Comparison of Araoye's criteria with Standard Electrocardiographic criteria for diagnosis of Left Ventricular Hypertrophy in Nigerian hypertensives

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Summary

Background: **Left ventricular hypertrophy (LVH) is a major risk factor for cardiovascular morbidity and mortality. Various electrocardiographic (ECG) criteria for LHV give poorer performance in black subjects when compared with white subjects. Araoye proposed a code system for improved ECG diagnosis of LVH in blacks. The Araoye's criteria are yet to be validated in black subjects.**
Study design: **Electrocardiograms and echocardiograms were obtained from 100 hypertensive subjects and 60 controls. ECG LVH was determined by the Araoye's code criteria, Sokolow-Lyon; Cornell voltage; and Romhilt-Estes point score. Echocardiographic LVH was defined by LV mass indexed for height at 97.5 percentile of the controls (126g.m^{-1} and 130g.m^{-1} in females and males respectively).**
Results: **The prevalence of echocardiographic LVH indexed for height was 34% and 1.67% in the hypertensive and controls respectively while the prevalence of electrocardiographic LVH among the hypertensives were 18% by Romhilt Estes score, 48% by Sokolow-Lyon's criteria, 22% by Cornell's criteria and 51% by Araoye's criteria. The sensitivity and specificity respectively of the various electrocardiographic criteria were 65.7% and 76.8% for Sokolow-Lyon, 25.7% and 88.8% for Cornell's criteria 25.7% and 92.8% for Romhilt-Estes score and 71.4% and 74.4% for Araoye's criteria. Araoye's criteria did not differ significantly from Sokolow-Lyon criteria in identifying LVH but differed significantly from Cornell and Romhilt-Estes criteria. The number of positive codes in Araoye's criteria was significantly associated with the blood pressures, LV dimensions, and LV mass.**
Conclusion: **The Araoye's code system for electrocardiographic diagnosis of LVH offer no comparative advantage over Sokolow-Lyon's criteria. However, the number of positive codes in Araoye's criteria identifies those individuals with more severe LVH.**

Key-words: ***Hypertension, Electrocardiographic criteria, Left Ventricular hypertrophy, Echocardiography, Nigeria, Blacks.***

Résumé

Introduction: Hypertrophie ventriculaire du gauche (HVG) est un facteur du risque majeur pour la morbidite et mortalité cardiovasculaire. Des critères électrocardiographique (BCG) divers pour HVG donne une execution mauvaise chez les sujets noirs par rapport aux sujets blancs. Araoye a proposé un système de code pour une amélioration diagnostique de ECG en ce qui concerne HVG chez des noirs. Le critère d' Araoye n'est pas encore confirmé chez des sujets noirs.
Plan d'étude: Electrocardiograms et échocardiograms ont été obtenus chez 100 sujets hypertensifs et 60 groupe de témoin. ECG HVG était décidé par le critère du code d'Araoye, Sokolow-Lyon; Cornell Voltage; et romhilt-Estes point du score. L'Echocardiographie HVG était défini par GV de masse indexé pour hauteur en 97,5 centile des contrôle (126g.m^{-1} et 130g.m^{-1} chez des sexes féminin et masculin respectivement.
Résultats: La fréquence d'HVG échocardiographique indexe pour l'hauteur était 34% et 1,67% chez les hypertensifs et le groupe de témoin respectivement. Tandis que la fréquence de HVG électrocardiographique parmi les hypertensifs sont 18% à travers le score de Romhilt Estes, 48% par le critère de Sokolow-Lyon, 22% par le critère de Cornell et 51 % par le critere d'Araoye. La sensitivité et spécificité respectivement de critère électrocardiographique divers sont 65,7% et 76,8% pour Sokolow-Lyon, 25,7% et 88,8% pour le critère de Cornell, 25,7 et 92,8% pour le score de Romhilt-Estes et 71,4 et 74,4% pour le critère d'Araoye. Le critère d'Araoye n'était pas différent sensiblement du critère de Sokolow-Lyon dans l'indentification du HVG mais diffère sensiblement par rapport au critère du Cornill et critere de Romhilt-Estes. Le nombre des codes positifs dans le critère d'Araoye était manifestement lié avec la tension arterielle, dimensions du VG et la VG de masse.
Conclusion: Le système du code d'Araoye pour le diagnostique électrocardiographique du HVG donne une avantage comparatif plus que le critère du Sokolow-Lyon. Toutefois, le nombre des codes positifs dans le critère d' Araoye identifient les individus atteints du HVG plus grave.

Introduction

Many electrocardiographic criteria for diagnosis of LVH are currently in use for clinical and epidemiological studies. Generally, the sensitivity and specificity patterns of these criteria are varied with some showing high sensitivity and low specificity while others have low sensitivity and high specificity.[1-3] Currently, no ECG criteria combine high sensitivity and specificity. In addition to this confusion about the best ECG criteria for diagnosis of LVH, most of the criteria currently in use demonstrate even poorer performance when applied to blacks. Standard

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diographic criteria for LVH had consistently showed increased sensitivity and reduction in specificity when compared to whites.[4-6] This created the need for electrocardiographic criteria that would be more appropriate for the diagnosis of LVH in blacks.

Araoye[7, 8] proposed a code system applicable to negroes for the diagnosis of LVH. For the standard 12 lead electrocardiogram, he proposed: a. SV2 +RV6 > 4.0mV in males =30years, SV2 + RV6 > 5.0mV in males aged 15-29yrs, and > SV2 + RV6 > 3.5mV in females; b. Flat or inverted T wave in V5 or V6; c. R1 amplitude > 1.2mV. Electrocardiographic LVH is diagnosed when any of the criteria is positive.

This study aimed to validate the Araoye's code system against echocardiography and to compare its performance with the Sokolow-Lyon voltage criteria,[9] the Romhilt-Estes score[10] and the sex-specific Cornell voltage criteria.[3]

Materials and methods

The study was carried out in the Cardiology Unit of the Department of Medicine, University College Hospital, Ibadan, Nigeria. All consecutive and eligible adult hypertensive patients aged 18 and above 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, anaemia 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 the BP on 2 visits at 2 weeks' intervals was greater than 140mmHg systolic and 90mmHg diastolic. The height and weight were measured using standard procedure. 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 using a commercially available Marquette ECG machine (Marquette Electronics, Milwaukee, WI) at 25mm.s^{-1} and 1 mV.cm^{-1} calibration. The ECG tracings were read using manual callipers. LVH was diagnosed 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), 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), and Araoye's criteria.[7,8]

Echocardiography

Echocardiographic examination was performed using a standard echocardiographic machine(Philips SDR 1550-X8 echocardiographic machine). Complete echocardiographic examination was performed as recommended by the American Society of Echocardiography.[11] A simultaneous ECG tracing was recorded on the screen during the examination. M-mode images were derived from the 2-D images. Measurements were averaged over three cardiac cycles. LVM was calculated using the Devereux-modified ASE Cube formula[12]: 0.8 [1.04((LVIDd + PWTd + IVSTd)^3 – (LVIDd)^3)] + 0.6 and 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, Texas). Data are presented as mean (SD) for continuous variables and counts (percentages) for categorical variables. For measurements of sensitivity and specificity, echocardiographic LV hypertrophy was used as the reference standard against which the performance of ECG criteria was compared. Differences in prevalence between groups were compared using $\div^2$ analyses, and mean values of continuous variables were compared using t test for independent groups. LVH by Araoye's criteria was compared with LVH by other criteria using the McNemar's modification of the $\div^2$ analysis for paired proportions. Kappa's analysis was also used to compare Araoye's criteria with others. The relationship between the number of positive codes in Araoye's electrocardiographic criteria for LVH (Araoye's code score) and some physical and echocardiographic characteristics was explored using ANOVA. Receivers operating characteristics (ROC) curves were generated for the Araoye's chest and limb leads criteria separately as well as for the standard electrocardiographic criteria. The areas under the ROC curves were compared. A two-tailed value of $P < 0.05$ was considered statistically significant.

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 1Table . There were no significant differences in the ages of the hypertensive and the control groups. The partition values for LVH by echocardiography were determined using the 97.5 percentile of the control subjects as cut-off points. The partition values obtained as cut-off point for echocardiographic LVH are 126g.m^{-1} and 130g.m^{-1} for females and males respectively.

Table 2 shows the application of Araoye's code system for diagnosis of LVH. The prevalence of ECG LVH rises with each level of application of the coding system. Only 8(5%) subjects were positive for the 3 criteria. Table 3 compares the clinical and echocardiographic characteristics of the subjects according to the Araoye's code score. Blood pressures, LV dimensions, and LV mass were significantly associated with the number of positive criteria defined in the Araoye's code system.

The prevalence of echocardiographic LVH indexed for height was 34% and 1.67% in the hypertensive and control group respectively. The prevalence of LVH by echocardiography among the hypertensives varied from 18% by Romhilt-Estes score to 51% by Araoye's criteria.(Table 4). Sensitivity and specificity of the differ-

Table 1 Clinical and Echocardiographic parameters of the study groups

Parameter	Hypertensives (n=100)	Controls (n=60)	p-value
Age(yrs)	55.2(11.07)	55.0 (10.38)	0.9250
M/F	46/54	32/28	0.935
Weight(kg)	69.35(13.15)	62.23 (9.22)	0.0001
Height(m)	1.64(0.083)	1.61(0.083)	0.0238
Body mass index ($g.m^{-2}$)	25.76(4.96)	23.96 (2.72)	0.0035
Body Surface area (m^2)	1.75(0.173)	1.65(0.148)	0.0004
Systolic Blood Pressure(mmHg)	160.1 (16.02)	123.6 (9.73)	<0.0001
Diastolic Blood Pressure(mmHg)	102.1 (7.20)	78.16 (6.09)	<0.0001
Left ventricular Septal thickness (cm)	1.11(0.178)	0.94(0.100)	<0.0001
Left ventricular Posterior wall thickness(cm)	1.13(0.177)	0.91(0.117)	<0.0001
LV End diastolic diameter(cm)	4.65(0.505)	4.57(0.399)	0.2551
LV Mass(g)	194.8 (62.47)	143.0 (27.92)	<0.0001
Males	210.6 (67.7)	141.4 (29.92)	0.0001
Females	181.2 (54.75)	144.4 (26.45)	<0.0001
LV mass/BSA($g.m^{-2}$)	111.7 (35.58)	87.2 (18.51)	<0.0001
Males	117.0 (38.73)	84.0 (19.14)	<0.0001
Females	107.1 (32.32)	89.96(17.76)	0.0021
LV mass/height($g.m^{-1}$)	118.5 (37.25)	89.1 (18.25)	<0.0001
Males	124.6 (40.40)	86.7 (17.88)	<0.0001
Females	113.3 (33.86)	91.2 (17.76)	0.0010

Table 2 Application of Araoye's Code System for diagnosis of Left ventricular hypetrophy

Code	No(%) Positive			Cumulative	positivity	N(%)
	Hypertensives	Controls	Total	Hypertensives	Control	Total
SV2 +RV6 > 4.0mV(Male); >3.5mV(Female)	33(33.0)	3(5.0)	36(22.5)	33(33.0)	3(5.0)	36(22.5)
Flat or Inverted T wave in V5 or V6	21(21.0)	0(0.0)	21(13.1)	43(43.0)	3(5.0)	46(28.8)
R1 Amplitude > 1.2mV	28(28.0)	3(5.0)	31(19.4)	51(51.0)	6(10.0)	57(35.6)

Table 3 Relationship between number of Araoye's positive criteria and some clinical and echocardiographic parameters

Parameter	No of positive criteria(Araoye's code)				
	0	1	2	3	
	n=103(64.4)	n=34(21.3)	n=15(9.4)	n=8(5.0)	P
Age (yrs)	54.8(10.40)	54.1(11.81)	56.9(9.77)	60.9(12.91)	0.3806
Weight(kg)	66.6(12.36)	66.4 (12.74)	70(11.30)	62.8(12.12)	0.5908
Height (m)	1.63(0.083)	1.61(0.085)	1.64(0.068)	1.65(0.125)	0.3915
SBP (mmHg)	140.9(22.95)	153.4(18.78)	158.7(14.65)	166.3(18.06)	0.0001
DBP (mmHg)	89.3(13.67)	97.6(10.51)	103.7(6.36)	102.8(11.56)	0.0001
LVEDD(cm)	4.55 (0.423)	4.70(0.498)	4.75(0.516)	4.50(0.612)	0.0209
PWT(cm)	0.98(0.154)	1.09(0.178)	1.26(0.173)	1.28(0.205)	0.0001
IVS (cm)	1.00(0.157)	1.06(0.115)	1.24(0.216)	1.20(0.216)	0.0001
BMI ($kg.m^{-2}$)	24.9(3.83)	25.7(5.28)	26.1(5.11)	23.1(4.62)	0.3446
MABP (mmHg)	106.5(16.03)	116.2(12.77)	122.0(7.02)	123.9(13.25)	0.0001
LVM(g)	157.7(42.25)	184.4(54.98)	235.4(75.27)	251.2(72.51)	0.0001
LVM indexed by height ($g.m^{-1}$)	96.55(24.91)	114.1(31.49)	143.6(46.76)	152.5(43.67)	0.0001

SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, LVEDD: Left Ventricular end-diastolic diameter, PWT: Posterior wall thickness, IVS: Inter-ventricular Septum, BMI: Body mass index, MABP: Mean Arterial Blood Pressure, LVM: Left Ventricular Mass.

Table 4 Prevalence of Electrocardiographic LVH among the subjects.

ECG criteria	Hypertensives	Controls
Sokolow-Lyon	48(48%)	4(6.67%)
Cornell	22(22%)	1(1.67%)
Romhilt Estes	18(18%)	0(0%)
Araoye	51(51%)	6(10.00%)

Table 5 Sensitivity, specificity, positive and negative predictive values of the different electrocardiographic criteria for LVH.

ECG criteria	Sensitivity (95% C. I.)	Specificity (95% C. I.)	PPV (95% C.I.)	NPV (95% C.I.)
Sokolow-Lyon	65.71%(58.36%, 73.07%)	76.80%(70.26%, 83.34%)	44.23%(36.54%, 51.93%)	88.89%(84.02%, 93.76%)
Cornell	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	25.71%(12.49%, 43.26%)	92.80%(86.77%, 96.65%)	50.00%(26.02%, 73.98%)	81.69%(74.33%, 87.68%)
Araoye	71.43%(53.70%, 85.36%)	74.40%(65.82%, 81.78%)	43.86%(30.74%, 57.64%)	90.29%(82.87%, 95.25%)

PPV – Positive predictive value, NPV – Negative predictive value

Table 6 Comparison of Araoye's criteria with other ECG LVH criteria

	LVH by Araoye's criteria		No LVH by Araoye's criteria		Chi square		Interrater agreement	
ECG criteria	LVH	No LVH	LVH	No LVH	c^2	p	k	p
Sokolow-Lyon	38	19	14	89	0.76	0.3841	0.5413	<0.0001
Cornell	18	39	5	98	26.27	0.0000	0.3083	<0.0001
Romhilt-Estes	17	40	1	102	37.10	0.0000	0.3406	<0.0001

Table 7 Area under the ROC curves with 95% confidence intervals

	ROC area	Std. Err.	95% C. I.
Sokolow-Lyon Voltage	0.8240	0.0412	0.74332 - 0.90468
Cornell Voltage	0.7599	0.0429	0.67573 - 0.84404
Estes Score	0.7387	0.0452	0.65024 - 0.82724
SV2+RV6	0.8168	0.0443	0.74444 - 0.88916
RI	0.7973	0.0436	0.71176 - 0.88275

Table 8 Comparing ROC from Araoye's voltage criteria with that of other ECG LVH criteria

	Araoye chest lead voltage criteria			Araoye limb lead criteria		
	Difference	95%C.I	p	Difference	95%C.I	p
Sokolow-Lyon Voltage	0.007	-0.060 - 0.075	0.8280	0.027	-0.073 - 0.127	0.5783
Cornell Voltage	0.057	-0.043 - 0.157	0.1971	0.037	-0.077 - 0.152	0.4860
Romhilt-Este Score	0.078	-0.030 - 0.186	0.0715	0.059	-0.046 - 0.163	0.2330

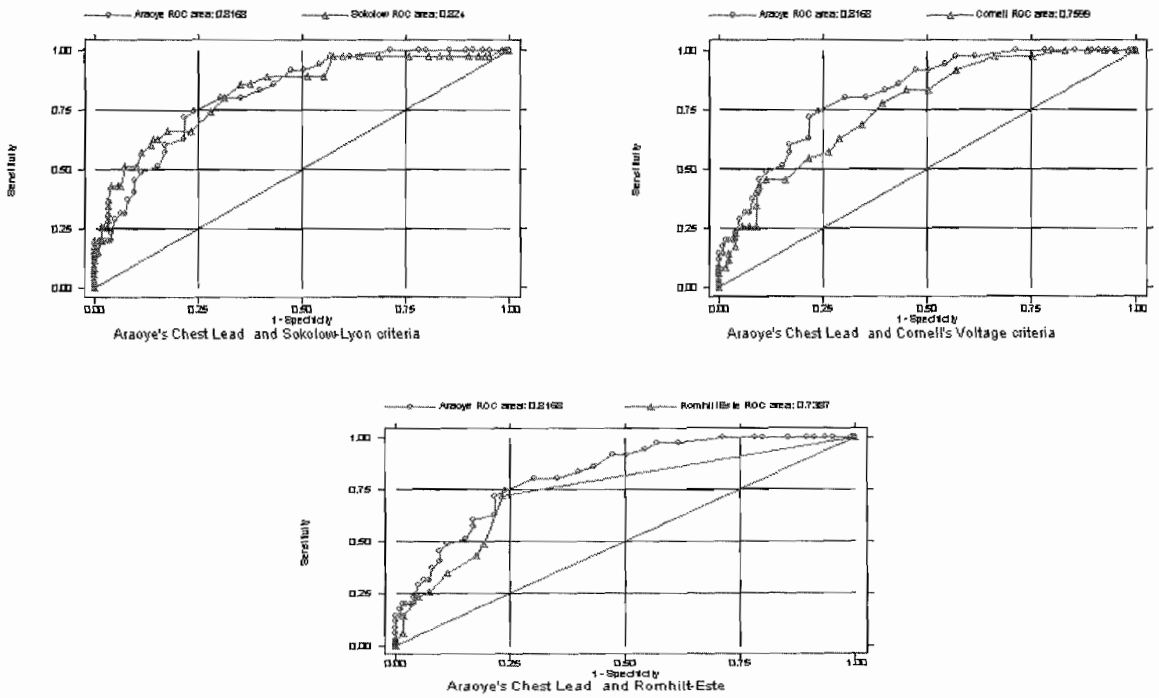

Figure 1 *Comparing ROC curves of Araoye's chest lead criteria and others*

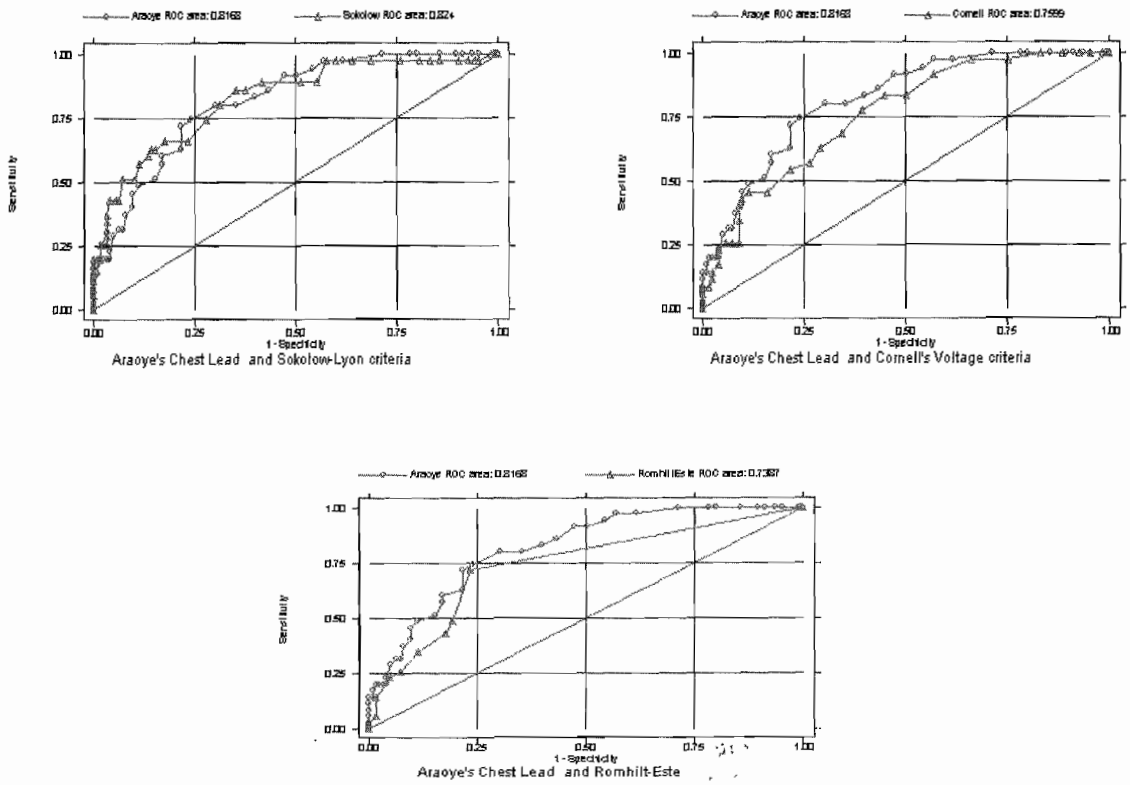

Figure 2 *Comparing ROC curves of Araoye's chest lead criteria and others*

ent electrocardiographic criteria for LVH are as in Table 5. The most sensitive criterion was Araoye's 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 high specificity than the others, they were much less sensitive than the other criteria.

Table 6 shows the comparison of Araoye's criteria for ECG LVH with other criteria. Araoye's criteria did not differ significantly from Sokolow-Lyon criteria in identifying LVH but differed significantly from Cornell and Romhilt-Estes criteria. While the interrater agreement in identifying LVH between Araoye's criteria and others is significant, only the agreement between Araoye and Sokolow-Lyon can be regarded as moderate.

Table 7 shows the area under the receivers operating characteristics(ROC) curves for the different ECG criteria while Table 8 and figures 1 and 2 shows the comparison of Araoye's chest leads and limb leads voltages with other criteria for ECG LVH. There is no statistical difference in the areas under the ROC curves between Araoye's voltages and other criteria.

Discussion

The adoption of a diagnostic test requires its comparison against a gold standard.[13] This enables the derivation of the sensitivity and specificity of the test. For a diagnostic test to be of clinical value, it should combine high sensitivity with high specificity.[14] This allows the test to identify most subjects with or without the condition. However, most electrocardiographic criteria for LVH suffer from low sensitivity and specificity.[15] The twin problem of low sensitivity and specificity had informed the use of echocardiography in identifying left ventricular hypertrophy in clinical practice. Echocardiographic LVH has been shown to correlate closely with necropsy data.[12] However, in resource poor setting like Africa where echocardiographic facilities are largely unavailable, the ECG still plays a significant role in determining the presence of LVH in clinical subjects. Thus the development of ECG criteria with good performance when compared with a gold standard is still a necessity. In addition, subjects of negroid extraction have been shown to have taller precordial voltages on the surface ECG.[16] This further reduces the sensitivity of the standard ECG criteria when applied to blacks. The Araoye's ECG LVH criteria are thus an attempt to develop ethnicity specific ECG criteria for LVH. However, Araoye's criteria are yet to be validated against an Echocardiographic standard.

The major components of the Araoye's criteria are the ECG voltages in the lead RI, the chest leads and the presence of T wave abnormalities. Many previous studies had observed the relationship between ECG voltages with the echocardiographic left ventricular mass.[17,18] Similarly, studies had also shown that T wave abnormalities correlated with more severe degrees of left ventricular enlargement.[19-21] Thus, the combination of ECG voltages with T wave abnormalities would likely be more sensitive and specific in predicting LV mass. However, in many studies, the Romhilt-Estes score that combined Chest lead voltage and T wave abnormalities among other criteria had consistently shown a very high specificity but very low sensitivity.[2,18,22]

In this present study, the sensitivities of the Sokolow-Lyon, Cornell, and Romhilt –Estes obtained were similar to those of published studies in black subjects.[6,23] In blacks, standard electrocardiographic criteria for left ventricular hypertrophy had consistently shown increased sensitivity with a reduction in specificity when compared to whites.[6,23] This study demonstrates that Araoye's criteria has higher sensitivity and lower specificity when compared with the Sokolow-Lyon's criteria. Also, while Araoye's criteria differed significantly from Cornell and Romhilt-Estes criteria in identifying LVH, it appears to offer no comparative advantage over the Sokolow-Lyon's criteria.

However, the number of positive codes in Araoye's criteria(Araoye's code score) predicts those subjects with higher blood pressures and larger LV dimensions and LV mass. The reason for this, as earlier highlighted, is due to the fact that T wave abnormalities are more common in those subjects with more severe degrees of LV enlargement.

Conclusion

This study, comparing Araoye's code system for the electrocardiographic diagnosis of LVH with standard electrocardiographic criteria, suggests that Araoye's criteria offer no comparative advantage over Sokolow-Lyon's criteria. However, the number of positive codes in Araoye's criteria would identify those individuals with more severe LVH.

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