Original Article

Accuracy of Electrocardiography Criteria for Left Ventricular Hypertrophy in Hypertensive Patients at Shahid Gangalal National Heart Centre

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Abstract

Background: Hypertension is the leading cause of cardiovascular disease and premature death worldwide. Left ventricular hypertrophy (LVH), a measure of hypertensive target organ damage in the heart is associated with increased morbidity, mortality and development of arrhythmias. This study was designed to identify the more accurate ECG criteria for identifying LVH taking LVH by echocardiography as reference.

Methods: A cross sectional study was conducted at Shahid Gangalal National Heart Centre. A total of 252 patients were included. A 12-lead ECG and Echocardiography were done. Analysis done by SPSS 25. Stata-14 software was used for ROC (Receiver operating characteristics) comparison and P<0.05 considered statistically significant.

Results: Sensitivity, specificity, PPV, NPV and accuracy of Sokolow-Lyon criteria in diagnosis LVH was 41.8%, 80.8%, 67.1%, 59.7% and 61.9% respectively. The results of the test parameters taking Cornell Voltage criteria to detect LVH was 65.6%, 73.1%, 69.6% 69.3% and 69.4%. Likewise, the test parameters of cornell voltage duration measurement was 57.4%, 84.6%, 77.8%, 67.9% and 71.4% respectively. Similarly results of the test parameters by Romhilt-Estes system was 36.9%, 88.5%, 75%, 59.9% and 63.5% respectively. Area under the curve(AUC) of Sokolow-Lyon index, Cornell voltage criteria, Cornell voltage duration measurement and Romhilt- Estes system was 0.613, 0.693, 0.71 and 0.627 respectively.

Conclusion: In our study Cornell Voltage duration measurement criteria had a higher sensitivity and higher AUC to detect LVH. The different ECG criteria must be integrated with the clinical scenario. Isolated interpretation of LVH using a single ECG criteria has a low diagnostic value.

Keywords: left ventricular hypertrophy, Sokolow-Lyon, Cornell Voltage, Romhilt-Estes point score

Introduction

Hypertension is the leading cause of cardiovascular disease and premature death worldwide.[1] Hypertension affects 1 billion worldwide and it remains the most common, readily identifiable, and reversible risk factor for myocardial infarction (MI), stroke, heart failure, atrial fibrillation, aortic dissection, peripheral arterial disease, and cognitive decline.[2] Left ventricular hypertrophy (LVH), a measure of hypertensive target organ damage in the heart, has been reported to be associated with increased morbidity and mortality and development of atrial arrhythmias.[3,4]

The presence of left ventricular hypertrophy, in addition to hypertension, thus has important implications for assessing risk and managing patients, including decisions on interventions other than antihypertensive treatment, such as lipid lowering treatment and life-style modifications.[5]

ECG LVH also provides unique prognostic information for increased risk of SCD, even when adjusted for echocardiographic LVH.[6] Electrocardiography (ECG) and echocardiography (ECHO) can be applied to detect LVH in clinical practice. The diagnosis of LVH should preferably be made by ECHO because

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it can visually measure every parameter of cardiac structure in a noninvasive method.[7] The greater convenience and lower cost of the ECG continue to support its widespread use for the diagnosis of ventricular hypertrophy in clinical practice, epidemiological studies, and clinical trials.

Several ECG criteria, such as the Sokolow–Lyon index, Cornell voltage or Cornell voltage duration product, and RavL are available to assess LVH. Most of previous studies have been conducted in Caucasians and the diagnostic performance of ECG criteria for Asians remains under investigation.[8,9] We believe that this study will aid in identifying the more accurate ECG criteria for identifying LVH taking LVH by echocardiography as reference and will help in identifying, assessing risk and managing such patients.

OBJECTIVES

To compare four different ECG criteria's of left ventricular hypertrophy in terms of diagnostic accuracy taking echocardiographically diagnosed left ventricular hypertrophy as reference standard.

OPERATIONAL DEFINITION

Hypertension: Hypertension be diagnosed when a person's systolic blood pressure (SBP) in the office or clinic is ≥140mmHg and/or their diastolic blood pressure (DBP) is ≥90mmHg following repeated examination in accordance with the methods and guidelines provided by the internationals society of hypertension[10] or patients taking anti- hypertensive medications for more than 6 months.

Left Ventricular Hypertrophy: LVH as defined by echocardiographic or electrocardiographic criteria. Electrocardiographically Sokolow-Lyon index, Cornell voltage criterion, Cornell voltage duration measurement and Romhilt-Estes point score system was applied to diagnose LVH. LVH is diagnosed as

1. Sokolow-Lyon index- SV1+RV5>3.5mV or RaVL>1.1mV
2. Cornell voltage criterion - SV3 + RaVL > 2.8 mV in males and > 2.0 mV in females
3. Cornell voltage duration measurement- Cornell voltage × QRS duration > 2436 mm-sec
4. Romhilt-Estes point score system

   Any limb lead R wave or S wave >2mV (3 points)

   SV1 or SV2 ≥ 3.0 mV (3 points)

   RV5 to RV6 ≥ 3.0 mV (3 points)

   ST-T wave abnormality, no digitalis therapy (3 points)

   ST-T wave abnormality, digitalis therapy (1 point)

   Left atrial abnormality (3 points)

   Left axis deviation ≥ −30 degrees (2 points)

   QRS duration ≥ 90 m sec (1 point)

   Intrinsicoid deflection in V 5 or V 6 ≥ 50 msec (1 point)

   Points of 5 or more was taken as LVH.

Echocardiographically LVH is diagnosed as LVM/BSA > 95 g/m2 in females and > 115 g/m2 in males and LVM/ height > 51 g/m2 in males and > 47 g/m2 in females according to the European Association of Cardiovascular Imaging (EACVI) and American Society of Echocardiography (ASE) recommendations.[11]

Obesity: Obesity is defined as abnormal or excessive fat accumulation that may impair health. Western Pacific Regional Office of WHO (WPRO) defined as overweight (BMI 23.0–24.9) and obesity (BMI ≥25.0) for Asian populations.[12]

The formula to calculate BMI = kg/m2 where kg is a person's weight in kilograms and m2 is their height in metres squared.

Smoking Status-As defined by CDC.

Current smoker-An adult who has smoked 100 cigarettes in his or her lifetime and who currently smokes cigarettes every day or some days.

Former smoker- An adult who has smoked at least 100 cigarettes in his or her lifetime but who currently do not smoke.

Never smokers- An adult who has never smoked, or who has smoked less than 100 cigarettes in his or her lifetime.

MATERIALS AND METHODS

Setting: Cardiology Department of Shahid Gangalal National Heart Centre, Kathmandu, Nepal.

Duration of the study: - 6 months from August 2021 to February 2022.

Sample size: 252

Calculated using Dr. Lin Naing calculator.

Sample selection

Inclusion criteria

1. All the patients presenting to the OPD diagnosed with hypertension or under anti-hypertensive medications irrespective of the presenting complain or duration of therapy.
2. Patient's age should be from 35-65 years of age.
3. Patients willing to take part with consent in the study.

Exclusion criteria

1. Patients with cardiomyopathies.
2. Patients with valvular heart diseases.
3. Patients with left/right bundle branch block
4. Patients with left anterior fascicular block
5. Patients with valvular heart diseases
6. Patients with any underlying kidney disease
7. Patients with other secondary causes of hypertension
8. Patients with gestational hypertension or pre-eclampsia.
9. Patients unwilling to participate

STUDY DESIGN: Cross sectional study

Following the ethical clearance from the Institutional Review Board (IRB) of the Shahid Gangalal National Heart Centre, a cross sectional study was conducted. Cases diagnosed with hypertension or under anti- hypertensive medications and fulfilling the inclusion criteria was enrolled as cases. They were explained about the purpose of the study and the methods used. Informed written consent was taken in either Nepali or English language whichever they feel comfortable assuring full confidentiality. All patients underwent full history taking and physical examination. A 12-lead resting ECG was recorded at 25 mm/s and 1 mV/cm standardization. The 12-lead

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ECG was read by two independent cardiologists and findings were recorded.

Defined electrocardiographic indices was applied to diagnose LVH. Echocardiography was done by using GE healthcare Vivid E95 echocardiography machine.

Echocardiographic measurement performed by the investigator measuring inter ventricular septum (IVS), left ventricular internal diameter (LVID), and posterior wall thickness (PWT) and left ventricular mass (LVM) was calculated using the American Society of Echocardiography (ASE) recommended formula:

LVM (g) = 0.8{1.04[(LVIDd + PW + IVSd)3 - (LVIDd)3]} + 0.6 g.10

LVM was standardized by body surface area (BSA) and body height as LVM/BSA and LVM/height respectively.

LVH was diagnosed as LVM/BSA > 95 g/m2 in females and > 115 g/m2 in males and LVM/ height > 51 g/m2 in males and > 47 g/m2 in females according to the EACVI and ASE recommendations.12

All the information such as age, gender, height, weight, BMI, SBP, DBP, origin, smoking status, LVH on ECG criteria, LVH on echocardiography was noted in a predesigned proforma.

DATA ANALYSIS PROCEDURE

The collected data was entered using data validation tool (MS-Excel worksheet 2010). Statistical analyses were performed with statistical software (IBM SPSS®statistics 25 for Windows). The data was presented in tables and diagrams. All measured values were reported as means ±SD for continuous variables like age, height, weight, BMI, SBP, DBP and BSA. Frequency and percentages for categorical variables like gender, area of origin, smoking status.

Sensitivity, specificity, PPV NPV and diagnostic accuracy of ECG different criteria like Sokolow-Lyon, Cornell criteria, Cornell voltage duration measurement, Romhis-Estes point scoring system for LVH was computed and echocardiography was taken as gold standard.

Receiver operating characteristic (ROC) curves and the areas under the curves analyses were conducted to compare diagnostic accuracy for the four ECG criteria using conventional cut-off values. Stata-14 software was used for ROC comparison and P<0.05 was considered of statistical significance.

RESULTS

A total of 252 patients diagnosed with hypertension or under anti- hypertensive medications irrespective of the presenting complain were included in this study. The average age of the patients was 50.32±6.95 years. There were 157(62.3%) male and 95(37.7%) female participants The mean systolic and diastolic blood pressure was 139.92 ± 26.97 and 88.37 ± 9.61 respectively. Almost 52% patients were from urban and 48% from rural areas (figure 5). Out of 252, 50%(126) of the population were nonsmokers; 28.2% were currently smoking and 21.8% had previously smoked. Almost 78% were currently taking anti hypertensive medications. The baseline characteristics of the patients are reported in Table 1.

Out of 252 study cases, 122(48.4%) of them had left ventricular hypertrophy on Echocardiography. According to ECG criteria, left ventricular hypertrophy was observed as defined by Sokolow-Lyon

criteria on 76(30.2%), as Cornell voltage criteria on 115(45.6%), as Cornell voltage duration measurement on 90(35.7%) and as Romhilt- Estes point score system on 60(23.8%) as shown in table 2.

Sensitivity, specificity, PPV, NPV and accuracy of Sokolow-Lyon criteria in diagnosis of left ventricular hypertrophy was 41.8%, 80.8%, 67.1%, 59.7% and 61.9% respectively. Likewise, diagnostics parameter of ECG by Cornell Voltage to detect LVH was 5.6%, 73.1%, 69.6% 69.3% and 69.4% respectively. Similar diagnostics parameter of ECG as defined by Cornell voltage duration measurement was 57.4%, 84.6%, 77.8%, 67.9% and 71.4% respectively and diagnostic parameters of ECG by Romhilt- Estes point score system was 36.9%, 88.5%, 75%, 59.9% and 63.5% respectively as shown in table 3. The different ECG criteria also seemed to have a better diagnostic accuracy in patients younger than 50 years of age as shown in supplementary table 1.

Receiver operating characteristic (ROC) curve for four criteria of Echocardiography to detect LVH is represented in figure 1. Area under the curve(AUC) of Sokolow-Lyon index, Cornell voltage criteria, Cornell voltage duration measurement and Romhilt-Estes point (score system was 0.613, 0.693, 0.71 and 0.627 respectively. Comparison of AUC among the ECG criteria is shown in table 4. AUC of Cornell voltage criteria and Cornell voltage duration measurement was significantly high in all criteria (p=0.038, p=0.047 and p=0.004). Our study also showed that the combined analysis of the 4 ECG criteria may have a higher diagnostic value than each ECG criterion alone as shown in supplementary table 2.

Table 1: Baseline characteristics of the patients   Total: 252

Males	157 (62.3%)
Age (years)	50.32 ± 6.95
BMI(kg/m2)	25.26 ± 2.66
BSA(m2)	1.77 ± 0.12
SBP (mmHg)	139.92 ± 26.97
DBP (mmHg)	88.37 ± 9.61
Current use of anti-hypertensive medications(%)	77.78 %
Urban residence(%)	51.98 %
Smoking status Current Ex-smoker None	28.2% 21.8% 50%

Table 2: Frequency of patients with left ventricular hypertrophy detected by electrocardiography And echocardiography

Diagnostic criteria	LVH Positive	LVH Negative
Sokolow-Lyon index	76(30.2%)	176(69.8%)
Cornell voltage criteria	115(45.6%)	137(54.4%)
Cornell voltage duration measurement	90(35.7%)	162(64.3%)
Romhilt-Estes point score system	60(23.8%)	192(76.2%)
Echocardiography	122(48.4%)	130(51.6%)

Table 4: Pair wise comparison of four electrocardiography finding taking echocardiographically as reference standard

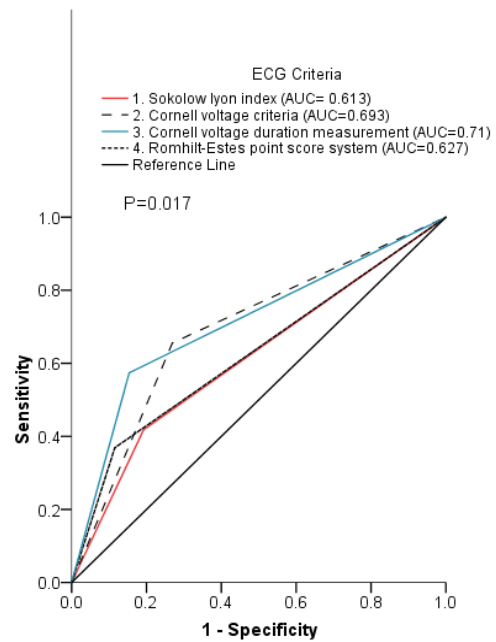| ECG diagnostic criteria for LVH		AUC	P-Value
Sokolow-Lyon index vs.	Cornell voltage criteria	0.613 vs. 0.693	0.038*
	Cornell voltage duration measurement	0.613 vs. 0.71	0.011*
	Romhilt-Estes point score system	0.613 vs. 0.627	0.706
Cornell voltage criteria vs.	Cornell voltage duration measurement	0.693 vs. 0.71	0.456
	Romhilt-Estes point score system	0.693 vs. 0.627	0.047*
Cornell voltage duration measurement vs.	Romhilt-Estes point score system	0.71 vs. 0.627	0.004*

This comparison was done by Stata-14 software

Table 3: Four different ecg criterias of left ventricular hypertrophy in terms of diagnostic accuracy taking echocardiographically as reference standard

Diagnostic Criteria of ECG	Sensitivity	Specificity	PPV	NPV	Accuracy
Sokolow-Lyon index	41.8%	80.8%	67.1%	59.7%	61.9%
Cornell voltage criteria	65.6%	73.1%	69.6%	69.3%	69.4%
Cornell voltage duration measurement	57.4%	84.6%	77.8%	67.9%	71.4%
Romhilt-Estes point score system	36.9%	88.5%	75%	59.9%	63.5

Figure 1: receiver operating characteristic (roc) curves for four different ecg criteria in prediction of lvh

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DISCUSSION

LVH is mainly determined by an increase in left ventricular mass, which can be estimated by the electrical voltage changes detected on the surface electrocardiogram. Because of this, the ECG is a good proxy for detecting changes in left ventricular mass. However, the electrical voltage of the heart is not only determined by the amount of myocardium present. It is instead reliant on active and passive electrical connections between the heart and torsum. These are influenced by variables such as the distance between the left ventricular cavity and the electrode, the position of the surface electrode, individual anthropometric variations, conduction problems, myocardial fibrosis, and pulmonary pathology.[13] Furthermore, the ECG voltage has been shown to vary dramatically from day to day, between patients, and even between individuals.

The only way to clarify whether or not ECG criteria are reliable in diagnosing LVH is to test them against echocardiography. In view of this, the present study evaluated the four more commonly used electrocardiographic criteria's for left ventricular hypertrophy, using echocardiography as diagnostic standard.

Our data confirms the high incidence of electrocardiographically-defined LV hypertrophy, 30.2% had LV hypertrophy as defined by Sokolow-Lyon criteria, Cornell voltage criteria 45.6%, Cornell voltage duration measurement 35.7% and Romhilt-Estes point score system 23.8%.

Certain groups of the population have showed even a higher prevalence of ECG defined Sokolow-Lyon criteria for left ventricular hypertrophy. In a study done by Sharma et al. the Sokolow-Lyon criteria was positive among 45% of 1000 young atheletes.[14]. Our study also showed similar findings that the ECG criteria seemed to have a better diagnostic accuracy in patients younger than 50 years of age.

Few previous studies investigated the accuracy of ECG criteria in the detection of LVH in Asians.[15-17] In 546 Chinese patients with hypertension, Xie et al. found that the Cornell voltage and product criteria had a higher sensitivity to detect echocardiographic LVH (28% and 36.6%, respectively).[15]

In our study Cornell Voltage and cornell voltage duration measurement criteria had had a higher sensitivity to detect echocardiographic LVH (65.6% and 57.4%) respectively. In a study done by Su et al. in Taiwan, among 539 young army men the Cornell voltage and cornell voltage duration product criteria had better performance for the echocardiographic LVH than the Sokolow–Lyon criteria, with a sensitivity of 22.2%, 27.8%, and 8.3%, respectively.[16] In 332 Korean patients, Park et al. demonstrated that the Cornell product criterion was superior to the Sokolow–Lyon voltage criterion in women, but the opposite was true in men.[17] It has been shown that QRS duration had a stronger association with Echo- LVH among all other single- lead components[18] which may have driven the better performances of Cornell- product- related criteria. QRS duration was reported to be an independent predictor for LVH in previous studies (Okin et al., 2002; Palmieri et al., 2007). Potential mechanisms included the longer time required to activate myocardium that was increasingly distant from specialized conduction tissue and the decreased conduction velocity in hypertrophied myocardium.

In the systematic review done by Pewnser et al the accuracy of different electrocardiographic indexes for the diagnosis of left ventricular hypertrophy had sensitivity ranging from 10.5-21% and median specificity of 89-99%.[5] In our study area under the curve of Cornell voltage criteria and Cornell voltage duration measurement was significantly high in all criteria (p=0.038, p=0.047 and p=0.004) and this is in accordance with previous studies by Salles et al[19] and by Xie et al.[15]

Previous studies often focused on the diagnostic sensitivity and specificity of single ECG criterion.[20,21] Our study found that the combined analysis of the 4 ECG criteria may have a higher diagnostic value than each ECG criterion alone. Also these criteria appear to have a higher diagnostic accuracy in those patients aged less than 50 years of age.

As the diagnostic accuracy of the Sokolow-Lyon criteria is comparably low, Cornell criteria and Cornell voltage duration measurement, should be implemented in routine clinical practice. In a resource-limited setting like ours where echocardiography facilities are not accessible in all rural settings, using ECG criteria such as Cornell voltage and Cornell voltage duration measurement can be considered to be standard investigations in the future for diagnosis of LVH based on the strength of their cost- effectiveness and availability. Also it has been reported that ECG-LVH can predict the outcome of heart failure outperforming MRI-LVH.[22] We also would recommend that the Cornell voltage duration algorithm be applied to the in-built software in ECG which would aid in decision making to physicians.

Our research must be understood in light of its limitations. Firstly, we just looked at four of the several ECG criteria's validated for diagnosis of LVH. Second, it was conducted in a single center. As a result, our study may be less representative than a larger multicenter study. Also left ventricular mass was established using echocardiography, cardiac magnetic resonance imaging is known to be more accurate. Nonetheless, the current study paved the way for future research in Nepal on the use of the current ECG crteria's for LVH and possibly the need of a better ECG LVH diagnosis criteria.

CONCLUSION

In our study Cornell Voltage criteria and cornell voltage duration measurement had the higher sensitivity to detect echocardiographic LVH (65.6% and 57.4% respectively. All of the ECG criteria must be integrated with the clinical scenario. Isolated interpretation of LVH using a single ECG criteria has a low diagnostic value. In the evaluation of hypertensive patients for LVH, echocardiography is still the method of choice. However, in resource limited settings where echocardiography might not be readily available, ECG criteria such as cornell voltage and cornell voltage duration measurement can be used regularly as screening investigation for LVH because of its cost-effectiveness and easy availability.

REFERENCES:

1. Mills KT, Stefanescu A & He J. The global epidemiology of hypertension. Nat Rev Nephrol.2020;16:223–37.

2. Blacher J, Levy BI, Mourad JJ. From epidemiological transition to modern cardiovascular epidemiology: hypertension in the 21st century. Lancet. 2016;388:

3. Ishikawa J, Ishikawa S, Kabutoya T, Gotoh T, Kayaba K, Schwartz JE, et al. Cornell product left ventricular hypertrophy in electrocardiogram and the risk of stroke in a general population. Hypertension. 2009;53(1):28-34.

4. Aro AL, Chugh SS. Clinical diagnosis of electrical versus anatomic left ventricular hypertrophy: prognostic and therapeutic implications. Circ ArrhythmElectrophysiol. 2016;9(4):e003629.

5. Pewsner D, Jüni P, Egger M, Battaglia M, Sundström J, & Bachmann LM. Accuracy of electrocardiography in diagnosis of left ventricular hypertrophy in arterial hypertension: Systematic review. BMJ. 2007;335(7622):711.

6. Zhou Y, & Zhang Y. A0420 Compatibility of left ventricular hypertrophy diagnosed by electrocardiography and by echocardiography. J Hypertension. 2018; 36.

7. Cuspidi C, Sala C, Negri F, Mancia G, Morganti A. Italian Society of Hypertension. Prevalence of left-ventricular hypertrophy in hypertension: an updated review of echocardiographic studies. J Hum Hypertens. 2012;26(6):343-349.

8. Wang D, Xu JZ, Zhang W, Chen Y, Li J, An Y, Bian R, Wang JG. Performance of Electrocardiographic Criteria for Echocardiographically Diagnosed Left Ventricular Hypertrophy in Chinese Hypertensive Patients. Am J Hypertens. 2020 Sep 10;33(9):831-836. doi: 10.1093/ajh/hpaa083. PMID: 32484222; PMCID: PMC7486900.

9. Spencer CG, Beevers DG, Lip GY. Ethnic differences in left ventricular size and the prevalence of left ventricular hypertrophy among hypertensive patients vary with electrocardiographic criteria. J Hum Hypertens 2004; 18:631–636.

10. Unger T, Borghi C, Charchar F. 2020 International Society of Hypertension global hypertension practice guidelines. J Hypertens 2020; 38:982-85.

11. Marwick TH, Gillebert TC, Aurigemma G, Chirinos J, Derumeaux G, Galderisi M. et al. Recommendations on the Use of Echocardiography in Adult Hypertension: A Report from the European Association of Cardiovascular Imaging (EACVI) and the American Society of Echocardiography (ASE). J American Society of Echocardiography. 2015;28(7), 727-754.

12. International Obesity Task Force. The Asia-Pacific perspective : redefining obesity and its treatment. World Health Organization – WesternPacificRegion.2000

13. Peguero J, Lo Presti S, Perez J, et al. Electrocardiographic Criteria for the Diagnosis of Left Ventricular Hypertrophy. J Am Coll Cardiol. 2017 Apr, 69 (13) 1694–1703.

14. Sharma S, Whyte G, Elliott P, Padula M, Kaushal R, Mahon N, et al. Electrocardiographic changes in 1000 highly trained junior elite athletes. Br J Sports Med 1999;33:319-324.

15. Xie L, Wang Z. Correlation between echocardiographic left ventricular mass index and electrocardiographic variables used in left ventricular hypertrophy criteria in Chinese hypertensive patients. Hellenic J Cardiol 2010; 51:391–401.

16. Su FY, Li YH, Lin YP, Lee CJ, Wang CH, Meng FC, et al. A comparison of Cornell and Sokolow-Lyon electrocardiographic criteria for left ventricular hypertrophy in a military male population in Taiwan: the cardiorespiratory fitness and hospitalization events in armed forces study. Cardiovasc Diagn Ther 2017; 7:244–251.

17. Park JK, Shin JH, Kim SH, Lim YH, Kim KS, Kim SG, et al. A comparison of Cornell and Sokolow-Lyon electrocardiographic criteria for left ventricular hypertrophy in Korean patients. Korean Circ J 2012; 42:606–613.

18. Lv, T., Yuan, Y., Yang, J., Wang, G., Kong, L., Li, H., Li, X., Sun, Y., Li, X., Zhang, Z., Cheng, X., Wu, L., Tan, X., Han, B., Li, H., Zhang, Z., Wang, J., Wu, Y., Wang, Y., Guo, J., ... Zhang, P. (2021). The association between ECG criteria and Echo criteria for left ventricular hypertrophy in a general Chinese population. Annals of noninvasive electrocardiology : the official journal of the International Society for Holter and Noninvasive Electrocardiology, Inc, 26(5), e12880.

19. Salles G, Leocádio S, Bloch K, Nogueira AR, Muxfeldt E. Combined QT interval and voltage criteria improve left ventricular hypertrophy detection in resistant hypertension. Hypertension. 2005;46(5):1207–12.

20. Jaggy C, Perret F, Bovet P, van Melle G, Zerkiebel N, Madeleine G, et al. Performance of classic electrocardiographic criteria for left ventricular hypertrophy in an African population. Hypertension 2000; 36:54–61.

21. 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; 25:417–23.

22. Oseni, A. O., Qureshi, W. T., Almahmoud, M. F. et al (2017). Left ventricular hypertrophy by ECG versus cardiac MRI as a predictor for heart failure. Heart, 103(1), 49–54.