

## Ventricular Mass and Electrocardiographic Criteria of Hypertrophy: Evaluation of New Score

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### Summary

**Background:** The left ventricular hypertrophy (LVH) is an important and independent cardiovascular risk factor. There is a scarcity of studies in Brazil designed to test the efficacy of the electrocardiogram (ECG) in the diagnosis of this important pathological process.

**Objective:** To evaluate a new electrocardiographic score for the diagnosis of LVH by ECG: the sum of the highest amplitude of the S wave and the highest amplitude of the R wave on the horizontal plane, multiplied by the result of the QRS duration [(S+R) X QRS] and comparing it with the classic electrocardiographic criteria.

**Methods:** The echocardiograms and ECG of 1,204 hypertensive patients receiving outpatient care were evaluated. The left ventricular mass index (LVMI) was assessed by the echocardiogram, with a diagnosis of LVH when the LVMI was  $\geq 96$  g/m<sup>2</sup> for women and  $\geq 116$  g/m<sup>2</sup> for men. Four classic criteria of LVH were analyzed at the ECG, in addition to the new score to be tested.

**Results:** In general, the studied ECG-LVH criteria showed significant statistical correlation to the echocardiographic LVMI. The (R+S) X QRS index, using 2.80 mm.s as the cutoff value, provided test accuracy regarding sensibility and specificity of 35.2% and 88.71%, respectively, representing the best correlation to LVMI ( $r=0.564$ ) when compared to the other indexes: Romhilt-Estes ( $r=0.464$ ); Sokolow-Lyon ( $r=0.419$ ); Cornell voltage ( $r=0.377$ ); Cornell product  $r=0.444$ ).

**Conclusion:** All the electrocardiographic criteria used for the assessment of the LV mass presented low sensitivity. The new score presented the best correlation with LVMI when compared to the other indexes. (Arq Bras Cardiol 2008; 90(4): 227-231)

**Key words:** Hypertrophy, left ventricular; electrocardiography; echocardiography.

### Introduction

The left ventricular hypertrophy (LVH) represents an important cardiovascular risk factor, independent from the systemic arterial hypertension (SAH), one of its main causes<sup>1,2</sup>.

Among the several propedeutic methods for the diagnosis of LVH, the least expensive, most broadly disseminated and easier to interpret method is the electrocardiogram (ECG), which presents 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<sup>3,4</sup>.

Additionally, the ECG presents excellent reproducibility, being very useful in the clinical follow-up of the patients. The

development of studies in SAH and valvulopathies has given rise to 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<sup>5,6</sup>.

However, the variability of the results in the studied populations is related to demographic aspects, such as gender, race, age and associated heart pathology. There is no 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.

The objective of this study is to evaluate a new electrocardiographic score for the detection of LVH in the

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Manuscript received August 23, 2007; revised manuscript received October 16, 2007; accepted October 16, 2007.

Brazilian 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.

## Methods

### Patients

The ECG tracings of 1,204 patients with SAH being followed on an outpatient basis were assessed at the Service of Hypertensive Cardiology of Universidade Federal de São Paulo - Escola Paulista de Medicina (UNIFESP-EPM) from March 1998 to December 2003. All of the ECG tracings were assessed according to the recommendations of the 1<sup>st</sup> Brazilian Directives of Arterial Hypertension<sup>7</sup>, i.e., at least two blood pressure measurements per medical visit on at least two different occasions, with SAH being diagnosed when the means of the measurements were  $\geq 140$  mmHg for the systolic pressure and 90 mmHg for the diastolic pressure. The exclusion criteria included: neoplasias, patients with valvular disease, acute coronary artery disease, previous myocardial infarction, Chagas' disease, blockage of the right or left branch, ventricular preexcitation syndrome or any other condition that could potentially disturb the LV geometry.

### Electrocardiogram

A resting ECG was carried out with the patient in the supine position and the 12-derivation ECG was obtained with a register velocity of 25 mm/s, calibration standardized at 1.0 mV/cm in a Dixtal EP3 equipment, Brazil. The tracing was decodified and a magnifying glass with a mm scale was used to analyze the several variables, which allowed a more precise analysis. The same observer quantified the axis and the duration of the QRS complex, the amplitude of the R wave at the  $D_1$ ,  $aV_L$ ,  $V_5$  and  $V_6$  derivations, amplitude of the S wave at  $V_1$ ,  $V_2$  and  $V_3$ , as well as the higher amplitude of the R and S waves at the horizontal derivations. Five electrocardiographic criteria of LVH were separately assessed: 1) Romhilt-Estes point score system – higher R amplitude or  $S \geq 30$  mm on the horizontal plane or  $\geq 20$  mm on the frontal plane or strain pattern in  $V_5$  or  $V_6$  (when using digital, the score is only one point), or left atrial growth by the Morris index (three points); electrical axis ( $\hat{A}QRS$ ) above less than  $30^\circ$  (two points); QRS duration  $\geq 90$  ms in  $V_3$  or  $V_6$  or left ventricular activation time  $\geq 50$  ms in  $V_5$  or  $V_6$  (one point). Using this score, the LVH is diagnosed when the sum of the points is  $\geq 5$ <sup>8</sup>; 2) Sokolow-Lyon voltage ( $SV_1 + RV_5$  or  $V_6 \geq 35$  mm)<sup>9</sup>; 3) Cornell's voltage ( $RaV_L + SV_3 \geq 20$  mm for women and  $\geq 28$  mm for men)<sup>10</sup>; 4) Cornell's duration ( $RaV_L + SV_3 \times QRS$  duration; for women add 8 mm,  $\geq 2,440$  mm.ms)<sup>11</sup>; 5) Perugia score – LVH is diagnosed by the presence of one or more of the following findings: Cornell's criterion, considering the limit for women  $\geq 20$  mm and  $\geq 24$  mm for men, Romhilt-Estes score and the strain pattern<sup>12</sup>. The new score proposed here takes into account the higher amplitude of the R or S waves on the horizontal plane (in mm), multiplying the value obtained by the QRS measurement (in seconds) where the complex is broader, usually in  $V_2$  and  $V_3$ . The analysis of reproducibility was carried out based on 100 tracings randomly withdrawn for the analysis of the amplitude of the R and S waves and QRS duration.

### Transthoracic Echocardiogram

The assessments were carried out at the Service of Doppler Echocardiography of UNIFESP-EPM in an ATL 1500 equipment (USA), using a 2.0 and a 3.5 MHz transducers. The patients was placed on the left lateral decubitus position and the images were obtained from the left parasternal region between the fourth or fifth intercostal spaces and the usual views were obtained for the complete M-mode and two-dimensional study, simultaneously with the ECG register. According to the recommendations of the Penn Convention, the following measurements were performed: size of the LV in systole and diastole, thickness of the interventricular septum and of the posterior wall of the LV at the end of the diastole, final diastolic and systolic volumes, diastolic shortening percentage and ejection fraction by the cube method. The left ventricular mass was calculated by the formula:  $LV\ mass = 0.8 \times \{1.04 [(IVSD + LVDD + PLVWD)^3 - (DDVE)^3]\} + 0.6\ g^{13}$ , where IVSD is the interventricular septum in diastole, LVDD is the final left ventricular diastolic diameter and PLVWD is the posterior LV wall in diastole. The LV mass was indexed for body surface area to adjust the differences of the heart size to the variations in patient size. Body surface area was calculated by the formula:  $BSA = (W - 60) \times 0.01 + H$ , where BSA is the body surface area in  $m^2$ , W is the weight in kilograms and H is height in meters<sup>14</sup>. The body mass index (BMI) was calculated by dividing the weight (in kilograms) by the square height (in meters). The diagnosis of LVH was attained when the LVMI was  $\geq 96\ g/m^2$  for women and  $\geq 116\ g/m^2$  for men<sup>15</sup>.

### Statistical Analysis

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 reproducibility study was carried out by three observers that interpreted the ECG assessments independently. The Kappa test was used to analyze the several ECG variables<sup>16</sup>. 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.

## Results

Of the 1,204 patients studied, 617 were males (51.2%) and 587 were females (48.8%), with a mean age of 57.4  $\pm$  4.7 years.

Table 1 shows Pearson's correlation among the several assessed electrocardiographic criteria and LVMI. The table shows that the new score is the one that maintains the best performance.

Table 2 shows the same Pearson's correlation among the assessed electrocardiographic criteria and the LVMI in the

**Table 1 - Correlation between the LMI and the assessed electrocardiographic criteria.**

Statistical Test	Electrocardiographic criterion				
	Romhilt-Estes	Sokolow-Lyon	Cornell-voltage	Cornell-duration	New score (mS+mR).QRS
Pearson's correlation	0.464*	0.419*	0.377*	0.444*	0.564*
p value	0.001	0.001	0.001	0.001	0.001
N	1,204	1,204	1,204	1,204	1,204

\*Significant correlation at 0.01 level (two-tailed)

**Table 2 - Correlation between the LVMI and the assessed electrocardiographic criteria, analysis of the general population and the obese and the non-obese groups.**

Population	Electrocardiographic criterion / Pearson's correlation				
	Romhilt-Estes	Sokolow-Lyon	Cornell-voltage	Cornell-duration	New score
General population (n = 1,204)	0.464*	0.419*	0.377*	0.444*	0.564*
Non-obese (n = 852)	0.500*	0.458*	0.385*	0.462*	0.606*
Obese (n = 352)	0.326*	0.285*	0.359*	0.392*	0.420*

\*p < 0.01.

general population, separating the patients in two groups: non-obese (BMI < 30 Kg/m<sup>2</sup>), or 852 patients (70.7%) and obese patients (BMI > 30 Kg/m<sup>2</sup>), a group represented by 352 patients (29.3% of the sample). As expected, among the obese patients the correlation between the ECG criteria and the LVMI decrease in general<sup>17</sup>. However, the new score is once more the one that presents the best performance.

Table 3 shows the sensitivity and specificity values of the new score, which was obtained from the ROC curve and the cutoff of 2.8 mm.s was arbitrarily used for the diagnosis of LVH.

Table 4 shows the values of sensitivity, specificity and accuracy of the five electrocardiographic criteria assessed, as well as of the new score proposed here, based on the assessed sample that consisted of 1,204 hypertensive individuals.

Regarding reproducibility, the level of concordance among the three observers varied from 0.82 to 0.98, considered to be an excellent level of concordance. The first value corresponds

to duration of the QRS complex and the last to the amplitude of the R and S waves.

## Discussion

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. 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.

On the other hand, studies that used the anatomical specimen obtained during the necropsy as the gold standard of LVH<sup>8,18</sup> 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 SAH and LVH<sup>3,19,20</sup>. The same reason justifies and encourages the research of new electrocardiographic methods capable of increasing its diagnostic sensitivity.

In 1967, Romhilt and Estes<sup>8</sup> 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 specificity value is similar; however, the sensitivity value is much lower (15.3%), with Pearson's correlation with the LVMI being 0.464.

**Table 3 - Sensitivity and specificity of the new score, according to the cutoff value calculated by the ROC curve.**

Cutoff value (mS+mR).QRS	Sensitivity (%)	Specificity (%)
≥ 2.50 mm.s	45.4	82.5
≥ 2.60 mm.s	40.9	83.9
≥ 2.70 mm.s	38.4	86.2
≥ 2.80 mm.s	35.2	88.7
≥ 2.90 mm.s	31.5	90.1
≥ 3.00 mm.s	28.1	91.7

**Table 4 – Sensitivity, specificity and accuracy of the classic electrocardiographic scores and the new score in the diagnosis of LVH.**

Criterion	Sensitivity (%)	Specificity (%)	Accuracy (%)
Romhill-Estes $\geq 5$ points	16.3	95.8	66.7
Sokolow-Lyon (mm) ( $SV_1 + RV_{5,6}$ ) $\geq 35$	13.4	96.8	66.3
Cornell voltage (mm) $RaV_L + SV_3 > 28$ when male or 20 when female	18.8	96.8	68.3
Cornell duration (mm.ms) ( $RaV_L + SV_3 + 8$ when female) $\times$ QRS $> 2440$	22.2	96.0	69.0
Perugia Strain pattern or Romhill-Estes $\geq 5$ points or $RaV_L + SV_3 > 24$ mm when male or 20 mm when female	38.6	89.6	71.0
New score (mS+mR) $\times$ QRS $\geq 2.8$ mm.s	35.2	88.7	68.7

The publication of the Sokolow-Lyon voltage criterion<sup>9</sup> 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. In the present population, the specificity was very high (96.8%), although the sensitivity decreased to 13.4%.

In the present study, the Cornell voltage criterion<sup>10</sup> presented a sensitivity of 22.2% and specificity of 96.8%. The results were similar regarding the specificity; however, the difference was significant regarding the sensitivity (42% vs. 22.2%). Additionally, Pearson's correlation for the same criterion was 0.377, much lower than that of the new score, of 0.564.

Regarding the Cornell duration criterion<sup>11</sup>, Pearson's correlation was higher ( $r=0.444$ ), suggesting that the methods that also take into account the duration of the ventricular depolarization, such as the new score, can be more reliable.

Schillaci et al<sup>12</sup>, in 1994, using the Perugia score for the diagnosis of LVH in the PIUMA study, found a sensitivity of 26% and a specificity of 90%. When testing this same score in the present sample, a sensitivity of 38.6% and a specificity of 89.6% were observed. It was not possible to carry out Pearson's correlation between the Perugia score and the LVMI, considering that it was the score of a qualitative variable.

It is noteworthy that Pearson's correlation among all the electrocardiographic criteria assessed with the LVMI lost

its strength, as expected, in the group of obese patients<sup>17</sup>. However, the new score presented here also showed a better performance in this group.

## Conclusion

The ECG is a safe, accessible, low-cost complementary test with an excellent reproducibility. Thus, the search for new criteria capable of increasing its diagnostic sensitivity in the detection of LVH must be stimulated and encouraged. The new score proposed here, of which cutoff for the diagnosis of LVH was arbitrarily set at 2.8 mm.s, is easily applicable in clinical practice and presented the best correlation with the LVMI, when compared to some classic electrocardiographic criteria, as well as presenting the best attenuation in the group of obese patients.

## Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

## Sources of Funding

There were no external funding sources for this study.

## Study Association

This article is part of the Master's Degree dissertation submitted by Cleber do Lago Mazzaro, from Universidade Federal de São Paulo, Escola Paulista de Medicina (Unifesp/EPM).

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