STANDARD ELECTROCARDIOGRAPHIC CRITERIA FOR LEFT VENTRICULAR HYPERTROPHY IN NIGERIAN HYPERTENSIVES

Adekola Dada, FWACP; Adewole A. Adebiyi, FWACP; Akinyemi Aje, FMCP; Olulola O. Oladapo, FWACP; Ayodele O. Falase, FRCP

Objectives: Left ventricular hypertrophy (LVH) is a major risk factor for cardiovascular morbidity and mortality. Various electrocardiographic criteria for LVH have differing sensitivities and specificities. Most of the available electrocardiographic criteria for LVH have not been evaluated in the African populace.

Methods: Electrocardiograms (ECGs) and echocardiograms were obtained from 100 hypertensive subjects and 60 controls. Electrocardiogram (ECG) LVH was determined by the Sokolow-Lyon, Sokolow-Lyon-Rappaport, Cornell voltage, Romhilt-Estes point score, and the Perugia score criteria. Echocardiographic LVH was defined by LV mass indexed for height at 97.5 percentile of the controls (126 g/m and 130 g/m in females and males respectively).

Results: The prevalence of echocardiographic LVH indexed for height was 34% and 1.67% in the hypertensive patients and controls respectively. The prevalence of ECG LVH obtained in the hypertensive patients with the various ECG criteria were 56% for Sokolow-Lyon-Rappaport voltage, 48% for Sokolow-Lyon voltage, 41% for Perugia score, 22% for Cornell sex specific voltage, and 18% for Romhilt-Estes score. Sokolow-Lyon-Rappaport voltage criteria had the best sensitivity (80%) and area under the receiver operating characteristic (ROC) curve while the Romhilt-Estes score had the best specificity (93%).

Conclusion: Sokolow-Lyon and Sokolow-Lyon-Rappaport voltage criteria combine the best sensitivity and specificity values and would seem better suited for the diagnosis of ECG LVH in Nigerians. (*Ethn Dis.* 2005; 15:578–584)

Key Words: Electrocardiogram, Hypertension, Left Ventricular Hypertrophy, Nigeria, Sensitivity, Specificity

From the Department of Medicine, University College Hospital (AD, AAA, OOO, AOF, AA); Department of Medicine, College of Medicine, University of Ibadan (AAA, OOO, AOF); Ibadan Nigeria.

Address correspondence and reprint requests to Adewole A. Adebiyi, FWACP; Department of Medicine, College of Medicine; University of Ibadan; University College Hospital; Ibadan Nigeria; 234-803-347-1650; 234-2-241-1768; wadebiyi@comui.edu.ng

INTRODUCTION

Left ventricular hypertrophy is a major complication of sustained arterial hypertension.[1] Numerous studies show that left ventricular hypertrophy diagnosed by the electrocardiogram (ECG) is a blood pressure-independent risk factor for sudden cardiac death, acute myocardial infarction, and cardiovascular morbidity and mortality.[2,3] Consequently, the detection of left ventricular hypertrophy becomes an important part of the cardiovascular assessment of hypertensive patients.

The electrocardiogram was long been the major means of detecting left ventricular hypertrophy, until the advent of echocardiography. While the ECG is relatively cheap and rapid, the numerous ECG criteria for the diagnosis of left ventricular hypertrophy with their different sensitivities and specificities when compared with a gold standard make it of limited value in correctly diagnosing left ventricular hypertrophy. On the other hand, echocardiography, though more expensive, has been standardized and correlates closely with autopsy-validated left ventricular mass measurements and is thus of superior benefit in the diagnosis of left ventricular hypertrophy.[4]

However, the expense of echocardiography, coupled with its relative unavailability in most developing countries, indicate that most parts of the world would have to depend on ECG for the diagnosis of left ventricular hypertrophy. Significant racial differences also exist in the structure and function of the left ventricle[5,6] and most of the previously defined criteria for the detection of left ventricular hypertrophy has been done in the Caucasian population.

The intention of this study is to appraise some ECG criteria in the diagnosis of left ventricular hypertrophy by using echocardiography as the gold standard.

Therefore, the intention of this study is to appraise some ECG criteria in the diagnosis of left ventricular hypertrophy by using echocardiography as the gold standard. This would assist in recommending any of these ECG criteria which may be most applicable in making a diagnosis of hypertensive left ventricular hypertrophy in Nigeria, where dearth and the expense of echocardiographic facilities limit its routine use for the diagnosis of left ventricular hypertrophy.

MATERIALS AND METHODS

The study was carried out in the Cardiology Unit of the Department of Medicine, University College Hospital, Ibadan. All consecutive and eligible adult hypertensive patients age ≥18 years of both sexes seen in the cardiology clinic were recruited for the study. Subjects were excluded from the study if they had evidence of valvular heart diseases, pregnancy, chronic renal failure, diabetes mellitus, anemia, or were athletic.

Ethical clearance was obtained from the Joint University College Hospital/University of Ibadan Ethical Committee, and informed consent was obtained from all the subjects. Subjects were deemed to be hypertensive if their blood pressure (BP) on two visits at two-week intervals was consistently >140 mm Hg systolic and >90 mm Hg diastolic. The height and weight were measured by using standard procedures. The body mass index (BMI) and the body surface area (BSA) were calculated.

Electrocardiography

A standard (resting) 12-lead ECG was obtained in each subject by using a commercially available Marquette ECG machine (Marquette Electronics, Milwaukee, Wis) at 25 mm/s and 1 mV/cm calibration. The ECG tracings were read by using manual calipers. Left ventricular hypertrophy was diagnosed by using the following criteria: Sokolow-Lyon voltage (sum of the amplitudes of S wave in V1 and R wave in V5 or V6 >3.5 mV), Sokolow-Lyon-Rappaport voltage (sum of the amplitudes of S wave in V2 and R wave in V5 or V6 >3.5 mV), Romhilt-Estes score of >5 points, sex-specific Cornell voltage (sum of the amplitudes of S wave in V3 and R wave in aVL >2.0 mV in women and >2.8 mV in men), Perugia score[7] (positivity of at least one of the following three criteria: SV3+RaVL >2.4 mV in men or >2.0 mV in women, a typical strain pattern, or a Romhilt-Estes point score of ≥5).

Echocardiography

Echocardiographic examination was performed with a standard echocardiographic machine. Complete echocardiographic examination was performed as recommended by the American Society of Echocardiography.[8] A simultaneous ECG tracing was recorded on the screen during the examination. M-mode images were derived from the two-dimensional images. Measurements were averaged over three cardiac cycles.

Left ventricular mass was calculated according to the Devereux-modified American Society of Echocardiography Cube formula.[4] 0.8 [1.04((LVEDD + PWTd + IVSTd)^3 − (LVEDD)^3)] + 0.6 where LVEDD is left ventricular end diastolic diameter, PWTd is posterior wall thickness in diastole, and IVSTd is interventricular septal thickness in diastole. Left ventricular mass was indexed for body surface area and height.

Data Handling and Analysis

Data management and analysis were performed with Stata 7.0 (Stata Corporation, College Station, Tex). Data are presented as mean (SD) for continuous variables and proportions for categorical variables. For measurements of sensitivity and specificity, echocardiographic left ventricular hypertrophy was used as the reference standard against which the performance of ECG criteria was compared. Differences in prevalence between groups were compared using χ^2 analyses, and mean values of continuous variables were compared by using an unpaired *t* test. Receiver operating characteristic (ROC) curves were constructed for each criterion to evaluate test performance over a wide range of possible partition values (Figures 1–5). A two-tailed value of $P<.05$ was considered statistically significant.

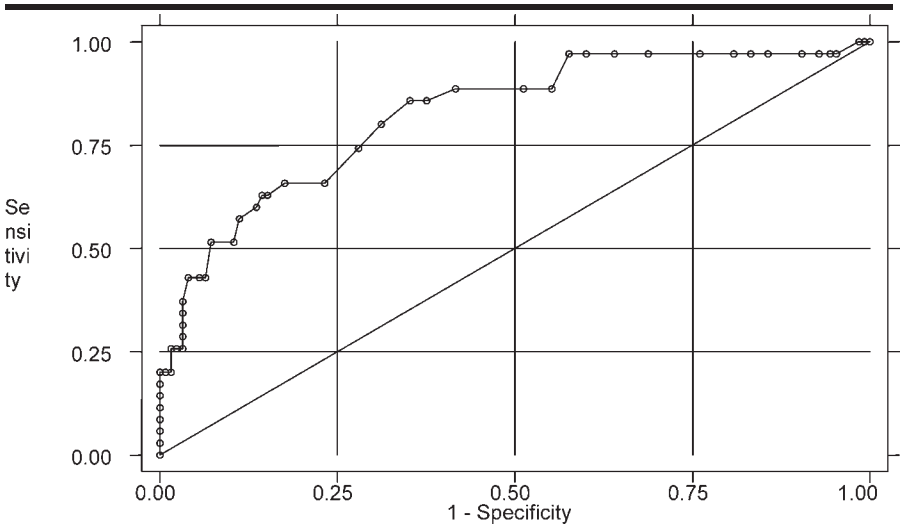

Fig 1. LVH by echocardiograpy vs Sokolow-Lyon Voltage. Receiver Operating Curve Characteristics. Area under ROC curve = 0.8240

RESULTS

A total of 100 hypertensive subjects (54 females and 46 males) and 60 controls (32 females and 28 males) were recruited for the study. The clinical and echocardiographic parameters of the subjects are shown in Table 1. No significant differences were seen in the ages of the hypertensive and the control groups. The partition values for left ventricular hypertrophy by echocardiography were determined by using the 97.5 percentile of the control subjects as cut-off points. The partition values obtained are 126 g/m and 130 g/m for females and males, respectively.

The prevalence of echocardiographic left ventricular hypertrophy indexed for height was 34% and 1.67% in the hypertensive and control groups, respectively. The prevalence of left ventricular hypertrophy by echocardiography among the hypertensives varied from 18% by Romhilt-Estes score to 56% by Sokolow-Lyon-Rappaport's criteria (Table 2). The sensitivity and

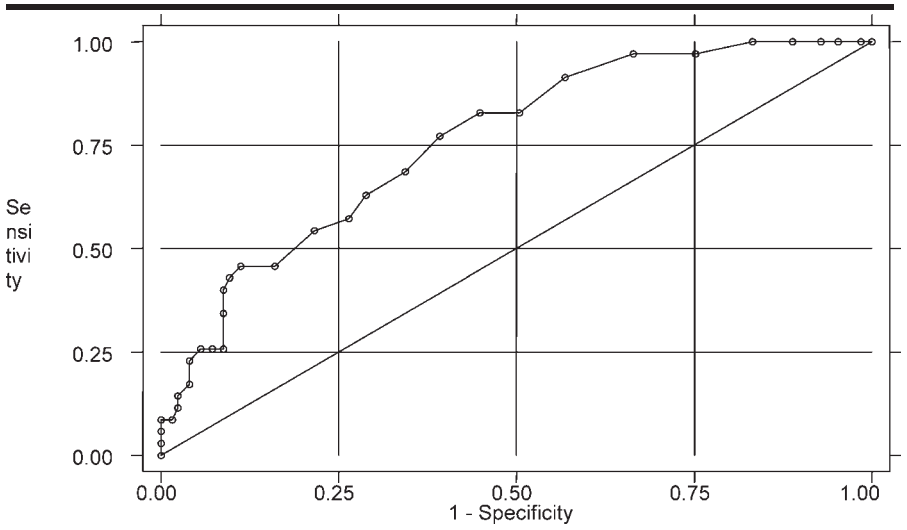

Fig 2. LVH by echocardiography vs Cornell Voltage. Receiver Operating Curve Characteristics. Area under ROC curve = 0.7599

specificity of the different electrocardiographic criteria for left ventricular hypertrophy are also in Table 2. The most sensitive criterion was the Sokolow-Lyon-Rappaport voltage criteria, while the most specific criterion was the point score criteria of Romhilt and Estes. Though the Cornell sex-specific criteria and Romhilt-Estes score had relatively higher specificity than the others, they were much less sensitive than the other criteria.

Table 3 shows the correlations between the echocardiographic left ventricular mass index and ECG indices. The highest correlations were obtained with the Sokolow-Lyon, Sokolow-Lyon Rappaport, and Tallest R in V5 or V6 voltages, while the lowest correlation was obtained with individual components of the Cornell sex-specific score (ie, R in AVL and S in V3).

Table 4 shows the area under the curves for the different ECG indices.

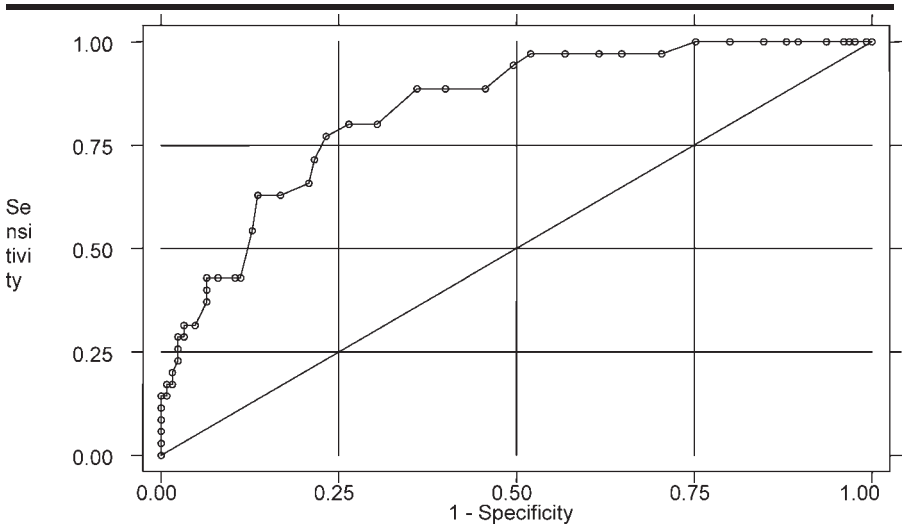

Fig 3. LVH by echocardiography vs Sokolow-Lyon-Rappaport Voltage. Receiver Operating Curve Characteristics. Area under ROC curve = 0.8362

. . . the Sokolow-Lyon and the Sokolow-Lyon-Rappaport voltage criteria appear to combine the best sensitivity and specificity values for routine electrocardiographic diagnosis of left ventricular hypertrophy [in this population].

The Sokolow-Lyon-Rappaport and the Sokolow-Lyon voltages had the largest areas under the curve while S in V3 had the smallest area.

DISCUSSION

Main Findings from the Study

In these groups of Nigerian hypertensive patients and normal controls, the Sokolow-Lyon and the Sokolow-Lyon-Rappaport voltage criteria appear to combine the best sensitivity and specificity values for routine electrocardiographic diagnosis of left ventricular hypertrophy. Echocardiographic left ventricular hypertrophy was present in approximately one third of the hypertensive patients, while the ECG criteria for the diagnosis of left ventricular hypertrophy gave prevalence rates varying from one fifth to approximately one half of the subjects.

Prevalence of Left Ventricular Hypertrophy in Blacks

The prevalence of left ventricular hypertrophy obtained in this study is comparable to that seen in other studies in Black hypertensive patients.[9,10] Many studies had noted higher left ventricular hypertrophy identified by echocardiography in Blacks.[11,12] Possible explanations for such findings include reduced

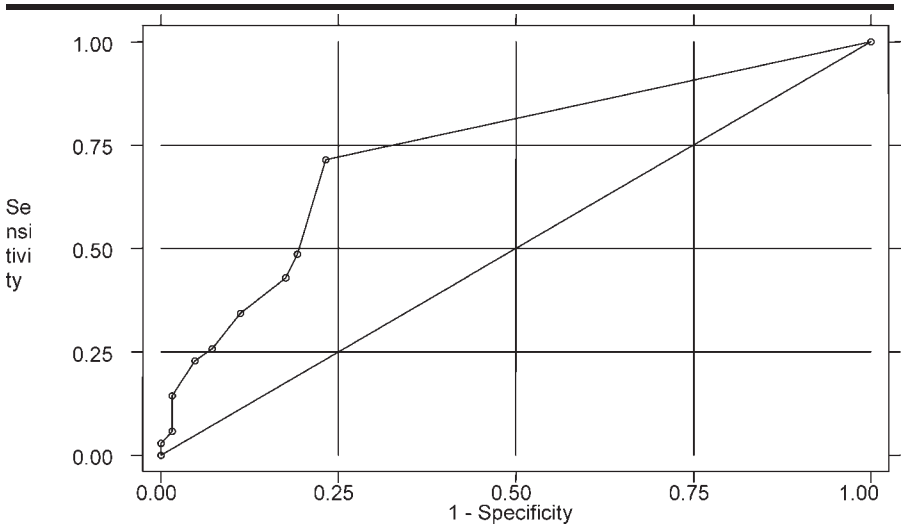

Fig 4. LVH by echocardiography vs Romhilt-Estes score. Receiver Operating Curve Characteristics. Area under ROC curve = 0.7387

diurnal variation of blood pressure in Blacks,[13,14] ethnic differences in neurohumoral[13,15] and hemodynamic[16] factors, and underestimation of the duration of hypertension in Blacks.[17]

ECG Voltages

The mean ECG voltages observed in this study are similar to voltages obtained in previous studies in Blacks.[11,18,19] It had been noted previously that Black subjects had taller ECG voltages than White subjects even after correction for confounding factors such as left ventricular mass, age, sex, and body mass index. While the reasons for the differences are unclear, plausible explanations include anthropomorphic differences between Blacks and Whites, tendency for Blacks to generate greater voltages for a given mass of myocardium than Whites, and minor ethnic differences in conduction velocities producing slightly shorter QRS duration and higher amplitude QRS complexes in Blacks. The later concept was suggested by Okin[18] and associates after finding out the multiplication of the Sokolow-Lyon voltage by the QRS duration diminished the ethnic differences in the Sokolow-Lyon criteria.

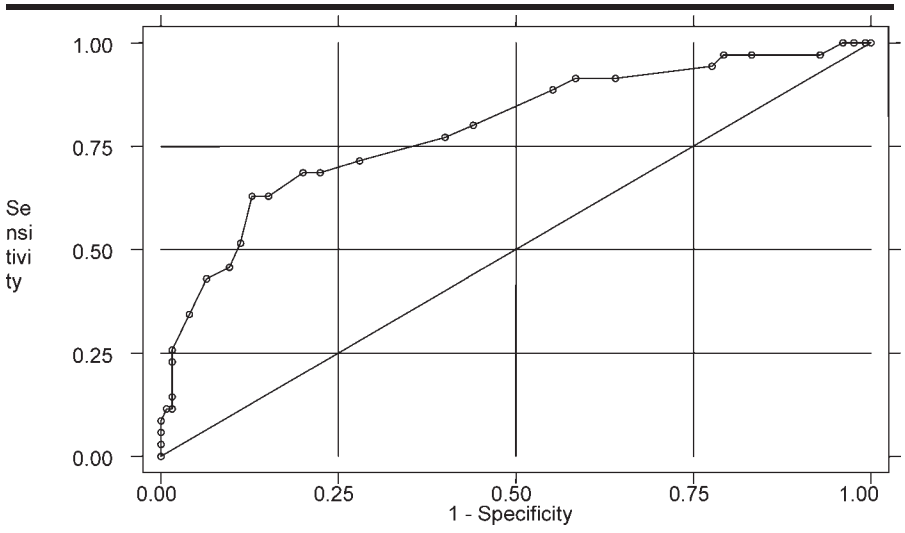

Fig 5. LVH by echocardiography vs Tallest R in V5 or V6. Receiver Operating Curve Characteristics. Area under ROC curve = 0.7918

Diagnosis of Left Ventricular Hypertrophy by ECG

The performance of standard electrocardiographic criteria in most previous studies is that of low sensitivity and high specificity. However in Blacks, standard electrocardiographic criteria for left ventricular hypertrophy had consistently shown increased sensitivity with a reduction in specificity when compared to Whites. The sensitivity and specificity values of various electrocardiographic criteria for left ventricular hypertrophy observed in this study were similar to findings from other studies in Blacks.[11,18,20]

The Sokolow-Lyon and the Sokolow-Lyon-Rappaport criteria that primarily measured the precordial leads gave the best combination of sensitivity and specificity in this study and might be more suited for the routine electrocardiographic diagnosis of left ventricular hypertrophy in this environment. Other criteria, although they had higher specificity than the Sokolow criteria, were much less sensitive. This finding is similar to those of other investigators. The Romhilt-Estes point score criteria was the most specific.

This study is probably the first to evaluate the Perugia score in an African population. The sensitivity of the Perugia score in this study is similar to that of previous studies, while the specificity was lower in this African populace.

The reduced specificity of the various electrocardiographic criteria in this African populace would indicate that a generally acceptable ethnicity-specific ECG criteria is needed to effectively diagnose electrocardiographic left ventricular hypertrophy in Africans. This might be achieved by raising the cut-off points for left ventricular hypertrophy of Sokolow-Lyon and the Sokolow-Lyon-Rappaport voltages, which would

Table 1. Clinical and echocardiographic parameters of the study groups

Parameter	Hypertensives (n=100)	Controls (n=60)	P value
Age	55.2 (11.07)	55.0 (10.38)	.9250
M/F	46/54	32/28	.935
Weight (kg)	69.35 (13.15)	62.23 (9.22)	.0001
Height (m)	1.64 (0.083)	1.61 (0.083)	.0238
Body mass index (g/m^2)	25.76 (4.96)	23.96 (2.72)	.0035
Body surface area (m^2)	1.75 (0.173)	1.65 (0.148)	.0004
Systolic blood pressure (mm Hg)	160.1 (16.02)	123.6 (9.73)	.0000
Diastolic blood pressure (mm Hg)	102.1 (7.20)	78.16 (6.09)	.0000
Left ventricular septal thickness (cm)	1.11 (0.178)	0.94 (0.100)	.0000
Left ventricular posterior wall thickness (cm)	1.13 (0.177)	0.91 (0.117)	.0000
Left ventricular end diastolic diameter (cm)	4.65 (0.505)	4.57 (0.399)	.2551
Left ventricular mass (g)	194.8 (62.47)	143.0 (27.92)	.0000
Males	210.6 (67.7)	141.4 (29.92)	.0001
Females	181.2 (54.75)	144.4 (26.45)	.0000
Left ventricular mass/BSA(g/m^2)	111.7 (35.58)	87.2 (18.51)	.0000
Males	117.0 (38.73)	84.0 (19.14)	.0000
Females	107.1 (32.32)	89.96 (17.76)	.0021
Left ventricular mass/height(g/m)	118.5 (37.25)	89.1 (18.25)	.0000
Males	124.6 (40.40)	86.7 (17.88)	.0000
Females	113.3 (33.86)	91.2 (17.76)	.0010

Table 2. Prevalence of electrocardiographic left ventricular hypertrophy, sensitivity, specificity, positive and negative predictive values of the different electrocardiographic criteria for left ventricular hypertrophy

ECG Criteria	Hypertensives (n=100)	Controls (n=60)	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Sokolow-Lyon	48 (48%)	4 (6.67%)	65.71% (58.36%–73.07%)	76.80% (70.26%–83.34%)	44.23% (36.54%–51.93%)	88.89% (84.02%–93.76%)
Sokolow-Lyon-Rappaport	56 (56%)	5 (8.33%)	80.00% (63.06%–91.56%)	73.60% (64.97%–81.08%)	45.90% (33.06%–59.15%)	92.93% (85.97%–97.11%)
Cornell	22 (22%)	1 (1.67%)	25.71% (12.49%–43.26%)	88.80% (81.92%–93.74%)	39.13% (19.71%–61.46%)	81.02% (73.44%–87.21%)
Romhilt-Estes score	18 (18%)	0 (0%)	25.71% (12.49%–43.26%)	92.80% (86.77%–96.65%)	50.00% (26.02%–73.98%)	81.69% (74.33%–87.68%)
Perugia score	41 (41%)	2 (3.33%)	45.71% (28.83%–63.35%)	78.40% (70.15%–85.26%)	37.21% (22.97%–53.27%)	83.76% (75.81%–89.93%)

CI=confidence interval; PPV=positive predictive value; NPV=negative predictive value.

Table 3. Correlation between echocardiographic left ventricular mass index and electrocardiographic indexes of left ventricular hypertrophy

	Correlations			
ECG Index	Left Ventricular Mass (g/m)	P	Left Ventricular Mass (g/m^2)	P
Sokolow-Lyon Voltage	0.5076	.0000	0.5335	.0000
Cornell Voltage	0.4227	.0000	0.4113	.0000
Sokolow-Lyon-Rappaport Voltage	0.5263	.0000	0.5603	.0000
RaVL	0.3508	.0002	0.3169	.0020
SV3	0.2941	.0072	0.3014	.0048
Tallest R in V5 or V6	0.5151	.0000	0.5441	.0000
R I	0.4521	.0000	0.4087	.0000
Estes score*	0.3909	.0000	0.3798	.0000

* Spearman rank correlation.

Table 4. Area under the ROC curves with 95% confidence intervals

	ROC Area	SE	95% CI
Sokolow-Lyon Voltage	0.824	0.0412	0.743–0.905
Cornell Voltage	0.760	0.0429	0.676–0.844
Sokolow-Lyon-Rappaport Voltage	0.836	0.0355	0.767–0.906
Tallest R in V5 or V6	0.792	0.0462	0.701–0.882
RaVL	0.774	0.0454	0.685–0.863
RI	0.797	0.0436	0.712–0.883
SV3	0.651	0.0543	0.545–0.758
Estes Score	0.739	0.0452	0.650–0.827

SE=standard error; CI confidence interval.

increase the specificity and decrease the sensitivity. Furthermore, longitudinal studies in this population would be needed to determine the prognostic importance of the different partition values of the ECG criteria.

Effect of Body Size on the Diagnosis of LVH

Obesity has been associated with increases in LV wall thickness, LV mass, and the prevalence of echocardiographic LVH, independent of the impact of blood pressure.[21,22] Previous studies have also found a decreased prevalence and sensitivity of precordial lead voltage criteria for detecting anatomic LVH in obese patients.[23–25] This decrease is thought to be largely attributed to attenuating effects of increased distance of exploring electrodes from the LV and attenuation of precordial QRS amplitudes by interposed tissue. Sokolow-Lyon voltage was inversely related to the square of the distance from the anterior chest wall to the mid-left ventricle,[26] which suggests that Sokolow-Lyon voltage varies inversely with increasing body size. Also, as in previous studies,[21,27] obesity is common in hypertensive patients. This finding is likely to influence the utility of electrocardiography in the diagnosis of LVH, especially in the obese.

Limitations of the Study

This study only evaluated hospital patients. The performance of the electrocardiographic criteria would likely be different when applied in the community. This study did not evaluate the voltage duration product of the various ECG criteria. This has been shown to minimize the differences observed in the diagnosis of left ventricular hypertrophy in Whites and Blacks.

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AUTHOR CONTRIBUTIONS

Design and concept of study: Dada, Oladapo, Falase
Acquisition of data: Dada, Aje
Data analysis and interpretation: Dada, Adebiyi, Aje, Oladapo, Falase
Manuscript draft: Adebiyi, Falase
Statistical expertise: Adebiyi
Administrative, technical, or material assistance: Aje, Oladapo
Supervision: Falase