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Original Research Article

Comparison of electrocardiogram diagnostic criteria in diagnosis of left ventricular hypertrophy using 3D echocardiography as standard

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ABSTRACT

Background: The echocardiogram (ECHO) has a better diagnostic performance for left ventricular hypertrophy (LVH) than the electrocardiogram (ECG), but ECG is most widely used diagnostic method. We aimed to assess the correlation between ECG based diagnosis of LVH with echocardiography-based diagnosis of LVH as standard.
Methods: Patients with evidence of LVH using echocardiographic criteria were included in the study. Patients were subjected to four electrocardiographic criteria to assess the LVH: 1. Sokolow-Lyon criteria; 2. Romhilt and Estes scoring system; 3. Cornell voltage criteria; and 4. Gubner voltage criteria. After assessing the results of ECG and echocardiography diagnostic validity tests (by calculating specificity and sensitivity), the Kappa measure of agreement was performed.
Results: In maximum patients (52.8%) LVH was detected by using ECG LVH Sokolow Lyon criteria, followed by Cornell voltage CR criteria that detected LVH in 38.9% cases. Sokolow Lyon ECG criteria showed high sensitivity while Romhilt and Estes criteria showed maximum 98% specificity in diagnosing LVH. Sokolow Lyon's ECG criteria was highly sensitive in assessing all co-morbidities, except CKD where it was diagnosed better by using Cornell voltage criteria**.**
Conclusions: In cases of diagnosing LVH in patients with co-morbidities, ECG LVH Sokolow Lyon CR was found to be the most sensitive criteria except CKD where it was diagnosed better by using Cornell voltage criteria. For assessing the patients for LVH, the role of ECG with all the commonly used criteria is of limited value and ECHO should be the method of choice.

Keywords: ECHO, ECG, LVH, Cardiovascular system

INTRODUCTION

Left ventricular hypertrophy (LVH) and an increase in the left ventricular mass (LVM) are observed to be the predictors of morbidity and mortality of cardiovascular disorders.[1-3] The condition can be reverted back by appropriate management of the underlying causative factors. Thus, precise and reproducible methods are required for appropriate diagnosis and follow-up of CVS disorders.[4] According to the Framingham and MESA cohort studies, left ventricular (LV) hypertrophy is revealed as a strong predictor of risk of cardiovascular disorders in future.[5,6] LVH is defined as an increase in the left ventricular mass (LVM), and is generally considered as a response to chronic volume or pressure overload. LVH is reported as an independent risk factor causing heart failure and subclinical atherosclerosis. Various studies reveal that LVH is an adaptive mechanism of the cardiac muscle because of an increased demand of activity and functional overload in various pathophysiological states.[7,8] In the general population, a prevalence rate of 15-20% is observed and it has been found that LVH is one of the best factors to predict the outcome of cardiac illness, being independent from

various other risk factors of cardiovascular disorders like hypertension, smoking ,diabetes mellitus, smoking, dyslipidaemia. Incidence of congestive cardiac failure, and sudden death and overall mortality and morbidity is related with presence of LVH.[9]

LVH is observed to be a significant and predicted morbidity of high blood pressure (BP) state.[10,11] In condition of persisting high BP and LVH, the functional adaptation at one point get decompensated and till an effective management is done, the left ventricular failure results as the major cardiac haemodynamic consequence.[12]

There are many ECG based diagnostic criteria for LVH which have been proposed, initially most of these were based on radiological and necropsy studies, and in recent years by echocardiographic correlations and lately by CMRI correlations. It has been demonstrated that left ventricular mass measured by echocardiography correlates with anatomic weight with high sensitivity (93%) and specificity (95%).

There are various echo-based methods to calculate LV mass from M-mode, 2D, and 3D echo. As per ASE recommendations all measurements should be performed at end diastole (frame before mitral valve closure or the frame in the cardiac cycle in which the ventricular dimension is largest).[13] All methods convert the volume to mass by multiplying the volume of myocardium by the myocardial density (1.05 g/mL). To measure LV mass in patients especially those with cardiac disease, the 3D echocardiographic methods have advantages over the linear dimension technique.[14]

However, there are limited studies of the prognostic value of LV mass calculated by these methods compared with the linear dimension. In contrast to the linear dimension and 2D method, the 3D echocardiographic methods are advantageous for the reason that they can accommodate for the shape of the ventricle and also for changes in LV size along the long axis of the chamber. This advantage of 3D echo has important implications as changes in LV geometry are frequent in various cardiac diseases especially in patients with prior MI. But in a busy echo lab however, when there is a need to screen or study large populations, M-mode method has clear advantages as it is far simple, less time consuming and has less intra and inter observer variability in measurements. Further there is a large data in support of the accuracy of this method. Most studies that relate LV mass to prognosis are based on this method. Most important caveat of M mode-based method is that it is critical that the measurements of wall thickness and LV dimensions should be strictly perpendicular to the long axis of the left ventricle. It is therefore preferred that 2D-guided M-mode measurements should use over blind M-mode imaging.

Good image quality and properly oriented parasternal short-axis views should be acquired for accurate assessment of wall thickness. Obtaining good epicardial definition can be a problem in patients with poor echo window. However, most studies that have compared 2D-guided M-mode measurements of LV mass with the 2D echo based area-length or truncated ellipsoid methods in normal shaped ventricles have shown insignificant differences and there is no clear advantage of one technique over the other.[15]

Drawbacks of 3D echo-based assessment are cumbersome methodology and measurement variability. Despite these drawbacks it is more reliable especially in subjects with distorted left ventricular geometry. In recent years CMR has emerged as a reliable imaging modality for assessment of left ventricular mass and volume, with probably even greater accuracy than echocardiography. It is more precise, and reproducible, especially in patients with distorted left ventricle (like patients with myocardial infarction scars). Cardiac magnetic resonance imaging (MRI) can be considered as the gold standard for evaluating the LVH.

There are few studies with 3D echocardiography as standard for LVH diagnosis. In one of recent study where investigators used both 3D echo and CMRI for LVH diagnosis ECG estimates of LVM correlated poorly with LVM by MRI whereas a moderate correlation between 2D and 3D echocardiography and MRI was observed.[16]

Although various newer diagnostic tools are available, but two-dimensional echocardiography still remains the main routine diagnostic tool for estimating the LV mass in clinical practice due to valid economic and logistic considerations. The echocardiography is less expensive, fast and has better time resolution, but it is more observer dependent than CMR. Biggest drawback of CMR is the fact that it is unrealistic for large-scale use in clinical practice. The ECHO reveals a better diagnostic performance than the ECG. But regarding daily clinical practice, ECG is far cheap, easy-to-reproduce, simple, routinely used, and readily available investigation that can be used in locations and services where ECHO is not still easily accessible tool.[9]

There are various ECG methods to detect LVH, which may be categorized as voltage criteria, point score systems, and the regression equation models. Although ECG criteria are being used with widespread acceptance but the diagnostic accuracies of these criteria are low, mainly with low sensitivity to rule-out the incidence of abnormally raised left ventricular mass (LVM). In the present study, we aimed to assess the correlation between ECG based diagnosis of LVH with 3D echo as standard for validation.

METHODS

This study was conducted in department of cardiology at MDM hospital of Jodhpur, Rajasthan between October 2021 to September 2022. The present study consists of

108 patients having history and clinical profile being suggestive of co morbidities like hypertension, DM, CAD, CKD, and PVD etc. which can contribute to LVH. In patients with evidence of LVH using 3D echocardiography as standard diagnosis of LVH performance of different electrocardiographic criteria was analysed. Patients who were having bundle branch blocks, ischemic heart disease with acute coronary syndrome, moderate or severe aortic stenosis and HCM, patients with physical abnormalities of chest wall, such as kyphosis or scoliosis and chronic obstructive lung disease, Patients with atrial fibrillation, or atrial flutter, Wolff-Parkinson-White syndrome and patients on digitalis or antiarrhythmic drugs were excluded from the study.

The study was explained to patients and a written informed consent was obtained. The study was approved by Institutional Ethical Committee. Patients were subjected to a detailed case history, thorough clinical examination, echocardiography and 12-lead ECG. We used four Electrocardiographic criteria to assess the LVH: 1. Sokolow-Lyon index; 2. Romhilt and Estes scoring system; 3. Cornell voltage criteria; and 4. Gubner voltage criteria.

LVH was measured on ECG by applying following criteria:

Sokolow-Lyon criterion: S in VI and R in V5 and V6 (whichever was 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

Gubner voltage criteria: R in lead 1 + S in lead 3 > 24 mm

Echocardiography was done with the help of GE ECHO machine. Borders were defined according to proposed criteria given by the American society of echocardiography (ASE).[14] Left ventricular mass was calculated area-length method using measurements based on 3D echo imaging. LV mass=(LV epicardial volume_LV endocardial volume). 1.05 = LV myocardial volume. 1.05. (Myocardial density=1.05 g/mL)

Mean wall thickness was calculated from epicardial and endocardial cross-sectional areas in short-axis view at the level of papillary muscle and papillary muscles considered part of the LV cavity. All measurements were made at the end of diastole in centimetres. We determined LV mass with 3D echo.

Statistical analysis

Statistical analysis was done using SPSS software (version 17, SPSS, Chicago, IL). Data was presented as number and percentage. After assessing the results of ECG and echocardiography diagnostic validity tests (by calculating specificity and sensitivity), the Kappa measure of agreement was performed. P values less than 0.05 were considered significant.

RESULTS

In present study mean age of patients with LVH was 59.08±11.22 years, with male predominance (77%). Mean BMI of subjects was 26.38.

We also observed presence of various co-morbidities among both the genders, and found that in males' obesity was most common, whereas in females CAD was most prevalent co-morbidity (Table 1).

Table 1: Distribution of study subjects according to presence of co-morbidities among males and females.

Co-morbidities	Male		Female		Total	
	N	%	N	%	N	%
CAD	38	49.4	24	77.4	62	57.4
CKD	13	16.18	8	25.8	21	19.4
LVSD	22	28.57	10	32.3	32	29.6
Obesity	42	54.54	18	58.06	60	55.56
Total	77	71.3	31	28.7	108	100

The present study revealed that all patients suffered with hypertension, and many patients had CAD and most males had habit of smoking (Figure 1).

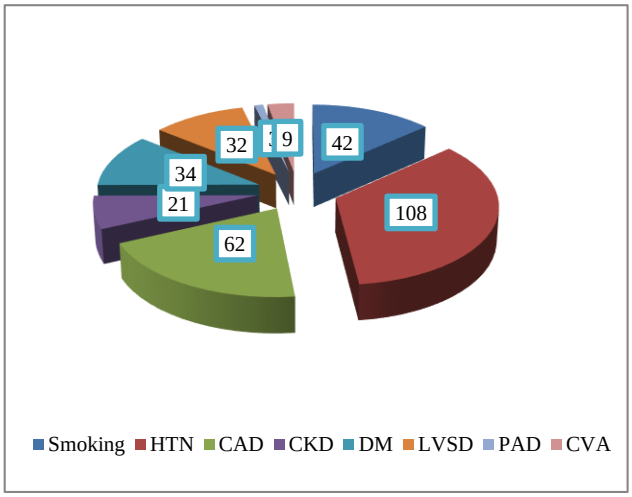

Figure 1: Distribution of study subjects according to presence of co-morbidities.

Among various criteria to identify LVHIt observed that in max 52.8% patients LVH detected using ECG LVH Sokolow Lyon criteria, followed by Cornell voltage CR criteria that detected LVH in 38.9% cases (Table 2).

Table 2: Distribution of study subjects according todetection of LVH by different ECG criteria.

ECG criteria	N	Percentage (%)
LVH Sokolow Lyon CR	57	52.8
Romhilt Estes CR	31	28.7
Cornell voltage CR	42	38.9
Gubner voltage CR	26	24.1
Total	108	100

The value of mean LV mass in study subjects was 228.89±55.17g. We also assessed sensitivity and specificity of various ECG criteria in detecting LVH. Sokolow Lyon criteria showed high sensitivity and Romhilt Estes criteria showed maximum 98% specificity in diagnosing LVH (Table 3).

We assessed sensitivity of various ECG criteria in detecting LVH in presence of various co-morbidities. Sokolow Lyon criteria was highly sensitive in assessing all co-morbidities, except CKD which was diagnosed better using Cornell voltage criteria. Presence of LV systolic dysfunction improves sensitivity of Romhilt Estes criteria (Table 4).

Table 3: Sensitivity and specificity of various ECG criteria in detecting LVH.

ECG criteria	Sensitivity (%)	Specificity (%)	Kappa coefficient	P value
Sokolow Lyon CR	38	92	-0.018	0.342
Romhilt Estes CR	27	98	0.007	0.524
Cornell voltage CR	33	94	-0.019	0.019
Gubner voltage CR	21	93	-0.018	0.074

Table 4: Sensitivity of various ECG criteria in detecting LVH in presence of various co-morbidities.

Co-morbidities	Sokolow Lyon CR (%)	Romhilt Estes CR (%)	Cornell voltage CR (%)	Gubner voltage CR (%)
HTN, (n=108)	52.78	28.70	38.89	22.07
Obesity, (n=60)	48.33	28.33	38.33	20.33
CAD, (n=62)	53.22	30.65	35.48	25.8
CKD, (n=21)	42.86	42.86	52.38	33.33
LVSD, (n=32)	59.38	50	46.88	32.5

DISCUSSION

An increased haemodynamic burden on heart leads to occurrence of LVH. Thus, an early diagnosis of LVH is highly significant to predict various cardiovascular disorders at early stage. As the 12-lead ECG is most commonly used diagnostic tool for LVH, thus a high sensitivity is desirable. Since many years, Echocardiography has been employed and has become one of the most significant non-invasive imaging techniques for assessing morphology and dynamics of heart.[17]

It has been advocated that LV mass increase with age, that causes a rise in electrically-inactive fibrous tissue. As ECG abnormalities are based on conduction defects, thus in elders ECG diagnosis of LVH become less accurate. ECG tests show low sensitivity, causing underestimation of LVH.[18] The present study was conducted to compare 4 most important electrocardiographic criterias for LVH, using 3D ECHO as diagnostic standard.

ECG LVH Sokolow Lyon CR is the simplest, oldest and quickest method to diagnose LVH. In present study it revealed highest sensitivity in diagnosing LVH in presence of various co-morbidities. Kappa measure of agreement was found to be 0.018, indicating that there was poor range of agreement between ECHO and ECG in diagnosing LVH. This criterion showed a sensitivity of 38% and specificity 92%. Similar to our study, Singh et al and Martin et al found similar range of Kappa coefficient value and sensitivity, with 75% specificity.[10,19] Reichek et al found a low range of sensitivity 21% and high specificity 95%.[20] Studies by Murphy et al and Jaggy et al reported high range of sensitivity of around 60% and specificity of around 75-80%.[21,22]

Romhilt Estes criteria uses a complicated data assessment for scoring. Found Kappa measure of agreement being 0.007 indicating a poor measure of agreement between both investigations. However, better specificity observed than Sokolow-Lyon criteria. Found sensitivity and specificity of 27% and 98% respectively, with specificity being maximum of all the criteria and sensitivity being lowest. However, in presence of LV systolic dysfunction sensitivity of Romhilt criteria is higher (50%). Study by Singh et al revealed a higher sensitivity 47% and lower specificity 75%.[10] Reichek et al, Murphy et al and Kansal et al found a higher sensitivity 50-60% and similar specificity 81-95% as in our study.[20,21,23]

We also observed that Cornell voltage criteria was highly sensitive in detecting LVH in patients having CKD. It has 33% sensitivity and 94% specificity, with kappa

coefficient being 0.019, showing a significant relation between both the techniques Echo and ECG statistically. Similar results were observed by Lv et al who found a stronger association with Echo-LVH and Cornell-related criteria.[8] Gubner voltage CR had a sensitivity and specificity in range of 21% and 93%, with poor kappa agreement of 0.018 between both investigation methods.

A raised risk of cardio vascular disorders and high rate of morbidity and mortality is correlated with incidence of LVH. Thus, it is important to detect the evidence of LVH at earlier stages. LVH is now referred as an important and independent risk factor for predicting stroke, acute myocardial infarction, sudden death, and congestive heart failure. Our study reflects that although various ECG criterias are being used to detect LVH, but all showed different range of sensitivity and specificity in diagnosing the condition in comparison with 3D Echo being the standard tool. We found that ECG LVH Sokolow Lyon CR showed high sensitivity and Romhilt Estes CR was most specific in diagnosing LVH. In cases of diagnosing LVH in patients with co-morbidities, ECG LVH Sokolow Lyon CR was found to be the most sensitive criteria of all.

Present study compared performance of various ECG criteria with 3D echo as standard however most of earlier studies used M mode-based echo assessment of LVH as standard. But still performances of various ECG criteria are comparable to earlier studies.

Limitations

The present study also had various limitations. MRI could have been a better standard tool than ECHO based assessment. We didn't compare the M mode-based assessment vs. ECG or 3D echo-based assessment of LVH. We did not use a multi-variate model to assess the correlation between ECG-LVH and ECHO-LVH. Thus, covariate variables were not adjusted.

CONCLUSION

Our study concluded that ECG LVH Sokolow Lyon CR showed high sensitivity and Romhilt Estes CR was most specific in diagnosing LVH. In cases of diagnosing LVH in patients with co-morbidities, ECG LVH Sokolow Lyon CR was found to be the most sensitive criteria of all. For assessing the patients for LVH, the role of ECG with all the commonly used criteria is of limited use and Echo is found to be the method of choice which also quantify LV mass which provide further prognostic value in these patients.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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