Assessment of LVH Criteria by Surface ECG

Assessment of Left Ventricular Hypertrophy (LVH) Criteria by Surface Electrocardiography in a Sample of Iraqi Patients with Systemic Arterial Hypertension

Rafid Bashir Altaweel¹, Maher Abdulla Radhi²

ABSTRACT

Background: Left ventricular hypertrophy (LVH) in hypertensive patients indicates an ongoing disease process involving the heart. Different electrocardiography (ECG) criteria were investigated; however, the results were conflicting. Objective: To evaluate different ECG criteria in diagnosis of LVH in hypertensive patients using echocardiography as a gold standard. Methods: A hospital based cross sectional observational study which included 140 adult patients with a history of hypertension. Patients were assessed for LVH using five ECG criteria: Romhilt-Estes, Sokolow-Lyon, Cornell voltage, Gubnere Ungerleider and Peguero-Lo Presti. Echocardiography was used to determine the left ventricular mass index for the patients. The sensitivity and specificity of each ECG criterion was determined considering echocardiography as a gold standard. Results: According to the echocardiographic results, 83 patients (59.29%) were found to have LVH. Age over 40 years, overweight and obesity, high systolic blood pressure (>170 mmHg) and using of antihypertensive drugs were significantly associated with the increased risk of LVH. All included ECG criteria showed low sensitivity and high specificity in detection of LVH in hypertensive patients. There were no significant differences in the efficiency of different ECG criteria in discrimination between mild, moderate and severe cases of LVH. Conclusion: LVH is very common among hypertensive patients, and the sensitivity of ECG criteria is low for these criteria to be clinically used for detection of LVH with high specificity, in which Cornell criterion is the best in detection. Keywords: Left ventricular hypertrophy, Left ventricular mass index, ECG criteria, systemic hypertension.

1. INTRODUCTION

Left ventricular hypertrophy (LVH) is defined as an increase in the left ventricular mass (LVM) in response to a disease state, due to either increase in left ventricular (LV) wall thickness or an increase in cavity size or both (1). There are several factors which can influence the incidence of LVH in adults e.g. Obesity (2), Race as LVH is more common in hypertensive African-Americans (50%) than in whites (33%), and the adjusted risk of having LVH, whether indexed by height 2.7 or by body surface area (BSA) (3, 4). Diabetes mellitus (DM) have higher LV mass, independent of hypertension (5). Electrocardiography is the cheapest and most readily available of the three tests for LVH. Many different criteria for electrocardiographic LVH have been proposed over the years. The diagnosis of LVH by electrocardiography is strongly influenced by age and ethnicity (6). The most well-known electrocardiographic criteria are the Cornell voltage, the Cornell product, the Sokolow-Lyon index, and the Romhilt-Estes point score system (7). Common electrocardiographic criteria for the diagnosis of left ventricular hypertrophy are described in table (1). Echocardiography (ECO) is an imaging technique that creates pictures of the heart utilizing high-frequency ultrasound waves. Whether it be two-dimensional, three-dimensional, or M-mode, ECHO is used to assess target organ damage (TOD) and measure LV mass (LVM). The LVM can then be indexed to BSA, or height 2.7 to determine LVH. For adults, a LVM index ≥51 g/m 2.7 is used to define LVH based on a study by Havranek et al., which showed LVMi above this threshold is associated with more than four times increased risk of morbidity and mortality (8). This study aimed
to evaluate the efficiency of five ECG criteria in the diagnosis of LVH in adult hypertensive patients based on echocardiography as a gold standard.

2. AIM

To evaluate different ECG criteria in diagnosis of LVH in hypertensive patients using echocardiography as a gold standard.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Lewis voltage</td>
<td>$R_s + R_a + S_p &gt; 1.7$ mV</td>
</tr>
<tr>
<td>Gubner-Ungerleider Voltage</td>
<td>$S_p + 2.5$mV</td>
</tr>
<tr>
<td>Sokolow-Lyon voltage</td>
<td>$S_n + 3.5$mV</td>
</tr>
<tr>
<td>Romhilt-Estes score</td>
<td>$S_n + R_e \geq 4$ (probable LVH)</td>
</tr>
<tr>
<td>Cornell voltage</td>
<td>$S_n + R_e \geq 2.8$mV (men), $&gt;2.0$mV (women)</td>
</tr>
<tr>
<td>Cornell product</td>
<td>$(S_n + R_e \text{ with 0.8mV added in women}) \times QRS$</td>
</tr>
<tr>
<td>Pegeuro lo persen</td>
<td>Deepest '$s' wave in any lead plus '$s' wave in lead $4$</td>
</tr>
<tr>
<td>Framingham Criterion</td>
<td>$S_n + R_e \geq 1.1$mV, $S_n + R_e \geq 3.5$mV, $S_n + R_e \geq 2.5$mV</td>
</tr>
<tr>
<td>Perugia Criterion</td>
<td>$S_n + R_e \geq 2.4$mV (men), $&gt;2.0$mV (women), and/or $S_n + R_e \geq 5$</td>
</tr>
</tbody>
</table>

Table 1. Table showing the commonest used ECG criteria to detect LVH

3. PATIENTS AND METHODS

This is a hospital based cross sectional observational study which was conducted at Al-Imamain Al-Kadhimain Medical city in Baghdad. It included a total of 140 adult patients 18 years of age or older in outpatients’ clinic of this tertiary care hospital with a history of hypertension from March 2018 to December 2018. All patients provided informed verbal consent and each patient was subjected to clinical examination after taking the sufficient history, data including age, sex, weight, height and basal metabolic rate (BMI). The body surface area was calculated according to the following formula (9):

$$\text{BSA} = \sqrt{\frac{\text{height} \times \text{weight}}{3600}}$$

Age above 18 years diagnosed with hypertension as per JNC-8 guidelines, regardless of treatment, were included in this study, while those with congenital heart disease, valvular heart disease, ischemic heart disease, pericardial disease, right ventricular hypertrophy, arrhythmias or conduction abnormalities, sinus node diseases, dilatation aneurysm of left ventricle, Wolff-Parkinson syndrome, ventricular or supraventricular tachycardia, Eligible patients (140 patients) were undergone echocardiography and ECG. ECGs had been recorded using the 'Mortara/ USA' machine (calibration 0.5, speed 25mm/sec), Echocardiography had been performed by experienced echo-radiologist using the 6S probe (2.7-8.0MHz) of the ‘GE Vivid SS’ machine and dimensions were measured while visualizing the heart in the long axis view. Transsthoracic echocardiography was used as a method of reference to estimate left ventricular mass. Left ventricular end-diastolic and end-systolic measurements were obtained with the patient in a partial left lateral decubitus position according to recommendations by the American Society of Echocardiography (10). Left ventricular mass was calculated by using the Devereux formula (11):

$$\text{LVMI} = \frac{4}{3} \pi \frac{(S_n + R_e \text{ with } 0.8 \text{mV added in women}) \times QRS}{\text{BSA}}$$

The left ventricular mass was indexed according to body surface area. LVH was defined as a left ventricular mass index $>115$ g/m$^2$ in male subjects and $>104$ g/m$^2$ in female subjects (12). According to the result of echocardiography, patients were divided into two groups as follows:

**LVH group**: Those patients whose echocardiography reveals concentric LVH and LVMI greater than or equal to 115 g/m$^2$ for males and 95 g/m$^2$ for females.

**Non-LVH group**: Those patients whose echocardiography reveals no evidence of concentric LVH and LVMI less than 115 g/m$^2$ for males and 95 g/m$^2$ for females.

The patients were divided by gender and degree of ventricular hypertrophy, calculated by the echocardiogram, according to the recommendations of the American Society of Echocardiography/European Association of Echocardiography. Thus, mild LVH was considered, for the female population, when the LVMI was 96-108 g/m$^2$; moderate LVH with LVMI of 109–121 g/m$^2$ and severe LVH with LVMI ≥ 122 g/m$^2$. For the male population, these values were 116–131 g/m$^2$; 132-148 g/m$^2$ and ≥149 g/m$^2$, respectively (12).

Statistical Package for Social Sciences (SPSS) software version 24 was used for all statistical analyses. Cases studied were analyzed after being subdivided into a group with normal and a group with increased left ventricle mass. Numerical variables were expressed as mean± standard deviation (SD), while binomial variables were expressed as frequency and percentages. Logistic regression test was used for calculation of odds ratio and its corresponding confidence interval (CI) to find out the predictors of LVH in hypertensive patients. Sensitivity and specificity of each ECG criteria compared to ECHO results were statistically analyzed with using Chi square test. Results were considered statistically significant when having p-values ≤ 0.05.

4. RESULTS

Mean age of the patients was 50.4±10.2 years (range 32 to 87 years), among whom 81 (57.86%) were males and 59 (42.14%) were females. The mean body mass index (BMI) and body surface area (BSA) were 31.7±4.2 kg/m$^2$ and 1.94±0.3 m$^2$, respectively.

**Incidence of LVH**

According to the echocardiographic results, 83 patients (59.29%) were found to have LVH, while (40.71 %) didn’t have LVH.

**Demographic and clinical risk factors for LVH**

Out of 9 demographic and clinical risk factors, only 4 showed significant association with the incidence of LVH. Patients with LVH had a significantly higher mean age, BMI and SBP (53.8±9.2 years, 32.5±4.7 kg/m$^2$ and 174.71±17.6 mmHg respectively) than their corresponding patients without LVH (45.4±7.7 years, 30.6±4.2 kg/m$^2$ and 165.61±17.4 mmHg respectively).

ORIGINAL PAPER | MED ARCH. 2020 DEC; 74(6): 428-432
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Predictors of left ventricular hypertrophy

Out of 83 patients with LVH, 71 patients (85.54%) were older than 40 years compared with 73.68% among patients without LVH who were older than 40 years (OR=2.52, 95% CI=1.09-5.79, P=0.028). Likewise, 73.49% of LVH patients had a BMI exceeded 28 kg/m² compared with only 36.84% among patients without LVH who had such BMI (OR=4.75, 95% CI=2.3-9.83, P<0.001). In the majority of patients with LVH (77.11%), the SBP was over 170 mmHg compared to about half patients without LVH who had such SBP (OR=3.5, 95%CI=1.68-7.23, P=0.001). Finally, the proportion of patients using antihypertensive drug in those with and without LVH was 89.16% and 75.44% respectively (OR=2.68, 95%CI=1.07-6.7, P=0.031) as shown in Table (2).

Assessment of different ECG criteria in detection of LVH

Romhilt-Estes Point-Scoring System

Out of these 83 patients with LVH, Romhilt-Estes Point-Scoring System criteria detected 42 patients. This gives a sensitivity and specificity of 51% and 79% respectively for this criterion

Sokolow-Lyon Voltage criteria

According to this criterion, 31 patients (out of 83) were positive for LVH. Thus, the sensitivity and specificity of the criterion were 37% and 75% respectively.

Cornell Criteria

In this criterion 54 out of 83 were positive for LVH. The sensitivity of the criterion was 65% while the specificity was as high as 97%.

Table 2. Showing association with LVH including the age, BMI, SBP and whether patient is taking medication or not

<table>
<thead>
<tr>
<th>Variables</th>
<th>Patients with LVH No  = 83(%)</th>
<th>Patients without LVH No  = 57 (%)</th>
<th>P-value</th>
<th>OR(95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 40</td>
<td>12(14.46%)</td>
<td>15(26.32%)</td>
<td>0.028</td>
<td>1.0</td>
</tr>
<tr>
<td>&gt;40</td>
<td>71(85.54%)</td>
<td>42(73.68%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (Kg/m²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤28</td>
<td>22(26.51%)</td>
<td>36(63.16%)</td>
<td>0.001</td>
<td>1.0</td>
</tr>
<tr>
<td>&gt;28</td>
<td>61(73.49%)</td>
<td>21(36.84%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP, mmHg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤170</td>
<td>19(22.89%)</td>
<td>29(50.88%)</td>
<td>0.001</td>
<td>1.0</td>
</tr>
<tr>
<td>&gt;170</td>
<td>64(77.11%)</td>
<td>28(49.12%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antihypertensive drug</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>9(10.84%)</td>
<td>14(24.56%)</td>
<td>0.031</td>
<td>1.0</td>
</tr>
<tr>
<td>Yes</td>
<td>74(89.16%)</td>
<td>43(75.44%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Showing the ability for each ECG criterion to detect increase in LVMI across different degrees of LVH which showed non-significant values for all the criteria to preferably detect LVH in certain degree over other

Figure 1. The percent sensitivity and specificity for each ECG criteria studied to detect increase in LMVI in comparison with 2D echocardiography

5. DISCUSSION

Incidence of LVH among patients with systemic hypertension

In this study about two-third (59.29%) had echocardiographic evidence of LVH. This result is much higher than that of Verdecchia et al. (13) who reported the prevalence of LVH of 27.2% using the same LVMI cut-off value (125 g/m²) for males and females. Dada et al. (14) obtained a prevalence of 34% at LVMI of 126 g/m and 130 g/m for females and males, respectively, while Katibi (15) reported a prevalence of 35%. Only 4 clinical risk factors showed significant association with the incidence of LVH. Older age (>40 years) were more prone...
for LVH (OR=2.52, 95% CI=1.09-5.79, P=0.028) i.e.2.5-
time risk to have LVH. In a Spanish study, Lazano et al. (16) assessed 15798 hypertensive patients and showed that LVH was independently associated with older ages. This trend may be explained by the prolonged period that elderly experiencing hypertension which eventually increases the load of left ventricle and induces LVH. Obesity (OR=4.75,95% CI=2.3-9.83, P=0.001) which indicates that patients with BMI >28 kg/m^2 will be at 4.75-times greater risk of LVH compared with those of lower BMI. In a systematic review (17) it was found that the likelihood to have LVH was much higher in obese than non-obese subjects (OR= 4.19, 95% CI= 2.67-6.53), as it results in greater metabolic requirements, and cardiac output and can be considered as a volume over-
loaded state (18). Thirdly, LVH was more with higher SBP (OR=3.5, 95%CI=1.68-7.23, P=0.001). In a Chinese study, Su et al. (19) evaluated SPB in 1120 patients and found a highly significant association between it and LVMI. LVH was also associated using antihypertensive drug (OR=2.68, 95%CI=1.07-6.7, P=0.031). This is not in consistence with the most previous studies which have reported 5–13% reductions of the left ventricular mass by using antihypertensive (20). The current results may have some bias because antihypertensive users are usually older ages with different comorbidities and have prolonged period of hypertension, all of which increase the risk of LVH.

Assessment of different ECG criteria in detection of LVH
The sensitivity and specificity of Romhilt-Estes criter-
ion to diagnose LVH in the current study was 51% and 79% respectively which is much higher that obtained by Dada et al. (14) and by Okin et al. (21) who showed sensitivities of (18%, 12%) and specificities of (92.8% and 100%) respectively. Therefore, the Romhilt-Estes cri-
terion can be considered with low sensitivity and high specificity in diagnosing LVH. For Sokolow-Lyon Volt-
age, the sensitivity and specificity were 37% and 75% respectively in the current study. Burgos et al. (22) as-
essessed this criterion in 2240 patients with hypertension. The reported sensitivity and specificity were 22.2% and 88.3% respectively. A higher sensitivity (58.62%) and lower specificity (60.66%) reported by Ogunlade et al. (23) among Nigerian study with hypertension. These data indicate the relatively low sensitivity and specificity of this criterion. In the current study, the Cornell voltage criteria were found to have the best detection rate with 65% sensitivity and 97% specificity. These results are in accordance of the Nigerian study in which Cor-
nell voltage was found to have better performance than the other criteria (24). This high performance can be ex-
plained by the fact that increased ventricular mass ori-
ents the electric forces both horizontally (corresponding to the R wave in a VL) and posterior (S wave in V3). In addition, the V3 lead is closer to the left ventricle and is probably less influenced by variations in the distance between the myocardium and the leads. The sensitivity and specificity of Peguero-Lo Presti in the current study were 47% and 70% respectively. In a recent study, Por-
wal (24) evaluated the sensitivity and specificity Peg-
uegro-Lo Presti for LVH detection and were 54.17% and 91.35% respectively. The sensitivity and specificity of Gubner-Ungerleider criterion in the present study were 12% and 91% respectively. A Nigerian study showed that Gubner-Ungerleider had the lowest sensitivity among five investigated criteria and the sensitivity and speci-
ficity of this criterion in detection of LVH were 13.79% and 86.89%; respectively. The present study showed no significant differences in efficiency of different ECG cri-
teria in detection of different severities of LVH that may be because the low number of included patients, there were no significant differences in detection rate. Unfor-
fortunately, there is no available study in literature which addressed the efficiency of different ECG criteria in de-
tection the LVH according its severity.

6. CONCLUSION
Finally, this study reaches the followings:
• Left ventricular hypertrophy is a common in hy-
pertensive patients.
• Age over 40 years, overweight and obesity, and high systolic blood pressure are associated with higher chances to develop LVH in hypertensive patients.
• Almost all ECG criteria have low sensitivity and high specificity in detection of LVH in hyperten-
sive patients, among which Cornell criterion is the best in detection.
• There are no significant differences in the efficien-
cy of different ECG criteria in discrimination be-
tween mild, moderate and severe cases of LVH.

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