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Evaluation of selected electrocardiographic criteria for diagnosing left ventricular hypertrophy in hypertensives in South-South Nigeria.

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ABSTRACT

Background: Criteria for left ventricular hypertrophy (LVH) have been almost exclusively elaborated and calibrated in white populations. Because several interethnic differences in ECG characteristics have been found, the applicability of these criteria to different races and ethnic groups needs to be demonstrated. **Objective:** We investigated the performance of four ECG criteria for LVH detection in Calabar, Nigeria. **Methodology:**12-lead ECG tracings were obtained. Left ventricular mass was calculated with M-mode echocardiography and indexed to Height $^{2.7}$ and body surface area as the gold standard. **Results:** The study population was 240 participants made up of 120 hypertensives and 120 normotensive controls. All echocardiographic parameters were significant in the hypertensives compared to the controls. On indexing for both Echo LVH HT $^{2.7}$ and Echo LVH BSA there was no significant difference in the results. Echocardiography was more sensitive than Electrocardiography in the detection of Left Ventricular Hypertrophy in this study. Sokolow-Lyon and Cornell product criteria had the highest sensitivity (34.1%) by Echo HT $^{2.7}$ but Cornell voltage criteria had the highest specificity (93.3%) by Echo HT $^{2..7}$. Cornell product had the highest sensitivity by Echo BSA (34.3%) while Cornell voltage had the highest sensitivity by Echo BSA (94.7%). **Conclusion:** Sensitivity of existing criteria is low, performance of classic ECG criteria for LVH detection appeared to be lower in this population of African origin. Further studies are required to generate new criteria to measure performance in Africans and those of black ethnicity.

Keywords: **ECG Criteria, Sensitivity, Left ventricular hypertrophy**

INTRODUCTION

Left ventricular hypertrophy has been shown to be an extremely strong predictor of cardiovascular morbidity and mortality whether it is diagnosed by the electrocardiogram or by the echocardiogram[1-3] so its detection is of major importance, especially for individuals with hypertension or other cardiovascular risk factors.

It has become necessary to establish diagnostic modalities to assist health care workers and clinicians make accurate diagnosis and institute proper follow up for cardiovascular patients. In clinical settings, both electrocardiography and transthoracic echocardiography has been shown to have diagnostic relevance in the detection of left ventricular hypertrophy however, their sensitivities vary leading to misdiagnosis during screenings.[7,8]

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Echocardiography is more preferred and the gold standard for the diagnosis of left ventricular hypertension due to its non-invasiveness, high specificity and sensitivity as it visualizes the heart and can measure all cardiac parameters. However, high cost and uneven technical knowhow by operators limit its use, making the electrocardiography (ECG) more convenient for use in both clinical settings and for screening purposes due to its simplicity and accessibility despite its relatively low sensitivity. [8]
The initial studies on the relationship of electrocardiographic parameters and LV hypertrophy

were autopsy based. Allenstein's review of ECG criteria in hypertrophy was based on wall thickness and ignored weight in 1964.[9]

Romhilt and others [10] in 1969 reviewed 33 different voltage criteria for LVH in 360 autopsied hearts and developed the Romhilt- Estes Point Scoring System, devised originally from an analysis of the electrocardiographic changes noted in left ventricular hypertrophy, was reported to be 60% sensitive and 95% specific in diagnosing left ventricular hypertrophy.[10]

The test performance of the ECG in diagnosing LVH is low in the Black African population, due to extracardiac factors such as age, sex, body habitus, and cardiac factors such as LVH severity and geometry. However, this performance is improved after adjustment for extracardiac factors. [24]

Factors affecting QRS voltage include race, body habitus, age, obesity and chest wall thickness. The intracardiac electrical activity is problematic to measure externally because the measurements are affected by everything between the myocardium and the electrodes, most notably fat, fluid, and air. Because of this effect, electrocardiography underdiagnoses LVH in patients with obesity, pleural effusions, pericardial effusions, anasarca, or chronic obstructive pulmonary disease. [25]

One of the earliest efforts in ECG LVH studies in hypertensives in Nigeria was published by Huston et al[16]. They studied 766 civil servants in Benin city. They found that the prevalence of ECG LVH ranged from 3 to 29% in the total population, depending on the criteria used, with four of the five criteria resulting in prevalence estimates of less than 10%. The prevalence of ECG LVH was significantly greater among those with hypertension (19% of the total population), ranging from 11 to 49%.

In Ibadan Dada[17] et al found that the prevalence of left ventricular hypertrophy by electrocardiography among the hypertensives varied from 18% by Romhilt-Estes score to 56% by Sokolow-Lyon-Rappaport's criteria. Sokolow-Lyon-Rappaport voltage criteria had the best sensitivity (80%) and they therefore concluded that Sokolow-Lyon and Sokolow-Lyon-Rappaport voltage criteria combined the best sensitivity and specificity values and would seem better suited for the diagnosis of ECG LVH in Nigerians. When comparing the Araoye code to other electrocardiographic criteria, Dada[18] asserted that the Araoye code system for electrocardiographic diagnosis of LVH offered no comparative advantage over Sokolow-Lyon's criteria. Araoye[19] had years earlier, proposed a code system for the electrocardiographic diagnosis of left ventricular hypertrophy applicable to negroes because it had been found that blacks exhibited higher voltages than the old and males overshot females in every lead.

In view of these obvious limitations several workers have attempted to correlate ECG LVH with Echo LVH and have found a poor correlation.[26,27]

In the present study, we examined the performance of 4 classic ECG criteria for LVH prediction in a group of 120 hypertensives and 120 normotensive controls with the use of echocardiography as the gold standard in a black African population.

Objective

1. To determine the frequency of Electrocardiographic Left Ventricular Hypertrophy by four selected criteria in Hypertensives and controls (normotensives).
2. To compare the sensitivity of the various Electrocardiographic criteria with Echocardiographic Left Ventricular Hypertrophy determined by two different indexation methods.

METHODOLOGY

A comparative cross-sectional study was conducted among normotensive individuals and hypertensive patients, including both newly diagnosed and those on treatment.

The sample size was calculated using Pocock's formula [34]

Formula: $n = [p(1-p) \times (Z\alpha + Z\beta)^2 \times 2] / d^2$

Where:

n = minimum sample size

p =proportion of LVH in hypertensives

d = difference to be detected at the end of the study

Zα - 95% confidence = 1.96

Zβ – 90% power = 1.28

A study done in University College Hospital Ibadan by Dada et al [17] was one of the earliest works in Nigeria to compare LVH criteria and had found the prevalence of Echocardiographic LVH indexed for height was 34% and 1.67% in the hypertensive and controls respectively.

Assuming a difference to be detected at the end of the study is 20%.

$n = [0.34(1 - 0.34) \times (1.96 + 1.28)^2 \times 2] / (0.20)^2$

$n = [0.2278 \times 10.4976 \times 2] / 0.04 = 119$

The calculated sample size was 119.

To improve power and allow for subgroup analysis, 240 participants were recruited 120 hypertensive patients and 120 controls.

Recruitment of Study Participants, Inclusion and Exclusion criteria

Study participants were recruited from the Cardiology and Medical Out-Patients Department (MOPD) of University of Calabar Teaching Hospital. All who consented to participate in the study were recruited. Both newly diagnosed hypertensives and those already on treatment were included. Controls for the study were healthy normotensive subjects, drawn from hospital staff and patient's relatives.

Inclusion criteria: Patients > 18years, newly diagnosed hypertensives (treatment naive) and all hypertensives on treatment who gave consent to the study.

Exclusion criteria: Those excluded included: Patients less than 18 years of age, Structural heart disease (i.e. Myocardial Infarction, Significant Valvular Heart disease, Cardiomyopathy and Chronic Pericardial diseases), Concomitant Diabetes Mellitus, Congestive Cardiac Failure, Chronic Renal Failure, technically inadequate echocardiograms, the presence of the following ECG abnormalities: uncontrolled atrial fibrillation, atrial flutter, bundle branch block, and pacemaker use.

Data Collection - Questionnaire

Baseline clinical and socio-demographic characteristics were obtained from the subjects using an interviewer- administered structured questionnaire. These included date of birth, age, gender, marital status, level of education, history of hypertension and diabetes, and a history of smoking and alcohol use. A standard mercury sphygmomanometer (Accosson, London) was used, and the systolic blood pressure (SBP) and diastolic blood pressure (DBP) taken as Korotkoff sound phases I and V, respectively. A cuff of appropriate size was applied to the exposed right upper arm and was gently inflated to 30 mmHg above the level at which the pulse disappeared and then deflated gradually. Blood pressure 140/90mmHg and above was taken as hypertension and individuals already on medication, were noted. [35]

Electrocardiography

Standard resting 12 lead ECG was performed on all subjects using Medigate ECG Model No: Me CA412i, 2009 at a paper speed of 25mm/s and a voltage calibration of 10mm/mV without filter with the subject's lying supine and the leads positioned in accordance with international recommendations[36].

ECG Left ventricular hypertrophy was defined as the presence of the Cornell voltage and Cornell product criteria [37, 38] Sokolow-Lyon criteria[11] and Araoye's criteria.[19]

Sokolow Lyon criteria is $SV_1 + RV_{5/6} > 35$mm or RaVL>11mm.

Cornell Voltage Index- $RaVL+SV_3 >28$mm for men and

$RaVL+SV_3 >20$mm for women.[37]

Cornell Product will be calculated as follows-

$RaVL+SV_3$ X QRS duration ≥ 2440ms for Men

SV_3 + (RaVL + 8mv) x QRS duration≥ 2440ms for Women. [38]

Araoye's criteria for LVH in blacks[19]

Code 1. $SV_2 + RV_6 >$ 40mV for males and 35mV for females

Code 2. Flat or inverted T waves "strain pattern" in V_5 or V_6.

Code 3. R_1 amplitude >12mV

Transthoracic Echocardiography

M-mode, 2D, and Doppler echocardiography were performed by the researcher alone on all 240 subjects using an ALOKA SSD–4000 machine (Aloka Co. Ltd., Tokyo, Japan) with a 3.5 MHz transducer, following the American Society of Echocardiography (ASE) guidelines. [39]

LV internal dimension, posterior wall thickness and interventricular septal thickness was measured at end-diastole and end-systole. When M-mode imaging was suboptimal, 2D measurements were used per ASE criteria. [39] Measurements were obtained in up to 3 cardiac cycles according to the ASE convention.[39]

LV systolic performance (fractional shortening and ejection fraction) was calculated using the Teichholz's formula.[40]

Left ventricular mass (LVM) was calculated using the Devereux-modified ASE cube formula. [41]

LVmass (ASE) = 0.8 x 1.04 x ([LVIDD + PWTD + IVSTD]^3- [LVIDD]^3)) + 0.6 g.

Where:

LVIDD = left ventricular internal dimension,

IVSTD = intraventricular septum thickness in diastole, and

PWTD = posterior wall thickness in diastole.

Left ventricular mass when derived by the above formula was normalized to both body surface area and height$^{2.7}$ (where height was in meters) to correct for the effect of overweight. [42] Echocardiographic patterns were thus determined as: normal geometry, concentric remodeling, eccentric and concentric hypertrophy in the subjects.

Left ventricular geometric patterns were defined as follows:

1. Normal geometry, when LVMI and RWT were normal;
2. Concentric remodelling, when LVMI was normal and RWT increased;
3. Eccentric hypertrophy, when LVMI was increased but normal RWT; and
4. Concentric hypertrophy, when both LVMI and RWT were increased [43]

Statistical analysis: Analysis was done using the SPSS version 28.0 software (SPSS, Chicago, IL, USA).

Categorical variables were expressed as proportions and percentages while continuous variables were expressed as means ± standard deviation.

Comparisons of continuous variables between groups was performed with the independent samples t-test.

Comparison between categorical variables was performed with the chi- square test.

Level of statistical significance was fixed at $p<0.05$.

Ethical Concerns

Ethical clearance was obtained from Ethical committee of the University of Calabar Teaching Hospital, Calabar.

All patients who participated in the study gave voluntary written informed consent. Non-consenting patients were excluded from the study. Participants confidentiality was maintained: Personal information is protected to ensure privacy by using initials only. The echocardiography was done at no cost. The results and implications were discussed with the patient. There was no harm from the tests and Echocardiography study. The participants' physical and psychological well-being were prioritized. Those who declined participation were not unduly punished or discriminated against.

RESULTS

Table 1: Characteristics of All Respondents

	Characteristic	Number (n=240)	Percentage (%)
Age	<30	9	3.8
	30-59	73.3	73.3
	60 and above	22.9	22.9
	Mean ± SD	49.7 ± 12.2	
Sex	Male	108	45.0
	Female	132	55.0
Marital status	Single	39	16.3
	Married	161	67.1
	Divorced	5	2.1
	Widow/Widower	35	14.6

Educational status	None	13	5.4
	Primary	34	14.2
	Secondary	31	12.9
	Post-Secondary	82	34.2
	Graduate	80	33.3
Ethnicity	Efik	89	37.4
	Ibibio	41	16.7
	Ekoi	30	12.6
	Annang	30	12.2
	Igbo	14	6.1
	Others	36	15.0
Residence	Urban	205	85.4
	Rural	35	14.6
HTN history	No HTN	120	50.0
	Newly diagnosed HTN	24	10.0
	Pre-existing HTN	96	40.0

Table 2: Comparing characteristics of all Hypertensive Respondents and Controls

	HTN (n=120)	**Control (n=120)**	**Test statistic /p-value**
Age			
<30	4 (44.4)	5 (55.6)	Fishers exact =
30-59	88 (50.0)	88 (50.0)	0.183
60 and above	28 (50.9)	27 (49.1)	p=1.000
Sex			
Male	58 (53.7)	50 (46.3)	Chi = 1.077
Female	62 (47.0)	70 (53.0)	P= 0.364
Marital status			
Single	8 (20.5)	31 (79.5)	Fishers exact =
Married	90 (55.9)	71 (44.1)	19.350
Divorced	1 (20.0)	4 (80.0)	P <0.001
Widow/Widower	21 (60.0)	14 (40.0)	
Educational status			
None	8 (61.5)	5 (38.5)	Chi = 22.325
Primary	29 (85.3)	5 (14.7)	P <0.001
Secondary	14 (45.2)	17 (54.8)	
Post-Secondary	32 (39.0)	50 (61.0)	
Graduate	37 (46.3)	43 (53.8)	
Ethnicity			
Efik	21 (23.6)	68 (76.4)	
Ibibio	20 (48.8)	21 (51.2)	Fishers exact =
Ekoi	17 (56.7)	13 (43.3)	55.398
Annang	26 (87.6)	4 (13.3)	P <0.001
Igbo	8 (57.1)	6 (42.9)	
Others	28 (77.8)	8 (22.2)	
Residence			
Urban	100 (48.8)	105 (51.2)	Chi = 0.836
Rural	20 (57.1)	15 (42.9)	P= 0.465

Table 3: Sensitivity and Specificity of the different Criteria compared to EchoHT2.7 and EchoBSA

Criteria	Echo Ht2.7		Echo BSA	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Sokolow Lyon	34.1	87.2	32.9	84.1
Cornell Voltage	19.8	93.3	22.9	94.7
Cornell Product	28.6	88.6	34.3	88.8
Araoye	33.0	87.9	32.9	85.3
Echo Ht2.7	-		88.6	82.9
Echo BSA	68.1	94.6	-	

Table 4: Prevalence of LVH for the different ECG & Echo criteria

Criteria ECG	LVH/NO LVH	Number (n=240)	Percentage (%)
Sokolow Lyon	LVH	50	20.8
	No LVH	190	79.2
Cornell Voltage	LVH	25	10.4
	No LVH	215	89.6
Cornell Product	LVH	43	17.9
	No LVH	197	82.1
Araoye	LVH	48	20.0
	No LVH	192	80.0
ECHO			
Echo Ht2.7	LVH	91	37.9
	No LVH	149	62.1
Echo BSA	LVH	70	29.2
	No LVH	170	70.8

Table 5: Comparing the prevalence of LVH among newly diagnosed HTN, Pre-existing LVH, and Controls

	Newly diagnosed HTN (n=24)	Pre-existing HTN (n=96)	Controls (n=120)	Test statistic; p-value
ECG				
Sokolow Lyon				
LVH	11 (45.8)	30 (31.3)	9 (7.5)	Chi = 28.345;
No LVH	13 (54.2)	66 (68.8)	111 (92.5)	p<0.0001
Cornell Voltage				
LVH	3 (12.5)	17 (17.7)	5 (4.2)	Fishers exact=
No LVH	21 (87.5)	79 (82.3)	115 (95.8)	10.605; p=0.004
Cornell Product				
LVH	6 (25.0)	28 (29.2)	9 (7.5)	Chi = 18.721;
No LVH	18 (75.0)	68 (70.8)	111 (92.5)	p<0.0001

Araoye					
LVH	8 (33.3)	33 (34.4)	7 (5.8)	Chi =	30.117;
No LVH	16 (66.7)	63 (65.6)	113 (94.2)	p<0.0001	
ECHO					
Echo Ht2.7					
LVH	13 (54.2)	56 (58.3)	98 (81.7)	Chi =	39.242;
No LVH	11 (45.8)	40 (41.7)	22 (18.3)	p<0.0001	
Echo BSA					
LVH	11 (45.8)	57 (59.4)	20 (16.7)	Chi =	18.403;
No LVH	13 (54.2)	39 (40.6)	100 (83.3)	p<0.0001	

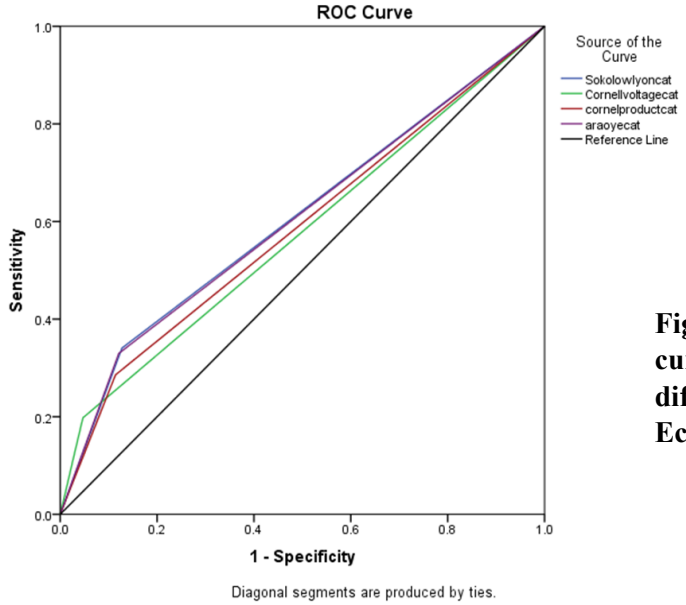

Figure 1: Receiver operator characteristic curve showing sensitivity and specificity of the different LVH criteria when compared to EchoHT2.7 as the gold standard.

Area Under the Curve

Test Result Variable(s)	Area
Sokolow Lyon	0.607
Cornell voltage	0.575
Cornel product	0.586
Araoye	0.604

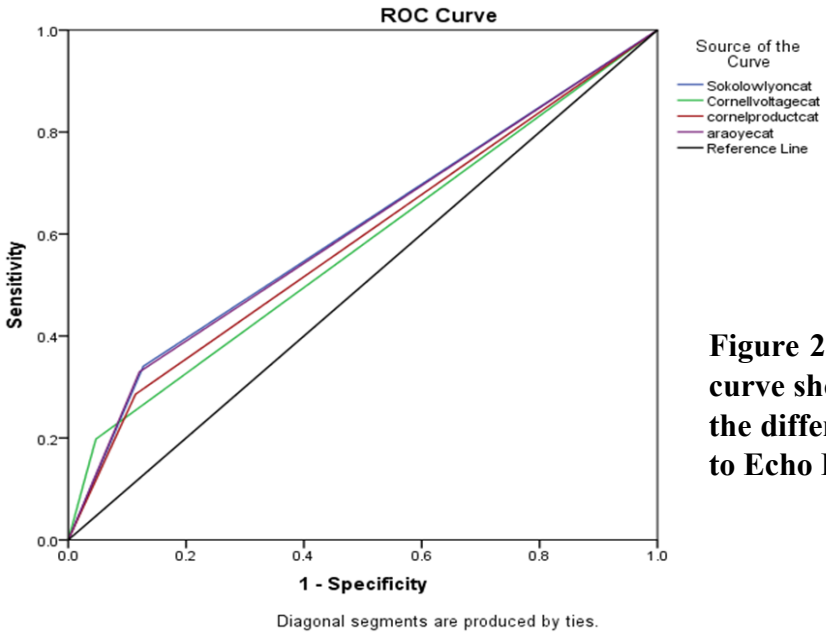

Figure 2: Receiver operator characteristic curve showing sensitivity and specificity of the different LVH criteria when compared to Echo BSA as the gold standard.

Area Under the Curve

Test Result Variable(s)	Area
Sokolow lyon	0.585
Cornell voltage	0.588
Cornel product	0.616
Araoye	0.591

DISCUSSION

This study aimed to determine to determine the frequency of Electrocardiographic Left Ventricular Hypertrophy by four selected criteria and to compare the sensitivity of the various Electrocardiographic criteria with Echocardiographic Left Ventricular Hypertrophy determined by two different indeation methods in hypertensive patients and normotensive controls. All echocardiographic parameters were significant in the hypertensives compared to the controls. On indexing for both Echo LVH HT $^{2.7}$ and Echo LVH BSA there was no significant difference in the results. Echocardiography was more sensitive than Electrocardiography in the detection of Left Ventricular Hypertrophy in this study.

Sokolow-Lyon and Cornell product criteria had the highest sensitivity(39.5% each) but Cornell voltage criteria had the highest specificity(87.2%). Araoye's 3 code criteria for negroes had a sensitivity of 37% and a specificity of 79.5%. This corresponds with the findings in most studies among Nigerians which had low sensitivities and high specificities[16].

The Cornell product criterion had the highest area under the curve (0.616) followed by Araoye

criterion (0.591). On the other hand, Sokolow Lyon criterion had the lowest area under the curve. Of the 240 total subjects who participated in the study, 29.2% were seen to have LVH using the diagnostic ECHO BSA. In contrast, for echocardiographic LVH, Sokolow Lyon and Araoye criteria both showed the highest prevalence of LVH at 20.8% and 20.0% respectively. Cornell Product and Cornell Voltage had a prevalence at17.9 % and 10.4% respectively.

Sokolow-Lyon in their original study claimed that the sensitivity of their Voltage Criteria was 32% and specificity 100%. [11] Okin[12] found that electrocardiographic criteria for left ventricular hypertrophy has lower sensitivity in women when compared to men even when the gender differences like left ventricular mass, height and weight were taken into account.

Levy et a1[13] examined the Framingham Heart Study on 4684 subjects and significant ECHO LVH was detected in 290 (14.2%) men and 466 (13.6%) women. But ECG LVH was seen in 60 (2.9%) men and 30 (1.5%) women. Hence, the overall sensitivity of LVH as determined by ECG was 6.9% with 98.8% specificity.

A study conducted by Norman et al [14] at Maryland University, USA evaluated five different ECG LVH criteria, comparing the performances of their original and adjusted versions. All adjusted criteria significantly outperformed their unadjusted counterparts. Of these five criteria, the Cornell voltage duration product exhibited the greatest sensitivity at all levels of specificity for both sexes (39 and 51% sensitivity at 95% specificity in men and women, respectively).

Denaire et al[15] found that sensitivity of Romhilt-Estes and Sokolow-Lyon criteria were from 20-25% but Cornell criteria had 50% correlation with ECHO.

Ngabea et al [20] studied the sensitivity and specificity of electrocardiographic left ventricular hypertrophy (LVH) Criteria amongst hypertensives in Abuja, Northern Nigeria and found the various ECG criteria for the diagnosis of LVH were lower in sensitivities (23.5%-38.6%) compared to specificities (64.1%-72.9%) with the Cornell voltage (CV) criterion combining the highest sensitivity and specificity at 38.6% and 72.9%, respectively. The prevalence of echocardiographic LVH was 32.4% among the hypertensives in the study. [20]

Ogunlade O et al in Ile -Ife found 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.

Many others have validated that the diagnosis of LVH by electrocardiography is strongly influenced by age and ethnicity. These interethnic differences in ECG characteristics which have been demonstrated especially in blacks are due to the higher precordial QRS voltages observed in blacks.[22,23]

A study by Katibi[28] in Ilorin ascertained that ECG variables correlated very poorly with Echo left ventricular mass with Estes point score showing the highest correlation (0.39) and R aVL the least (-0.01). Apart from detecting LVH, ECG also provides information related to arrhythmia, conduction defects and myocardial ischaemia. Although it is relatively insensitive, the ECG does have prognostic significance[29]. Hypertensive patients with echocardiographically proven LVH who also meet ECG criteria have a greater left ventricular mass than those without the expected ECG changes.[30] Left ventricular mass is highest in those with a "strain" pattern.[31] Serial monitoring of ECG voltage also may be helpful. In particular, changes in ECG voltage over time may reflect changes in left ventricular mass and correlate with cardiovascular risk.[32]

The ECG criteria have been found to have high specificity but low sensitivity for the diagnosis of LVH, regardless of the pattern of LVH and using several ECG criteria may be considered instead of a single ECG criterion for the diagnosis of LVH hypertensive patients. [3]In conclusion, the performance of classic ECG criteria for LVH detection appeared to be lower in this population African origin than in white subjects. Newly

generated criteria might provide improved performance in Africans and those of black ethnicity.

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