Original article

Assessment of voltage criteria for left ventricular hypertrophy in adult hypertensives in south-western Nigeria

Oluwadare Ogunlade^{a,*}, Anthony Olubunmi Akintomide^b^a Department of Physiological Sciences, Obafemi Awolowo University, Ile-Ife, Nigeria^b Department of Medicine, Obafemi Awolowo University Teaching Hospital Complex, Ile-Ife, Nigeria

ARTICLE INFO

Article history:

Received 25 January 2012

Accepted 4 July 2012

Available online 27 February 2013

Keywords:

Assessment

Hypertensives

Voltage criteria

ABSTRACT

Background: Left ventricular hypertrophy (LVH) is a common pathophysiological consequence of hypertension. Various voltage (ECG) criteria exist for evaluation of LVH. This study assessed the performance of 4 commonly used ECG criteria in south-western Nigeria.

Materials and methods: A cross-sectional descriptive study of adult hypertensive subjects. Participants were assessed for LVH using 4 ECG criteria: Sokolow–Lyon, Araoye code system, Cornell voltage, and Gubner–Ungerleider criteria. Echocardiography was used to determine the left ventricular mass index for the participants, and a value greater than 125 g/m² was used as the cut-off point for LVH. The sensitivity, specificity, accuracy, positive and negative predictive values were determined for each of the ECG criteria.

Results: 90 subjects (45 males, 45 females) participated in the study. The prevalence of LVH by echocardiography was 32.2%. The prevalence of LVH by voltage criteria were: 45.6%, 42.2%, 34.4%, 13.3% by Sokolow–Lyon, Araoye code system, Cornell, and Gubner–Ungerleider criteria, respectively. The sensitivity and specificity respectively of the ECG criteria were 58.62% and 60.66% (Sokolow–Lyon), 48.28% and 60.65% (Araoye code system), 51.72% and 73.77% (Cornell), and 13.79% and 86.89% (Gubner–Ungerleider).

Conclusion: Out of the 4 ECG criteria, Araoye code system, Cornell and Sokolow–Lyon criteria compared favorably well with echocardiography and may be used in the initial assessment of LVH in adult hypertensive subjects. However, a combination of any of the 3 criteria with Gubner–Ungerleider criterion will be more clinically useful.

Copyright © 2013, SciBioMed.Org, Published by Reed Elsevier India Pvt. Ltd. All rights reserved.

1. Introduction

Left ventricular hypertrophy (LVH) is a progressive structural change involving the left ventricular myocardium. LVH is characterized by increase in the size and workload of the cardiac chambers. LVH, which is assessed by electrocardiogram or echocardiogram, is an independent risk factor for cardiovascular and cerebrovascular events. LVH is also a major factor in the etio-pathogenesis of cardiac arrhythmias, ischemic heart disease, congestive heart failure, and sudden cardiac death.^{1–4}

LVH is a common complication of hypertension, the leading non-communicable disease in Nigeria.⁵ The prevalence of hypertension varies with the cut-off value used and the population involved. The crude prevalence of hypertension in Nigeria is 11.2%.⁵ Therefore, proper assessment of left ventricular hypertrophy in

patients with hypertension is not only important but also of therapeutic and prognostic relevance.⁶

Many methods are used to assess LVH though the gold standard is probably the echocardiogram.⁷ However, this facility is still largely a specialized one, available only in a few hospitals in Nigeria. A set of criteria based on electrocardiogram (ECG), a more readily available, simple, affordable, easy to use and portable tool has been developed for assessment of LVH. These include; Sokolow–Lyon⁸ and Cornell's criteria,⁹ Cornell's voltage product,¹⁰ Araoye code system,^{11,12} Gubner–Ungerleider criterion,⁹ Framingham score,¹³ Mcphie¹⁴ and Wilson criteria,¹⁵ Manning and Smiley criterion,¹⁶ Mazzoleni criterion,¹⁷ Perugia score,¹⁸ Minnesota code¹⁹ and Romhilt–Estes Point Score System.²⁰ In Nigeria, only few studies have evaluated the suitability of the electrocardiographic criteria in the assessment of LVH among adult hypertensive subjects. This study, therefore, compared 4 commonly used voltage criteria with echocardiography to assess their suitability for routine use in the assessment of LVH in adult hypertensive subjects.

* Corresponding author.

E-mail address: oogunlade@oauife.edu.ng (O. Ogunlade).

2. Materials and methods

Ninety consecutive adult subjects with established hypertension diagnosed at the cardiac clinic were recruited for the study. There were 45 males and 45 females. The ECGs of the patients were evaluated for the presence of left ventricular hypertrophy using 4 ECG criteria: Sokolow–Lyon (SV1 + RV5 or V6 > 35 mm), Gubner–Ungerleider (SIII + RI > 25 mm), Araoye code system (SV2 + RV6 > 35 mm in women or > 40 mm in men or RI > 12 mm in both sexes), and Cornell's criteria (SV3 + RaVL > 20 mm in women or > 28 mm in men). The subjects were re-evaluated using echocardiography. Sonoline G60S Ultrasound system with 4.2 MHz transducers was used for cardiac scanning. Two Dimensional (2D)-guided M-mode measurements were made according to American Society of Echocardiography (ASE) convention.²¹ The linear dimensions of septal wall, left ventricular cavity, and posterior wall along the left ventricular minor axis, identified as the largest diameter perpendicular to the septum and posterior wall, were measured at the end of diastole (at onset of R wave). The measurements were recorded in centimeters. The estimation of left ventricular mass (LVM) was based on the formula derived by Devereux and colleagues.⁷

$$\text{LVM} = 0.8 \left(1.04 \left[(\text{LVIdD} + \text{PWTd} + \text{IVSTd})^3 - (\text{LVIdD})^3 \right] + 0.6g \right)$$

where LVIdD = left ventricle internal dimension in diastole, PWTd = posterior wall thickness in diastole, IVSTd = interventricular septal thickness in diastole, 1.04 = specific gravity of the myocardium.

The LVM index partition value > 125 g/m² for both sexes²² was utilized for determination of left ventricular hypertrophy and the sensitivity, specificity, accuracy, positive predictive value and negative predictive value of each of the voltage criteria were estimated. The Ethics and Research Committee of Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC), Ile-Ife approved the study. The data was analyzed using the Statistical Package for Social Sciences (SPSS) version 15.0 software. Continuous variables were expressed as mean ± standard deviation (SD). Categorical variables were expressed as percentages. Comparison of means was done by Student *t* test. 95% confidence interval was used to determine significance of probability, and *P* value of <0.05 was taken as statistically significant.

3. Results

Ninety (90) hypertensive subjects (45 males, 45 females) participated in the study. 75.6% of the study population was above 50 years of age. The mean age was 57 ± 12 years. The most frequent age-group was 50–59 years. The mean height for males and females were 1.71 ± 0.08 m and 1.60 ± 0.07 m, respectively. The mean

Table 1
Demographic characteristics.

Variable	Range	Mean ± SD	Mode	Median
Age (years)	30–87	57.17 ± 12.07	57.00	56.50
Height (m)	1.50–1.97	1.65 ± 0.09	1.55	1.65
Weight (kg)	41–115	72.57 ± 16.19	55.00	71.50
BMI (kg/m ²)	15.6–43.4	26.66 ± 5.94	16.95	26.2
SBP (mmHg)	90–220	141.74 ± 13.05	140	140
DBP (mmHg)	50–130	87.00 ± 13.05	90	90
BSA (m ²)	1.04–2.96	1.79 ± 0.25	1.61	1.79

DBP = diastolic blood pressure, SBP = systolic blood pressure, BSA = body surface area, BMI = body mass index.

Table 2
Demographic characteristics according to gender.

Variable	Male (N = 45)	Female (N = 45)	<i>P</i> value
	Mean ± SD	Mean ± SD	
Age (years)	57.44 ± 11.84	56.89 ± 12.41	0.829
Height (m)	1.71 ± 0.08	1.60 ± 0.07	< 0.001*
Weight (kg)	75.41 ± 15.45	69.73 ± 16.59	0.096
BMI (kg/m ²)	25.94 ± 5.34	27.38 ± 6.46	0.251
BSA (m ²)	1.85 ± 0.19	1.74 ± 0.29	0.041**
SBP (mmHg)	141.40 ± 18.39	140.67 ± 18.76	0.852
DBP (mmHg)	90.44 ± 11.27	85.33 ± 9.44	0.022**

BSA = body surface area, BMI = body mass index, SD = standard deviation, DBP = diastolic blood pressure, SBP = systolic blood pressure, **P* value < 0.001, ***P* value < 0.05.

weight ± SD for male and female were 75.41 ± 15.45 kg and 69.73 ± 16.59 kg, respectively. The mean body mass index ± SD was 27.38 ± 6.46 kg/m² in females and 25.94 ± 5.34 kg/m² males (Tables 1 and 2).

The prevalence of LVH by echocardiography was 32.2%. The prevalence of LVH by voltage criteria were: 45.6%, 42.2%, 34.4%, 13.3% by Sokolow–Lyon, Araoye code system, Cornell, and Gubner–Ungerleider criteria, respectively. Table 3 showed the comparison among the voltage criteria using echocardiography as the gold standard. The sensitivity and specificity respectively of the ECG criteria were 58.62% and 60.66% (Sokolow–Lyon), 48.28% and 60.65% (Araoye code system), 51.72% and 73.77% (Cornell), and 13.79% and 86.89% (Gubner–Ungerleider). The accuracies, positive, and negative predictive values of each of the ECG criteria were shown in Table 4.

4. Discussion

This study evaluated 4 ECG criteria for LVH using echocardiography as the gold standard. In all, 90 (45 males, 45 females) hypertensive subjects were assessed in this study, of which about a third (32.2%) had echocardiographic evidence of LVH. Our study was consistent with that of Verdecchia et al²³ which reported the prevalence of LVH of 27.2% using the same LVMI cut-off value (125 g/m²) for males and females. The prevalence of LVH in hypertension varies with the echocardiographic cut-off value used. Dada et al²¹ in a study of 100 hypertensive subjects, obtained a prevalence of 34% at LVMI of 126 g/m and 130 g/m for females and males, respectively, while Katibi^{24,25} reported a prevalence of 35% among 60 hypertensive subjects studied. Adebisi²⁶ in the study of 457 hypertensive Nigerians, obtained a prevalence range of 30.9%–56.0% using various partition values for LVMI. The lowest prevalence was obtained when LVM was indexed for body surface area (BSA) using a partition value of 125 g/m². The highest prevalence was obtained when LVM was indexed for height raised to power of 2.7 using a partition value of 46.7 g/Ht^{2.7} and 49.2 g/Ht^{2.7} for females and males, respectively.

The prevalence of LVH determined by ECG criteria obtained in this study ranged from 13.3% to 45.6%. The prevalence obtained by

Table 3
Comparisons among ECG criteria using echocardiography as the gold standard.

Criteria	TP	TN	FP	FN
SLC	17 (18.9%)	37 (41.1%)	24 (26.7%)	12 (13.3%)
ACS	14 (15.6%)	37 (41.1%)	24 (26.7%)	15 (16.7%)
CC	15 (16.7%)	45 (50.0%)	16 (17.8%)	14 (15.6%)
GUC	4 (4.4%)	53 (58.9%)	8 (8.9%)	25 (27.8%)

ACS = Araoye code system, CC = Cornell criterion, SLC = Sokolow–Lyon criterion, GUC = Gubner–Ungerleider criterion, TP = True positive, TN = True negative, FP = False positive, FN = False negative.

Table 4
Performance of four ECG criteria.

ECG criteria	Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV (%)	NPV (%)
ACS	48.28	60.65	56.67	36.84	71.15
CC	51.72	73.77	66.67	48.39	76.27
SLC	58.62	60.66	60.00	41.46	75.51
GUC	13.79	86.89	63.33	33.33	67.94

PPV = positive predictive value, NPV = negative predictive value, ACS = Araoye code system, CC = Cornell criterion, SLC = Sokolow–Lyon criterion, GUC = Gubner–Ungerleider criterion.

Sokolow–Lyon criteria was the highest (45.6%), and the value obtained by Gubner–Ungerleider criterion was the lowest (13.3%). The prevalence of LVH by Araoye code system, Sokolow–Lyon, and Cornell criteria were higher than that obtained by echocardiography. Falsely high prevalence of LVH obtained by the ECG criteria likely occurred because of the presence of false positives in the LVH cases identified by the various criteria. However, the prevalence of LVH obtained by Gubner–Ungerleider criterion (13.3%) was too low when compared with that obtained by echocardiography because of the low sensitivity of the criterion. This finding was consistent with the report from a study by Verdecchia et al.²³ Dada et al.²¹ reported a higher prevalence of LVH using the Araoye code system and Sokolow–Lyon criteria than that obtained by echocardiography while the prevalence of LVH obtained by Cornell's criteria and Romhilt–Estes score were lower than that obtained by echocardiography.

This present study revealed that ECG has low sensitivity and high specificity as a diagnostic tool for left ventricular hypertrophy among adult hypertensive subjects. The low sensitivity of various ECG criteria is a challenging issue, which limits the diagnostic value of electrocardiogram in the assessment of LVH.^{21,27} Despite this, LVH diagnosed by ECG is clinically important because of its prognostic and therapeutic values.¹

Dada et al.²¹ demonstrated that the Araoye code system had higher sensitivity and lower specificity when compared with Sokolow–Lyon and Cornell criteria. However, in this present study, Araoye code system, Cornell voltage, and Sokolow–Lyon criteria compared favorably well with echocardiography. The 3 ECG criteria (Araoye code system, Cornell voltage, and Sokolow–Lyon criteria) had good combined performance indices and were more sensitive than Gubner–Ungerleider criterion.

5. Conclusion

Out of the 4 ECG criteria, Araoye code system, Cornell, and Sokolow–Lyon criteria compared favorably well with echocardiography and may be used in the initial assessment of LVH in adult hypertensive subjects. However, a combination of any of the 3 criteria with Gubner–Ungerleider criterion will be more clinically useful.

Conflicts of interest

All authors have none to declare.

References

- Hsieh BP, Pham MX, Froelicher VF. Prognostic value of electrocardiographic criteria for left ventricular hypertrophy. *Am Heart J*. 2005;150:161–167.
- Balogun MO. Preventing Sudden Cardiac Death-The Role of Non-invasive Assessment of Heart Function. In: *Inaugural Lecture Series*, vol. 166. Nigeria: OAU Press Ltd.; 2004:21–22.
- Bots ML, Nikitin Y, Salonen JT, et al. Left ventricular hypertrophy and the risk of fatal and non-fatal stroke. EUROSTROKE: a collaborative study among research centres in Europe. *J Epidemiol Community Health*. 2002;56:18–113.
- Kannel WB, Cobb J. Left ventricular hypertrophy and mortality – results from the Framingham study. *Cardiology*. 1992;81:291–298.
- National Expert Committee on Non-Communicable Diseases. Hypertension and diabetes mellitus. In: Akinkugbe OO, ed. *Non-communicable Diseases in Nigeria*. Lagos: Federal Ministry of Health; 1997:64–90.
- Lip GY, Felmeden DC, Li-Saw-Hee FL, Beevers DG. Hypertensive heart disease. A complex syndrome or a hypertensive 'cardiomyopathy'? *Eur Heart J*. 2000;21:1653–1665.
- Devereux RB, Alonso DR, Lutas EM, et al. Echocardiographic assessment of left ventricular hypertrophy: comparison to necropsy findings. *Am J Cardiol*. 1986;57:450–458.
- Sokolow M, Lyon TP. The ventricular complex in left ventricular hypertrophy as obtained by unipolar precordial leads. *Am Heart J*. 1949;37:161–186.
- Casale PN, Devereux RB, Kligfield P, et al. Electrocardiographic detection of left ventricular hypertrophy: Development and prospective validation of improved criteria. *J Am Coll Cardiol*. 1985;6:572–580.
- Okin PM, Roman MJ, Devereux RB, Kligfield P. Electrocardiographic identification of increased left ventricular mass by simple voltage duration products. *J Am Coll Cardiol*. 1995;25:43–52.
- Araoye MA. Left ventricular hypertrophy by electrocardiography: a code system applicable to Negroes. *Niger Postgrad Med J*. 1996;3:92–97.
- Araoye MA. *Basic Electrocardiography*. Nigeria: Nathadex Publishers; 2004: 85–134.
- Levy D, Labib SB, Anderson KM, Christiansen JC, Kannel WB, Castelli WP. Determinants of sensitivity and specificity of electrocardiographic criteria for left ventricular hypertrophy. *Circulation*. 1990;81:815–820.
- McPhie J. Left ventricular hypertrophy. Electrocardiographic diagnosis. *Australas Ann Med*. 1958;7:317–320.
- Wilson FM, Johnson FD, Rosenbom FF. The precordial electrocardiogram. *Am Heart J*. 1944;27:19–24.
- Manning GW, Smiley JR. QRS voltages for left ventricular hypertrophy in a normal male population. *Circulation*. 1964;29:224–229.
- Mazzoleni A, Wolff L, Reiner L. Correlations between component cardiac weight and electrocardiographic patterns in 185 cases. *Circulation*. 1964;30:808–829.
- Schillaci G, Verdecchia P, Borgioni C, et al. Improved electrocardiographic diagnosis of left ventricular hypertrophy. *Am J Cardiol*. 1994;74:714–719.
- Blackburn H. Classification of the electrocardiogram for population studies: Minnesota code. *J Electrocardiol*. 1969;2:305–310.
- Romhilt DW, Estes JR. A point score system for the diagnosis of left ventricular hypertrophy. *Am Heart J*. 1968;75:752–758.
- Dada A, Adebisi AA, Aje A, Oladapo OO, Falase AO. Comparison of Araoye's criteria with standard electrocardiographic criteria for the diagnosis of left ventricular hypertrophy in Nigerian hypertensives. *West Afr J Med*. 2006;25:179–185.
- Koren MJ, Devereux RB, Casale PN, Savage DD, Laragh JH. Relation of left ventricular mass and geometry to morbidity and mortality in uncomplicated essential hypertension. *Ann Intern Med*. 1991;114:345–352.
- Verdecchia P, Dovellini EV, Gorini M, et al. Comparison of electrocardiographic criteria for the diagnosis of left ventricular hypertrophy in hypertension: MAVI study. *Ital Heart J*. 2000;1:207–215.
- Katibi IA. Left Ventricular Hypertrophy Among Hypertensive Nigerians: Correlation Between Echocardiogram and Electrocardiogram. WACP Dissertation. Lagos: West African Postgraduate Medical College; 1998.
- Katibi IA. Left ventricular hypertrophy and hypertension. *Niger J Med*. 2004;13:8–17.
- Adebisi AA, Ogah OS, Aje A, et al. Echocardiographic partition values and prevalence of left ventricular hypertrophy in hypertensive Nigerians. *BMC Med Imaging*. 2006;6:10.
- Cabezas M, Comellas A, Ramon GJ. Comparison of the sensitivity and specificity of electrocardiography criteria for left ventricular hypertrophy according to the methods of Romhilt–Estes, Sokolow–Lyon, Cornell and Rodriguez Padial. *Rev Esp Cardiol*. 1997;50:31–35.