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A Study of Efficacy of the Classic ECG Criteria to Diagnose Left Ventricular Hypertrophy in Hypertensive Subjects and Evaluation of a New Score

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Abstract: ***This observational cross-sectional study was done in the Institute of Cardiovascular Sciences in R. G. Kar Medical College and Hospital from February, 2015 to December 2016. A total of 220 hypertensive patients were included through simple random sample selection. Patients who fulfil the inclusion and exclusion criteria were enrolled for the study after getting written informed consent.This study was carried out using the echocardiogram as the gold standard for the diagnosis of LVH. The new score proposed here, of which cutoff for the diagnosis of LVH was arbitrarily set at 2800mm-ms, is easily applicable in clinical practice and presented the best correlation with the LVMI, when compared to some classic electrocardiographic criteria.***

Key words-Hypertension, Left Ventricular Hypertrophy, ECG voltage criteria

1. Introduction

Affecting 1 billion people worldwide hypertension remains the most common, readily identifiable and reversible risk factor for myocardial infarction (MI), stroke, heart failure, atrial fibrillation, aortic dissection, and peripheral arterial disease[1]. The global burden of hypertension is rising owing to escalating obesity and population aging and the condition is projected to affect 1.5 billion persons—one third of the world's population—by 2025. The prevalence of hypertension is increasing rapidly in developing countries, where poor hypertension treatment and control contribute to the growing epidemic of cardiovascular disease[2].High blood pressure currently causes two thirds of all strokes and half of all cases of ischemic heart disease worldwide[3].

Hypertension is a disease affecting about 65.4% of people aged over 60 years and is responsible for 13-15% of all deaths worldwide[4,5] . Its prevalence in India is 22% – 45% among men and about 16% – 38% among women[6]. Long standing hypertension often progresses to left ventricular hypertrophy (LVH), an independent risk factor for predicting acute coronary syndrome, stroke, sudden cardiac death or heart failure[7,8,9]. Although LVH can be caused by other cardiovascular conditions too, this study specifically considers LVH caused by hypertension alone due to the large disease burden of hypertension in our country.

Among the several methods for the diagnosis of LVH, the least expensive, most wodely available and easier to interpret method is the electrocardiogram (ECG), which presents excellent reproducibility, high specificity, although it has low diagnosis sensitivity. However, in spite of this limitation, it remains a broadly used complementary test in medical practice as well as in population studies, in the prevention as well as in the analysis of regression of the hypertrophic process[10,11].

There are several electrocardiographic criteria for the detection of LVH, with variable sensitivities and specificities, depending on the studied population. These criteria, some with simpler applicability, others with a more complex one, have been used and correlated with methods of better accuracy in the assessment of the left ventricular mass (LVM), such as magnetic resonance and especially, the echocardiogram[12,13].

However, the variability of the results in the studied populations is related to demographic aspects, such as gender, race, age and associated heart pathology[14]. There is hardly any record of such a study, in our country, that has evaluated the efficacy of the ECG in the diagnosis of LVH, which is relevant information, considering that our population has a high rate of miscegenation and must have its own characteristics of electrocardiographic presentation and response, regarding the sensitivity and specificity of the several criteria used to detect LVH.

Further, being equipped with at least echocardiographic facilities requires not just the infrastructure but also the presence of skilled personnel. The lack of financial support and manpower in the medical field especially in rural primary health centres certainly poses a challenge to the feasibility of echocardiographic evaluation at the grass root level of medical care. Hence it is essential to find out whether the ECG can be used as a tool to screen for LVH in the rural setup (or even in urban areas as echocardiography is more expensive if the only indication is 'screening')

instead of echocardiography. If so, it may be utilised effectively in identifying LVH at rural primary health centres thus reducing the already saturated patient load at higher centres and the facilities could be availed by the more deserving patients[15].

Certainly, there are better imaging modalities than two-dimensional echocardiography to measure left ventricular mass index like three-dimensional echocardiography and cardiac magnetic resonance imaging. These advanced imaging modalities definitely have better sensitivity, specificity and accuracy of diagnosis of LVH. However, they are time-consuming and expensive and are not employed as often as the gold standard – two-dimensional echocardiography. In fact, these advanced modalities are not common even at tertiary health centres, and even when available, they are too expensive to be considered as tools to screen for left ventricular hypertrophy[15]. Hence this study compares the diagnostic efficacy of ECG with that of two-dimensional echocardiography.

The objective of this study is to evaluate a new electrocardiographic score for the detection of LVH in the INDIAN population, in a sample consisting of hypertensive individuals being followed on an outpatient basis and compare it with some of the classical ECG criteria used for the diagnosis of LVH, using the LVMI as the gold standard for the analysis. There is only a few records of such study, in our country, that has evaluated the efficacy of the ECG in the diagnosis of LVH, which is relevant information, considering that our population has a high rate of miscegenation and must have its own characteristics of electrocardiographic presentation and response, regarding the sensitivity and specificity of the several criteria used to detect LVH. This observational study is thus a relevant one in our setting.

Aims and Objectives:

- To evaluate efficacy of classic ECG criteria for the diagnosis of Left Ventricular Hypertrophy.
- To evaluate a new ECG score criteria for the diagnosis of Left Ventricular Hypertrophy.
- To compare the new ECG score with the classic ECG criteria.
- To correlate the ECG score with left ventricular mass index (LVMI)

Inclusion Criteria

Age above 18 years, diagnosed hypertension as per JNC - 7 guidelines, either on or off treatment

Exclusion Criteria

1) Patients with valvular heart disease,
2) Ischemic heart disease
3) Previous myocardial infarction,
4) Chagas' disease,
5) Blockage of the right or left bundle branch,
6) Ventricular pre-excitation syndrome or
7) Patient taking digoxin
8) Any other condition that could potentially disturb the ECG and the LV geometry

2. Methods

During the study period, a total of 220 patients fulfilling the inclusion criteria, aged 18 years and above with hypertension were examined clinically and with 12-leads ECG and standard echocardiographic technique.Following electrocardiographic criteria of LVH will be separately assessed [1] :-

-Romhilt-Estes point score system for LVH
-Sokolow-Lyon voltage critreria for LVH
-Cornell's voltage criteria for LVH-
-Cornell voltage duration measure(Cornell product)[1]-

The new score proposed here takes into account the maximum amplitude of the R(mR) + maximum amplitude of S(mS) waves on the horizontal plane (in mm), multiplying the value obtained by the QRS measurement (in seconds) where the complex is broader, usually in V2 and V3.
(mS+mR) in mm x QRS in sec

3. Observations

This study was carried out using the echocardiogram as the gold standard for the diagnosis of LVH. It is unquestionable that this imaging procedure represents a great advancement in the diagnosis of several heart pathologies, including LVH[16]. However, its cost is quite higher than that of the ECG, as well as being less reproducible, as it depends very much on the observer, a fact that restricts its use in epidemiological studies[28].

On the other hand, studies that used the anatomical specimen obtained during the necropsy as the gold standard of LVH34[19],presented higher distortions, as depending on the time and clinical condition of the patient before death, there can be a relevant bias.

Thus, considering its low cost and excellent reproducibility, the ECG is still important for the diagnosis of LVH, which is why it has been broadly used in clinical studies that involve Hypertension and LVH[20,21,22]. The same reason justifies and encourages the research of new electrocardiographic methods capable of increasing its diagnostic sensitivity.

In this present study, the youngest patient with hypertension was 20 years old and the oldest patient was 90 years old. Mean age was 60.4 years. Commonest age group of hypertensive patient was 61-70 years i.e. out of 220 patients 89(40.4%) were aged between 61-70 years. Most of the patients were aged above 60 years.

Out of all 220 patients 120 (54.5%) were male and 100 (45.4%) were female. Evidently, male outnumbered female in this study.

Among all 220 patients, 116 patients (52.7%) had LVH as detected by echocardiography and 104 patients (47.2%) of the patients did not have any LVH. More than half of the patients had LVH. This is almost similar to the observation in the study in southern India by Jostol Pinto et al[15].

Out of 116 patients having LVH, 62 patients (53.4%) were men and 54 patients (46.5%) were women. So LVH was almost equally prevalent in both sexes.

Among all 116 patients with LVH, 53 patients (45.6%) had mild LVH, 43 patients (37%) had moderate LVH and 20 patients (17.2%) had severe LVH. So, most of the patients had mild LVH and severe LVH was prevalent in least number of patients.

Out of all 220 patients, 147 patients (66.8%) were on regular antihypertensive therapy and 73 patients (33.2%) were not on regular antihypertensive therapy. Although most of the patients were taking antihypertensive medicines regularly, the proportion of those patients not taking regular treatment was also significant. Out of all patients who were on regular antihypertensive treatment, only 42.6% had LVH. On the other hand, out of all patients who were not on regular antihypertensive treatment, 75.3% had LVH. Prevalence of LV was very high among those patients on irregular treatment.

In this present study, 73 patients (33.1%) were taking ARB or ACE inhibitor either alone or in combination with some other antihypertensive drug. Among them, 16 patients (21.9%) had LVH. On the other hand, those patients who were not on any ARB or ACE inhibitor, 66.6% of them had LVH. Prevalence of LVH was significantly less among those taking ARB or ACE inhibitor.

Continuous variables were expressed as means and standard deviations. Categorical variables were expressed as percentages. Pearson's correlation coefficient was used to associate LVMI and the several electrocardiographic criteria that were analyzed. The ROC curve was used to validate the new score proposed here and a cutoff that presented better sensitivity and specificity was established. The Kappa test was used to analyze the several ECG variables. This test is a measurement index for nominal or categorical variables that corrects the observed concordance for the expected one, only due to a matter of probability. Values > 0.75 are considered to be excellent; those below 0.40 show poor concordance and those between 0.40 and 0.75 show good concordance. In order to verify the statistical significance, 95% confidence intervals and $p < 0.01$ were considered.

Correlation between LVMI and five assessed ECG criteria was tested with Pearson's correlation. r= 0.478, 0.450, 0.517, 0.558 and 0.647 were noted with Sokolow- Lyon, Cornell voltage, Cornell product, Romhilt- Estes and the proposed new score respectively with significant 2-tail.

Among all the five score, new score had the best correlation with LVMI detected by echocardiography.

Sensitivity and specificity of the proposed new score were calculated at different cut-off values by the ROC curve. Sensitivity decreased but the specificity improved progressively with higher cut-off values.

In the present study, sensitivity and specificity of the new score were 65.3% and76.4%, 59.5% and 81.9%, 55.4% and 86.1%, 53.1% and 96.9% , 40.7% and 97.2% , and 27.0% and 98.1% with 2500 mm-ms, 2600 mm-ms, 2700 mm-ms, 2800 mm-ms, 2900 mm-ms and 3000 mm-ms respectively. In this study, cut-off of 2800 mm-ms was arbitrarily used for the diagnosis of LVH with the new score which had the sensitivity of 52% and a specificity of 96.5%.

At partitions with a matched specificity of 95%, Comparison of receiver operating characteristic curves confirmed the superior performance of the proposed new score than the other classic scores.

Sensitivity of Sokolow-Lyon, Cornell voltage, Cornell product and Romhilt- Estes were 29.3%, 24.5%, 36.2%, and 31.8% respectively in our study. In this study all of these classic ECG criteria had low sensitivity.

In our study, specificity of these classic criteria were 97.6%, 96.7%, 98.6% and 96.3% respectively. All of these classic ECG criteria showed very high specificity in this study.

PPV and NPV of all the five ECG criteria were assessed. PPV and NPV of Sokolow-Lyon, Cornell voltage, Cornell product and Romhilt- Estes were 94.4% and 42.3%, 93.3% and 50.5%, 97.6% and 50.3%, 92.5% and 49.0%, and 96.7% and 54.0% respectively. All these classic criteria showed high PPV but low NPV.

The publication of the Sokolow-Lyon voltage criterion[18] dates from 1949 and is still very often used in clinical practice, given its easy applicability. In the original study, the authors studied 200 patients with some heart disorder capable of causing LV stress. The sensitivity and specificity values observed were 32% and 96%, respectively; it is important to note that it was a selected sample. Still in the present population, the sensitivity and specificity is almost similar to the observations in the original study.

Morrison et al., evaluated 127 patients using ECG and echocardiography, of whom 60 patients had LVH by echocardiographically determined LVMI[23]. Their study revealed sensitivity of the Sokolow-Lyon criteria to be very low (6.7%), which contradicts our values of 29.3%. However the specificity of the criteria by Morrison et al., were 95.7% comparable to 97.6% in this study.

Reichek N and Devereux RB studied 34 patients by comparing similar ECG criteria with echocardiography and chamber dissection findings of LVH [24]. According to them, Sokolow-Lyon criteria was poorly sensitive (21%), somewhat comparable to results of our study. But the specificity of the criteria was 95% which is similar to our study.

Moloy TJ et al, and Okin PM et al in their studies had shown incorporation of QRS duration (as a part of time-voltage integral) can improve sensitivity of Cornell voltage criteria. Moloy TJ et al showed the sensitivity and specificity of Cornell voltage vs. Cornell product is 36% vs. 51%. But in our study the sensitivity of these two criteria is 24.5% vs. 36.2%. The sensitivity and specificity of the Cornell voltage criteria was 22.2% and 96.8% in the study by Cléber do Lago Mazzaro et al[16]which is similar to the presentstudy. Regarding the Cornell duration criterion, Pearson's

correlation was higher (r=0.517), suggesting that the methods that also take into account the duration of the ventricular depolarization, such as the new score, can be more reliable.

In 1967, Romhilt and Estes[17] studied 90 hypertrophied hearts and 60 normal hearts. The specimens were obtained during necropsies and the ECG tracings had been performed at least 3 months before death. The sensitivity and the specificity of the original study were 57.8% and 96.7%, respectively. In the present sample, the sensitivity value is 31.8% which is much lower than the original study. The specificity (96.3%) of this classic criteria was almost similar to the original study. The sensitivity (31.85%) of the Romhilt- Estes criteria in this study was in agreement (sensitivity of 27%) with the study done by Moloy TJ et al.

Reichek N and Devereux RB studied 34 patients by comparing similar ECG criteria with echocardiography and chamber dissection findings of LVH [24]. They also tested Romhilt-Estes criteria along with Sokolow- Lyon criteria and they found a sensitivity and specificity of 50% and 95% respectively. The sensitivity is lower but the specificity of this classic ECG criteria in the present study is also in synchrony with that study.

Diagnostic strength of isolated typical strain pattern without other ECG feature of LVH was also tested separately. Its sensitivity, specificity, PPV and NPV were 17.2%, 100%, 100% and 50% respectively. It had the lowest sensitivity but highest specificity and positive predictive value.

In the present study, proposed new score with the cut-off value of 2800mm-ms had significantly higher (actually the highest) sensitivity (53.1%) than all the classic ECG criteria viz. the Sokolow- Lyon (29.3%), Cornell voltage (24.5%) and Cornell product (36.2%) and Romhilt- Estes criteria (31.8%). At the same time it also showed very high specificity comparable to the classic criteria. These criteria also had the highest correlation with the LVMI detected by the echocardiography. The study results are in agreement with that of the study done by Cléber do Lago Mazzaro et al[16].

Burden of high rates of cardiovascular disease and barriers in access of diagnostic centres and referral protocols[25]and Socio-economic disparities exist in our health care response in both public and private health facilities and policy efforts have been suggested to improve these disparities at the health system level[26]. In a country like India, where the disease burden of hypertension is overwhelming, it is important to decide which patients are to be evaluated for LVH. Prevalence of hypertension in India according to the recent NPCDCS study is 15.95%, with and incidence of 3.7%. It is projected that by 2025, the number of hypertensive individuals in India will be over 214 millions. It is not feasible to subject all hypertensive patiets to echocardiography to detect LVH. If ECGs were to be efficiently utilised at the primary health centres to identify LVH, only those patients could be referred at a higher centre for evaluation.

4. Conclusions

Both sexes are almost equally affected by hypertension and LVH. LVH was more prevalent in those who were not on regular treatment

Prevalence of LVH is less among patients who are on treatment with ARB or ACE inhibitor can prevent LVH compared to otherantihypertensive agents. New score had the best correlation with LVMI as detected by echocardiography.

All the classic ECG criteria had poor sensitivity but very high specificity. Sensitivity and specificity of Sokolow-Lyon, Cornell voltage, Cornell product and Romhilt- Estes were 29.3% and 97.6%, 24.5% and 96.7%, 36.2% and 98.6%, 31.8% and 96.3% respectively.

PPV and NPV of all the five ECG criteria were assessed. PPV and NPV of Sokolow-Lyon, Cornell voltage, Cornell product, Romhilt- Estes and new score were 94.4% and 42.3%, 93.3% and 50.5%, 97.6% and 50.3%, 92.5% and 49.0% and 96.7% and 54% respectively.

The new score had much better sensitivity (52%) compared to all the classic criteria. At the same time this new score had very high specificity (96.5%) similar to all the classic criteria.

Typical strain pattern alone has the lowest sensitivity (17.2%) but the highest specificity and PPV (100%)

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