table 1:

	ECHO positive	ECHO negative	
ECG positive	a (true +ve)	b (false +ve)	a+b
ECG negative	c (false-ve)	d (true-ve)	c+d
	a+c	b+d	

Sensitivity = (True positive × 100) / (true positivity + false negativity)

Specificity = (True negativity × 100) / (false positivity+ true negativity)

Positive predictive valve = (true positive × 100) / total positive

Negative predictive value = (true negative × 100) / total negative

Accuracy = (Positive + negative correctly diagnosed × 100) / total tested

Kappa measure of agreement,

Observed agreement Io = (a + d) / n

Expected agreement Ie = [(a+c) x(a+b) + (b+d) x(c+d)] / n^2

n= total number of patients

K = (Io-Ie) / (1-Ie)

Sample size calculation

Since there was no previous Indian study which included all the seven criteria for diagnosing LVH in comparison with ECHO, and doing a pilot study will take at least 2-3 months, exact sample size cannot be determined. So sample size was calculated using "rule of thumb" which states minimum of 10 subjects per variable is required to get adequate sample size. As we have total of 8 variables (7 in ECG and ECHO) in our study, 80 should be the minimum sample size. We have included 100 patients in our study.

RESULTS

A total of 100 patients were included in the present study, of which 63 were male and 37 were female. Echocardiographic evidence of LVH was observed in 34 (34%) patients; among those 34 patients with LVH, 23 were males and 11 were females. Electrocardiogram was performed on all the 100 patients. Sokolow-Lyon criteria detected LVH in 16 patients. Cornell criteria detected LVH in 12 patients, Modified Cornell showed LVH in 15 patients, Framingham adjusted Cornell Voltage, Minnesota and Cornell product detected LVH in 9 patients and Framingham criteria showed LVH in 16 patients (Figure 1).

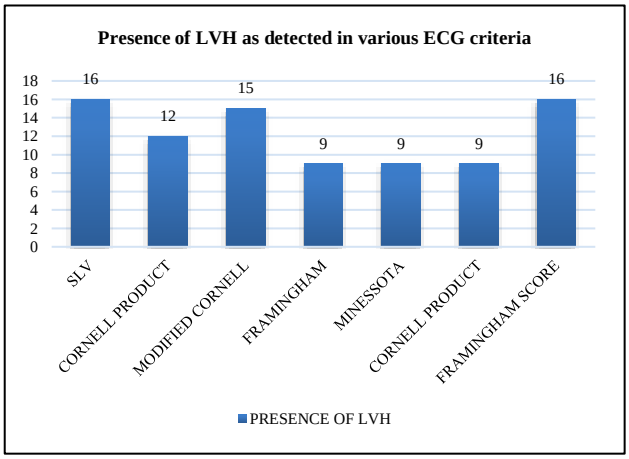

Figure 1: Presence of LVH in the study population as detected by various ECG criteria.

Performance of each ECG criteria in detecting LVH

Sokolow-Lyon criteria: Out of 16 patients who were detected to have LVH by Sokolow-Lyon criteria, 12 were true positive and 4 were false positive. Out of 84 patients who did not have LVH by Sokolow-Lyon criteria, 62 were true negative and 22 were false negative. Sokolow-Lyon criteria had a sensitivity of 35.29%, specificity of 93.93%, PPV of 75%, NPV of 73.8% and accuracy of 84%. The Kappa measure of agreement was 0.7 (Table 2).

Table 2: Sensitivity, specificity, positive predicted value, negative predicted value and Kappa measure of agreement of various electrocardiographic criteria for detecting LVH.

ECG criteria	Sensitivity	Specificity	PPV	NPV	Kappa measure of agreement
Sokolow-Lyon voltage	35	94	75	74	0.7
Cornell voltage	26	95	75	72	0.62
Modified Cornell	32	94	73	73	0.61
Framingham adjusted Cornell voltage	23.5	98.4	88.8	71	0.63
Minnesota	23.5	98.4	88.8	71	0.63
Cornell product	23.5	98.4	88.8	71	0.63
Framingham score	38	95.4	81	75	0.6

PPV- positive predictive value; NPV- negative predictive value

Cornell criteria: Out of 12 patients who were detected to have LVH by Cornell criteria, 9 were true positive and 3 were false positive. Out of 84 patients who did not have LVH by Cornell criteria, 63 were true negative and 25 were false negative. Cornell criteria had a sensitivity of 26.4%, specificity of 95.45%, PPV of 75%, NPV of 71.59% and accuracy of 72%. The Kappa measure of agreement was 0.62.

Modified Cornell criteria: Out of 15 patients who were detected to have LVH by Modified Cornell criteria, 11 were true positive and 4 were false positive. Out of 85 patients who did not have LVH by Modified Cornell criteria, 62 were true negative and 23 were false negative. Modified Cornell criteria had a sensitivity of 32.35%, specificity of 93.93%, PPV of 73.33%, NPV of 72.94% and accuracy of 73%. The Kappa measure of agreement was 0.61.

Framingham adjusted Cornell voltage criteria: Out of 9 patients who were detected to have LVH by Framingham adjusted Cornell voltage criteria, 8 were true positive and 1 was false positive. Out of 91 patients who did not have LVH by Framingham adjusted Cornell voltage criteria, 65 were true negative and 26 were false negative. Framingham adjusted Cornell voltage criteria had a sensitivity of 23.52%, specificity of 98.48%, PPV of 88.88%, NPV of 71.42% and accuracy of 73%. The Kappa measure of agreement was 0.63.

Minnesota criteria: Out of 9 patients who were detected to have LVH by Minnesota criteria, 8 were true positive and 1 was false positive. Out of 91 patients who did not have LVH by Minnesota criteria, 65 were true negative and 26 were false negative. Minnesota criteria had a sensitivity of 23.52%, specificity of 98.48%, PPV of 88.88%, NPV of 71.42% and accuracy of 73%. The Kappa measure of agreement was 0.63.

Cornell product: Out of 9 patients who were detected to have LVH by Cornell product, 8 were true positive and 1 was false positive. Out of 91 patients who did not have LVH by Cornell product, 65 were true negative and 26 were false negative. Cornell product had a sensitivity of 23.52%, specificity of 98.48%, PPV of 88.88%, NPV of 71.42% and accuracy of 73%. The Kappa measure of agreement was 0.63.

Framingham score: Out of 16 patients who were detected to have LVH by Framingham score, 13 were true positive and 3 were false positive. Out of 84 patients who did not have LVH by Framingham score, 63 were true negative and 21 were false negative. Framingham score had a sensitivity of 38.23%, specificity of 95.45%, PPV of 81.25%, NPV of 75% and accuracy of 76%. The Kappa measure of agreement was 0.6.

Sensitivity was highest for Framingham score with positive predictive value of 81%. Sensitivity was least for Framingham adjusted Cornell voltage, Minnesota score and Cornell product with a positive predictive value of 88.8%. Specificity was highest for Framingham adjusted Cornell Voltage, Minnesota score and Cornell product with a negative predictive value of 71%. Specificity was least for Sokolow-Lyon criteria with a negative predictive value of 74%. Sokolow-Lyon criteria had highest Kappa measurement of agreement (0.7) and Framingham score had least Kappa measurement of agreement (0.6).

Among all the criteria used, Framingham adjusted Cornell voltage, Minnesota and Cornell product criteria showed least number (1 each) of false positive LVH finding among the total study population while SLV and Modified Cornell criteria showed highest number (4 each) of false positives (Table 3).

Table 3: Number of patients who were found to have false positive LVH by ECG criteria.

Name of the ECG criteria	False positives
Sokolow-Lyon voltage	4
Cornell voltage	3
Modified Cornell	4
Framingham adjusted Cornell voltage	1
Minnesota	1
Cornell product	1
Framingham score	3

DISCUSSION

The present study compared seven ECG criteria for diagnosing LVH in hypertensive patients with echocardiography as a diagnostic tool. The Sokolow-Lyon criteria is the oldest, simplest and the quickest method for detecting LVH, devised by Sokolow M. and Lyon TP in 1949. The Sokolow-Lyon criteria has been used in many studies to determine the sensitivity and specificity of ECG. In a study by Reichek et al, echocardiographic and ECG findings were compared in 34 patients.[8] Echocardiography had a sensitivity of 93% and specificity of 95% whereas Sokolow-Lyon criteria had a sensitivity of 21% and specificity of 95% in that study. They concluded that ECG is specific but less sensitive than echocardiography in recognising LVH. In another study by Norman et al, concluded that incorporation of obesity and age in ECG algorithm consistently improves their performance in the detection of LVH.[9] Sokolow-Lyon criteria showed a sensitivity of 30% with a specificity of 86% in that study. In present study, for Sokolow-Lyon criteria, sensitivity was 35% and specificity was 94%.

Cornell voltage is another criterion based on finding of how the hypertrophied heart electrically orientates, it adds the amplitude of R wave in AVL and S wave in V3. In a study by Casale et al on 459 patients, sensitivity of Cornell voltage was 8% to 33.[10] Okin et al found Cornell voltage had sensitivity of 37% and specificity of 45%.[11] In our study, for Cornell voltage, sensitivity was 26% and specificity was 95%.

Casale has proposed new Cornell voltage criteria, modified Cornell voltage with sensitivity of 40-53%.[10] Modified Cornell voltage showed better sensitivity when compared to Cornell voltage.

Moreover, Morrison et al, in 2007, found out that Framingham adjusted voltage had sensitivity of 45% and specificity of 50%.[12] In our study sensitivity was 23.5% and specificity was 98.4%. Recently, Mahn et al, found out in their study that Minnesota score had a sensitivity of 21.9% and specificity of 68%.[13] In our study sensitivity was 23.5% and specificity was 98.4%. Morrison et al, found out in their study that Cornell product had sensitivity twice as that of Cornell voltage.[12] In another study, Mahn et al, found out a sensitivity of 21.9% and specificity of 68% for Cornell product in their study.[13] In our study sensitivity (23.5%) was similar to the previous studies but specificity (98.4%) was higher than those studies, for Cornell product.

Framingham score was chosen in our study because of the documented relation between LVH assessed in this way and a variety of cardiovascular sequelae.[2,14-17] Framingham score had a better sensitivity (38%) when compared to others in our study. In a previous study that comprised of 476 patients, echocardiographic LVH was present in 167 patients (35%). The sensitivity of 5 different electrocardiographic criteria in diagnosing LVH varied from 12% to 29%, the specificity from 93% to 96%, the positive predictive value from 62% to 71%, and the negative predictive value from 67% to 71%.[18] Khaznadar et al included 200 patients in their study, of which 30% patients revealed LVH through echocardiography. Three criteria for ECG were applied in their study, and observed that sensitivity/specificity of Sokolow-Lyon voltage, Cornell voltage and strain pattern were 30/89, 25/93, and 20/96, respectively.[19]

The literature state no particular standardised values for specificity and sensitivity of various ECG criteria. However, if some recommendations are adhered during diagnosing through ECG, the variations can be minimised. ECG should be done for all patients with hypertension. The presence of LVH should be actively looked for in all patients with hypertension. If ECG shows evidence of LVH, it should be confirmed by echocardiogram preferentially with objective assessment of LVH by use of LV mass index. However, if ECG does not show evidence of LVH, the clinician should have high index of suspicion to rule out LVH in selected patients and perform echocardiogram for detecting LVH, as sensitivity of ECG is poor in detecting LVH.

There were some limitations of the present study. As Indian standards were not available for detecting LV mass index, we have taken American society of echocardiography guidelines for detecting LVH using LV mass index. Strict inclusion criteria resulted in a smaller sample size. Further study with larger number of subjects is required to confirm our observations.

CONCLUSION

In view of results, it can be concluded that among all the different criteria used in the study, Framingham score showed better sensitivity compared to others. In the evaluation of hypertensive patients for LVH, the role of ECG with all the commonly used criteria is of limited value and echocardiography is the method of choice. However, in the resource limited country like ours and ECG showing high specificity in the diagnosis of LVH can be of considerable value.

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