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ORIGINAL RESEARCH

Consistency of left ventricular hypertrophy diagnosed by electrocardiography and echocardiography: the Northern Shanghai Study

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Background: Left ventricular hypertrophy (LVH) is one of the preclinical manifestations of hypertensive target organ damage (TOD). However, it remains unclear which electrocardiographic criterion perform better in diagnosing LVH.

Purpose: To investigate the consistency of LVH diagnosed by electrocardiography (ECG) and echocardiography (ECHO). Taking LVH by ECHO as reference, to compare three different ECG criteria (Sokolow-Lyon, Cornell and Cornell Product criteria) and find the best ECG indicator for identifying LVH in community-based elderly Chinese.

Patients and methods: Echocardiography and electrocardiography were applied to define LVH in 1789 elderly Chinese aged >65 years old in communities located at the northern Shanghai. Echocardiographic LVH (ECHO-LVH) was defined by left ventricular mass indexed for Body Surface Area (LVM/BSA) or for height$^{2.7}$ (LVM/height$^{2.7}$). Electrocardiographic LVH (ECG-LVH) was defined by Sokolow-Lyon (SL), Cornell and Cornell Product (CP) criteria. ECHO-LVH was defined by LVM/BSA≥125 g/m^2 in male or ≥110 g/m^2 in female (LVH1); LVM/BSA≥115 g/m^2 in male, or ≥95 g/m^2 in female (LVH2) and LVM/height$^{2.7}$ ≥51 g/m$^{2.7}$ in male or ≥47 g/m$^{2.7}$ in female (LVH3).

Results: As compared with SL and Cornell criteria, CP had the greatest correlation coefficient in the association with echocardiography-defined LVH, except for LVM/BSA in men. Of note, CP criterion had the greatest area under curve of ROC than Cornell criterion and the SL index, not only in total population but also in subgroups classified by blood pressure.

Conclusion: In ECG-LVH criteria, CP criterion complies better than SL index and Cornell criterion in assessing cardiac hypertrophy.

Keywords: left ventricular hypertrophy, electrocardiography, echocardiography, population study, accuracy

Introduction

Left ventricular hypertrophy (LVH) is one of the preclinical manifestations of hypertensive target organ damage (TOD).[1] It is an independent risk factor of cardiovascular events and the diagnosis of LVH in the early stage is a strong predictor of morbidity.[2–5] Long-term increased afterload may generate cardiac remodeling, which explains the formation mechanism of LVH.

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 it can visually measure every parameter of cardiac structure in a noninvasive method. Furthermore, its high sensitivity and specificity make it a golden standard for the LVH detection. However, many conditions have restricted ECHO application in routine clinical practice, including operators' uneven levels and high expense.

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The 12-lead resting ECG, another noninvasive method for detecting LVH, on the other hand, is more convenient, economic, and suitable for screening in a large scope.

More than 30 ECG criteria have been invented to define LVH over the past decades,[6] including Lewis voltage, Gubner–Ungerleider voltage, RaVL, Romhilt–Estes score, left ventricular strain, RV6:RV5 ratio, Framingham criterion, Perugia criterion, and so on. But a few of them are still used in routine clinical practice. For instance, Sokolow et al developed Sokolow voltage to detect LVH in 1949 for the first time and it was widely used in the past.[7] Lyon and Rappaport developed the method successively. Sokolow-Lyon (SL) index is a classical approach to define LVH, and it calculates the sum of QRS voltage of S wave in V1 and R wave in V5 or V6. Some investigators pointed out that QRS duration is an independent predictor of LVH;[8] as a result, Cornell criterion and Cornell voltage-duration product (CP) were developed. The Cornell criterion means S wave in V3 plus R wave in aVL, and the CP criterion means Cornell criterion multiplied by the QRS duration.

In some studies, it was indicated that Cornell and CP criteria performed better than the SL index,[9] whereas some studies tend to deliver a different opinion.[10,11] It remains unclear which ECG criterion shows better reasoning in diagnosing LVH. Considering most ECG criteria have been established in the Caucasian, we aim to compare three different ECG criteria, taking LVH by ECHO as reference, to find out the best ECG indicator for identifying LVH in a community-based elderly Chinese.

Materials and methods

Study design and subjects

The Northern Shanghai Study (NSS) is a prospective population study with 1,789 community-dwelling elderly Chinese aged >65 years old. A systematic cardiovascular risk was conducted. Individuals who met the following eligible criteria were enrolled for this study: 1) those who are aged >65 years of age (based on birthday in their identity card); 2) those who volunteer to sign an informed consent; 3) long-term residents in northern part of Shanghai. Individual is excluded if he or she is: 1) unwilling to participate in the clinical study; 2) suffering from severe cardiac disease (New York Heart Association IV) or end-stage renal disease (Chronic kidney disease stage 4 or above); 3) diagnosed with cancer with life expectancy of less than 5 years; 4) developed stroke within 3 months; 5) suffering from other diseases to quit the study; 6) against the protocol; and 7) losing contact with laboratory staff. A total of 1,758 participants out of 1,789 subjects of NSS were included in the study, with 31 excluded because of absence of data. Subjects were notified both through phone calls and local neighborhood committees. Each subject was asked to undergo laboratory and clinical tests at either the Tenth People's Hospital of Tongji University or in the communities. The operators of ECG and ECHO were well-trained and we would readily test again if it was necessary to ensure accuracy of the data obtained from ECG and ECHO. All participants signed the informed consent. The protocol of the present study was approved by the ethics committee of the Shanghai Tenth People's Hospital. The study was conducted in accordance with the Declaration of Helsinki.

ECG

A 12-lead resting ECG was recorded at 25 mm/s and 1 mV/cm standardization with equipment that have frequency response characteristics conforming to the recommendations of the American Heart Association.[12] Electrocardiographic QRS wave voltage was detected in this study. Parameters include the voltage of the S wave of the leads V1 (SV1) and V3 (SV3), R wave of lead V5 (RV5) and aVL (RaVL), and the duration of QRS wave. Several electrocardiographic indices, namely SL index, Cornell criterion, and Cornell QRS duration product, were applied to assess high voltage of left ventricle to diagnose LVH. LVH was diagnosed as SV1 + RV5 ≥3.5 mV for SL index,[7] SV3 + RaVL ≥2.8 mV in males and ≥2.0 mV in females for Cornell criterion,[13] and (SV3 + RaVL) × QRS duration ≥244 mV/ms in males and (SV3 + RaVL + 0.6) × QRS duration ≥244 mV/ms in females for CP criterion.[14]

ECHO

Echocardiographic measurement was performed by one sonographer who was blind to other data. Interventricular septum (IVS), left ventricular internal diameter (LVID), and posterior wall thickness (PWT) were measured, and left ventricular mass (LVM) was calculated using the American Society of Echocardiography (ASE) recommended formula:

$$\text{LVM (g)} = 0.8 \times 1.04 \times ([\text{IVS} + \text{LVID} + \text{PWT}] 3 - \text{LVID } 3) + 0.6$$[15]

LVM was standardized by body surface area (BSA) and body height$^{2.7}$ as LVM/BSA and LVM/height,$^{2.7}$ respectively. LVH was diagnosed as LVM/BSA >95 g/m^2 in females and >115 g/m^2 in males[15] as per the novel ASE criterion, LVM/BSA >110 g/m^2 in females and >125 g/m^2 in males[1] according to the former ASE criterion, and LVM/height >51 g/m$^{2.7}$ in males and >47 g/m$^{2.7}$ in females[16] by other criteria.

Statistical analyses

All data statistics were analyzed using SAS software, version 9.3 (SAS Institute, Cary, NC, USA) and SigmaPlot software, version 12.5 (Systat Software, Inc., San Jose, CA, USA). All measured values were reported as means ± SD for continuous variables, numbers and percentages in parenthesis for categorical variables. Pearson's correlation coefficients were used to evaluate the degree of correlation between the three ECG criteria and the two indexed LVMs, namely LVM/BSA and LVM/height$^{2.7}$, and chi-squared test was used to analyze the categorical variables. Fisher transformation analysis was conducted to compare the correlation coefficients. Receiver operating characteristic (ROC) curves and the areas under the curves analyses were conducted to compare the sensitivity and specificity for the three ECG criteria using conventional cut-off values. $P<0.05$ was considered statistical significance.

Results

Characteristics of participants

Characteristics of participants by gender are shown in Table 1, including conventional cardiovascular risk factors, hypertensive TOD, and ECG and ECHO parameters. Among 1,758 participants, 784 (44.6%) were men, of which 336 (19.1%) participants were suffering from diabetes, and 921 (52.4%) from hypertension. Men, compared with women, were significantly taller (164.4±6.1 vs 154.8±5.7 cm, $P<0.001$), and had higher BSA (1.76±0.15 vs 1.58±0.14 m^2, $P<0.001$), S wave amplitude in V3 lead (0.82±0.46 vs 0.65±0.42 mV, $P<0.001$), QRS duration (95.90±15.35 vs 87.47±12.81 ms, $P<0.001$), SL index (2.61±0.85 vs 2.31±0.73, $P<0.001$), Cornell criterion (1.23±0.57 vs 1.08±0.53), PWT (9.27±1.57 vs 8.96±1.54 mm, $P<0.001$), LVID (47.90±7.05 vs 45.75±6.43 mm, $P<0.001$), and LVM (161.0±57.1 vs 143.1±48.1 g, $P<0.001$), but lower CP criterion (118.8±64.7 vs 147.5±53.1 mV/ms, $P<0.001$) and LVM/height$^{2.7}$ (40.8±14.3 vs 44.2±15.5, $P<0.001$).

Characteristics of participants by hypertensive status are shown in Table 2. All observation indices, such as age, R wave amplitude in lead aVL, S wave amplitude in lead V3, QRS duration, SL index, Cornell criterion, CP criterion, IVS, PWT, LVID, LV, LVM/BSA, and LVM/height$^{2.7}$ had significantly greater value in hypertensive participants ($P<0.05$).

Table 1 Characteristics of participants by gender

Characteristics	Overall (n=1,758)	Men (n=784)	Women (n=974)	*P*-value
Age, years	71.4±6.1	71.4±6.0	71.4±6.1	0.88
Body height, cm	160.0±8.3	166.4±6.1	154.8±5.7	<0.001
Body weight, kg	62.5±10.6	67.6±10.0	58.3±9.1	<0.001
BMI, kg/m^2	23.9±3.5	23.9±3.2	23.9±3.6	0.81
BSA, m^2	1.66±0.17	1.76±0.15	1.58±0.14	<0.001
SBP, mmHg	134.5±17.7	134.6±16.7	134.4±18.4	0.80
DBP, mmHg	78.90±9.2	79.9±9.3	78.1±9.0	<0.001
Diabetes, n (%)	336 (19.1)	146 (18.6)	190 (19.5)	0.65
Hypertension, n (%)	921 (52.4)	421 (53.8)	500 (51.3)	0.31
ECG parameters and indices				
RaVL, mV	0.42±0.29	0.41±0.30	0.43±0.28	0.14
SV3, mV	0.72±0.44	0.82±0.46	0.65±0.42	<0.001
QRS duration, ms	91.23±14.61	95.90±15.35	87.47±12.81	<0.001
SL index, mV	2.44±0.80	2.61±0.85	2.31±0.73	<0.001
Cornell criterion, mV	1.15±0.55	1.23±0.57	1.08±0.53	<0.001
CP criterion, mV/ms	134.7±60.3	118.8±64.7	147.5±53.1	<0.001
ECHO parameters and indices				
IVS, mm	9.47±1.87	9.61±1.94	9.38±1.81	0.011
PWT, mm	9.10±1.56	9.27±1.57	8.96±1.54	<0.0001
LVID, mm	46.71±6.80	47.90±7.05	45.75±6.43	<0.0001
LVM, g	151.1±53.1	161.0±57.1	143.1±48.1	<0.0001
LVM/BSA, g/m^2	90.5±28.9	90.8±29.7	90.3±28.3	0.74
LVM/height$^{2.7}$, g/m$^{2.7}$	42.7±15.1	40.8±14.3	44.2±15.5	<0.0001

Notes: Data means ± SD or numbers with percentages in parenthesis. Student's *t*-test and chi-squared analysis were conducted for the comparison of continuous and dichotomized variables between men and women.

Abbreviations: BMI, body mass index; BSA, body surface area; CP, Cornell Product; ECG, electrocardiography; ECHO, echocardiography; height$^{2.7}$, LVM indexed for 2.7 power of body height; IVS, interventricular septum; LVID, left ventricular internal diameter; LVM, left ventricular mass; LVMI/BSA, LVM indexed for BSA; LVMI/PWT, LVM indexed for posterior wall thickness; PWT, posterior wall thickness; RaVL, R wave of lead aVL; SL, Sokolow-Lyon; SV3, S wave of the leads V3.

Table 2 Characteristics of participants by hypertensive status

Characteristics	Overall (n=1,757)	Hypertension (n=921)	No hypertension (n=836)	*P*-value
Age, years	71.4±6.1	72.0±6.2	70.8±5.8	<0.001
ECG parameters and indices				
RaVL, mV	0.42±0.29	0.46±0.30	0.38±0.26	<0.001
SV3, mV	0.72±0.44	0.77±0.47	0.68±0.42	<0.001
QRS duration, ms	91.22±14.61	91.88±15.26	90.48±13.82	0.044
SL index, mV	2.44±0.80	2.54±0.84	2.33±0.74	<0.001
Cornell criterion, mV	1.15±0.55	1.23±0.58	1.06±0.51	<0.001
CP criterion, mV/ms	134.7±60.3	143.0±65.2	125.5±52.8	<0.001
ECHO parameters and indices				
IVS, mm	9.49±1.87	9.79±1.96	9.15±1.71	<0.001
PWT, mm	9.10±1.56	9.30±1.62	8.88±1.46	<0.001
LVID, mm	46.70±6.79	47.73±6.88	45.57±6.52	<0.001
LVM, g	151.0±53.0	161.8±55.6	139.1±47.2	<0.001
LVM/BSA, g/m^2	90.5±28.9	95.7±29.8	84.7±26.7	<0.001
LVM/height$^{2.7}$, g/m$^{2.7}$	42.7±15.1	45.7±15.3	39.3±14.1	<0.001

Abbreviations: BSA, body surface area; CP, Cornell Product; ECG, electrocardiography; ECHO, echocardiography; IVS, interventricular septum; LVID, left ventricular internal diameter; height$^{2.7}$, LVM indexed for 2.7 power of body height; LVM, left ventricular mass; PWT, posterior wall thickness; RaVL, R wave of lead aVL; SL, Sokolow-Lyon; SV3, S wave of the leads V3.

Correlations between ECG and ECHO parameters

As shown in Table 3, SL, Cornell, and CP parameters were all significantly correlated with LVM/BSA in total population, in both men and women (all $P \leq 0.01$). There were no significant differences in correlation coefficients among those parameters by the Fisher transformation analysis. As for LVH parameter and LVM/height$^{2.7}$, all the three ECG parameters were significantly correlated in total population, in both men and women ($P<0.01$), except for the association of LVM/height$^{2.7}$ with SL index in females ($P=0.09$).

Discrepancies in the diagnosis of LVH by ECG and ECHO

In Table 4, echocardiograph-diagnosed LVH is defined by LVM/BSA ≥125 g/m^2 in males and ≥110 g/m^2 in females as LVH1, by LVM/BSA ≥115 g/m^2 in males and ≥95 g/m^2 in females as LVH2, and by LVM/height$^{2.7}$ ≥51 g/m$^{2.7}$ in males and ≥47 g/m$^{2.7}$ in females as LVH3. In order to determine whether the Chinese method is superior to the commonly used SL criterion, we conducted SL-China criterion as well. Electrocardiograph-diagnosed LVH is defined by SV1 + RV5 ≥4.0 mV in males and ≥3.5 mV in females by the

Table 3 Correlation coefficient (*R*) between the electrocardiographic and echocardiographic parameters for the detection of LVH in total participants, in both males and females

Index	SL (SV1 + RV5)		Cornell (SV3 + RaVL)		CP (SV3 + RaVL) × QRS duration	
	R	*P*-value	*R*	*P*-value	*R*	*P*-value
LVM/BSA						
Total	0.15	<0.001	0.16	<0.001	0.18	<0.001
Male	0.23	<0.001	0.17	<0.001	0.21	<0.001
Female	0.09	<0.01	0.15	<0.001	0.16	<0.001
LVM/height$^{2.7}$						
Total	0.09	<0.001	0.15	<0.001	0.21	<0.001
Male	0.20	<0.001	0.17	<0.001	0.21	<0.001
Female	0.05	0.091	0.17	<0.001	0.17	<0.001

Note: Pearson's correlation analysis was applied between the electrocardiographic and echocardiographic parameters for the detection of LVH in total participants, in both males and females.

Abbreviations: BSA, body surface area; CP, Cornell Product; LVM, left ventricular mass; RaVL, R wave of lead aVL; RV5, R wave of lead V5; SL, Sokolow-Lyon; SV1, S wave of the leads V1; SV3, S wave of the leads V3.

Table 4 Chi-squared test between LVH diagnosed by ECG and by ECHO

Index	LVH1: LVM/BSA M ≥125 g/m², F ≥110 g/m²		LVH2: LVM/BSA M ≥115 g/m², F ≥95 g/m²		LVH3: LVM/height$^{2.7}$ M ≥51 g/m$^{2.7}$, F ≥47 g/m$^{2.7}$	
	χ^2	*P*-value	χ^2	*P*-value	χ^2	*P*-value
LVH diagnosed by ECHO						
SL-China (M ≥4.0 mV, F ≥3.5 mV)	24.15	<0.001	16.00	<0.001	15.99	<0.001
SL (M/F ≥3.5 mV)	14.34	<0.001	7.52	<0.01	9.67	<0.01
Cornell (M ≥2.8 mV, F ≥2.0 mV)	5.92	0.02	4.30	0.04	5.51	0.02
CP (M/F ≥244 mV/ms)	2.71	0.10	5.10	0.02	9.23	<0.01

Abbreviations: BSA, body surface area; CP, Cornell Product; ECG, electrocardiography; ECHO, echocardiography; F, female; LVH, left ventricular hypertrophy; LVM, left ventricular mass; LVH1, LVH diagnosed by LVM indexed for BSA (LVMI ≥125 g/m² in males and ≥110 g/m² in females); LVH2, LVH diagnosed by LVM indexed for BSA (LVMI ≥115 g/m² in males and ≥95 g/m² in females); LVH3, LVH diagnosed by LVM indexed for body height$^{2.7}$ (LVMI2 ≥51 g/m$^{2.7}$ in males and ≥47 g/m$^{2.7}$ in females); M, male; SL, Sokolow-Lyon.

SL-China criterion, by SV1 + RV5 ≥3.5 mV irrespective of genders for SL criterion, by SV3 + RaVL ≥2.8 mV in males and ≥1.0 mV in females for Cornell criterion, and by (SV3 + RaVL) × QRS duration ≥244 mV/ms in males and (SV3 + RaVL + 6) × QRS duration ≥244 mV/ms in females for CP criterion. Significant discrepancies were found between LVH diagnosed by the Cornell criterion and LVH1 (*P*=0.02), between LVH diagnosed by the Cornell criterion and LVH2 (*P*=0.04), between LVH diagnosed by the CP criterion and LVH2 (*P*=0.02), and between LVH diagnosed by the CP criterion and LVH3 (*P*<0.01). Of note, LVH diagnosed by the SL-China criterion and SL criterion were significantly and consistently different from LVH1, LVH2, and LVH3 (all *P*<0.01); furthermore, SL criterion was slightly superior to SL-China criterion.

Area under receiver operating characteristic (ROC) curve

In Figure 1, the ROC curve is applied to estimate the diagnostic value of CP criterion compared to Cornell and SL in detecting LVH. As shown in Figure 1, CP criterion has the largest area under curve, not only in total population but also in subgroup classified by hypertension.

Discussion

In this study, three commonly used ECG criteria, the SL index, Cornell criterion, and CP criterion, were compared for detecting LVH in a large community-based elderly population located in the northern part of Shanghai, taking echocardiograph-defined LVH as reference. The major finding of this study was that CP criterion is superior to SL index and Cornell criterion for LVH assessment.

Two LVM indices were determined by echocardiograph in this study, namely, LVM/BSA and LVH/height$^{2.7}$. The index of LVM to height$^{2.7}$ was supposed to be a more sensitive one for estimating LVH.[17] Moreover, the index of LVM to BSA was implemented as well. As shown in Table 1, there was no significant difference of LVM/BSA between genders (*P*=0.54), whereas the difference of LVM/height$^{2.7}$ between genders is significant (*P*<0.001). On the contrary, previous study by Simone et al[17] and Park et al[18] reported the opposite results. The difference may rely on different populations.

Okin et al,[8] Hsieh et al,[4] Molly et al,[14] Xie et al,[19] and Peguero et al[20] argued that isolated QRS voltage amplitude combined with QRS duration might enhance diagnostic sensitivity when ECG was used to detect LVH in the previous studies. We analyzed CP criterion, the composite one that is derived by multiplying Cornell voltage criterion and QRS duration, together with Cornell voltage criterion and SL index. The higher correlation coefficient, lower chi-squared values and greater area under the ROC curve of CP criterion make it the best indicator to evaluate LVH, and this is in accordance with previous studies by Salles et al[21] and by Xie et al.[19] However, subjects from the Salles's study were resistant hypertensives with a prevalence of LVH 87%, which is much higher than the current study.

Even integrating isolated QRS voltage without QRS duration, Cornell criterion is still superior to SL index in detecting LVH.[22] The same findings are detected in the study by Casale et al[23] as well. Based on a meta-analysis by Pewsner et al,[24] the highest sensitivity of electrocardiographic LVH (ECG-LVH) was 68%. Nevertheless, the lowest is only 0, and the sensitivity in most of the collected studies ranges from 10% to 30%. By studying different ethnic groups, Rodrigues et al[25] and Park et al[18] demonstrated that Cornell criterion performs better than SL index, though the sensitivity of both criteria is low.

Of note, an overwhelming majority of Chinese clinicians adopt a gender-specified SL index to diagnose LVH and

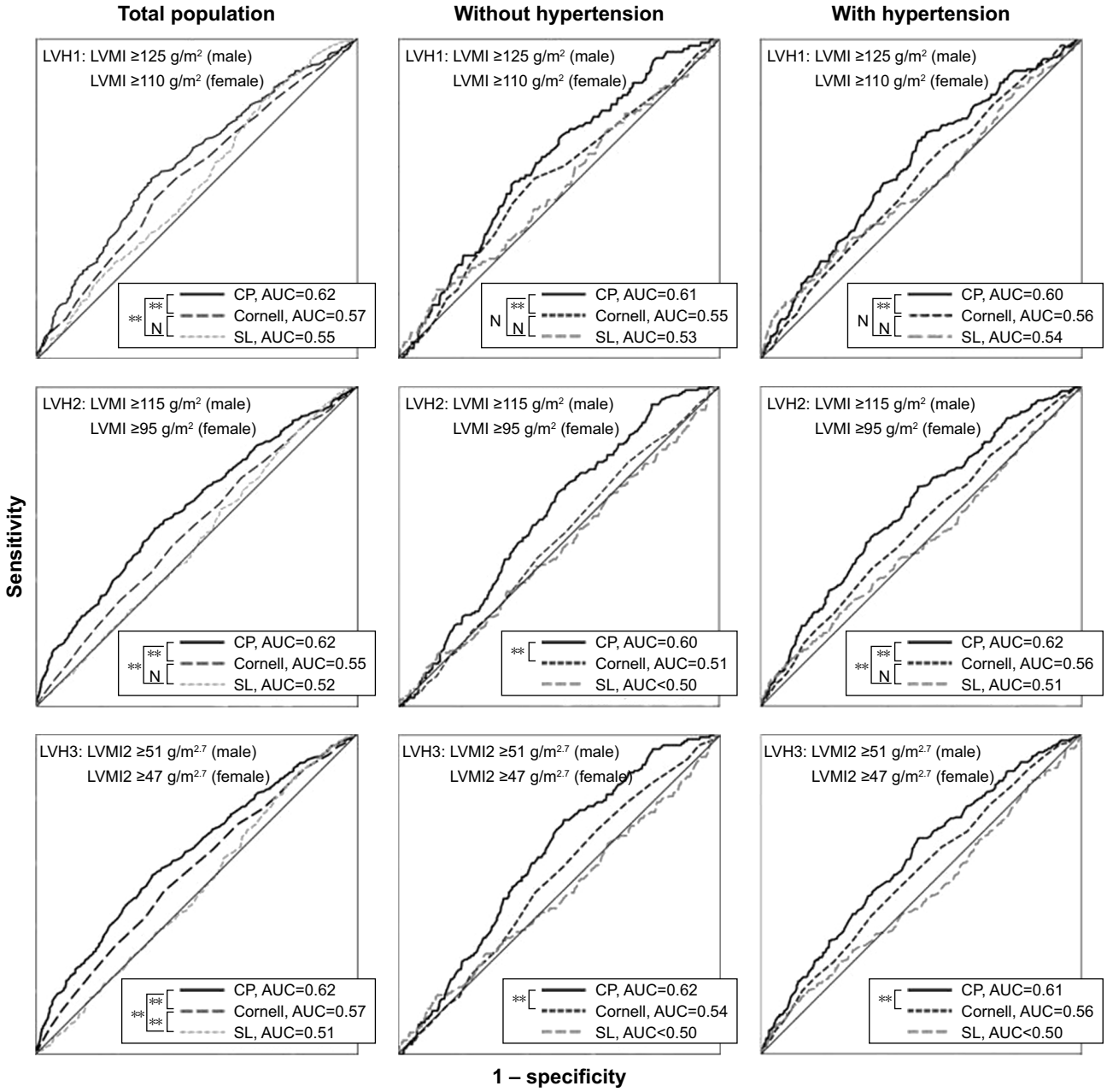


Figure 1 ROC curve with three electrocardiographic criteria for detecting LVH1, LVH2, and LVH3, the ROC curve for defining LVH1 using LVM indexed for BSA (LVMI) ≥125 g/m² in males and ≥110 g/m² in females; the ROC curve for defining LVH2 using LVM indexed for BSA (LVMI) ≥115 g/m² in males and ≥95 g/m² in females; the ROC curve for defining LVH3 using LVM indexed for BSA (LVMI2) ≥51 g/m$^{2.7}$ in males and ≥47 g/m$^{2.7}$ in females. N indicates $P>0.05$ and **indicates $P<0.01$.
Abbreviations: AUC, area under curve; BSA, body surface area; CP, Cornell Product; LVH, left ventricular hypertrophy; LVM, left ventricular mass; ROC, receiver operating characteristic; SL, Sokolow-Lyon.

the threshold is defined as SV1 + RV5 ≥4.0 mV in males and ≥3.5 mV in females.[26] Comparison of SL-China and SL index is shown in Table 4. Though the discrepancies between the two SL criteria and ECHO were still high ($P<0.01$), SL-China even had larger chi-squared values than commonly used SL index. Over the past 60 years, Chinese clinicians have been keeping faith in the conventional ECG-LVH criterion formed in the 1950s.[26] In addition, a recent investigation by Antikainen et al[27] reported that there is no significant increase in the risk of any cardiovascular events associated with LVH diagnosed by SL index. Moreover, Wong et al[28] and Courand et al[29] once proposed to give up SL criterion as well.

The findings of this study have important clinical implications. The expenditure of LVH diagnosed by ECHO is much greater than by ECG. Besides, ECG is cheaper and more convenient in routine clinical practice than ECHO or

magnetic resonance imaging. Generally, ECHO is used for correct diagnosis of LVH in inpatients rather than to screen LVH in community or outpatients. LVH is a common hypertensive TOD. It has significant association with events related to cardiovascular diseases. Therefore, it is very important to diagnose LVH. As the diagnostic accuracy of the SL criterion is very low, Cornell criterion, especially CP criterion, should be implemented in routine clinical practice. Okin et al successfully applied CP to detect LVH in the LIFE study. Because the algorithm of CP criterion is slightly complex, it is strongly recommended to adapt this algorithm to the inbuilt software, in order to automatically offer those indices to physicians and decision-makers. Considering the differences between LVH electrocardiographic criteria in their ability to detect LV, CP criterion is recommended.

It is noteworthy that the study results are derived from a population-based cross-sectional study. Therefore, we aim at investigating the accuracy of different ECG-based formulas in estimating cardiac hypertrophy rather than the prognostic value of those formulas for predicting future cardiovascular events and mortality. With the ongoing follow-up, the prognostic data will be provided in the near future.

The findings of the present study need to be interpreted within the context of its limitations. First, we only applied conventional echocardiograph to define LVH, without using some novel technologies, such as tissue Doppler imaging or speckle tracking. But our conventional measurements are also widely applied in the routine clinical practice. Second, though some ECG measurements were repeated for some cases with large discrepancies, we did not perform the analysis for the day-to-day variability of measurements.

Conclusion

In summary, by comparing echocardiographic-LVH with ECG-LVH in a community-based cohort, it is indicated that CP criterion performs better than Cornell voltage criterion and SL index. CP may substitute the SL index to detect LVH, particularly in China.

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Author contributions

Original data was provided by Wei Zhang, Yiwu Zhou, Bin Bai, Shikai Yu, Jing Xiong, Chen Chi, Jiadela Teliewubai and Jue Li for this study. Methods and protocol were formulated and designed by Jacques Blacher, Yi Zhang and Yawei Xu. Manuscript was drafted by Wei Zhang and Yiwu Zhou. All authors contributed to data analysis, drafting and revising the article, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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