Blood Pressure

ISSN: 0803-7051 (Print) 1651-1999 (Online) Journal homepage: informahealthcare.com/journals/iblo20

Variability and concordance of Cornell and Sokolow–Lyon electrocardiographic criteria in hypertensive patients

Ernest Vinyoles, Teresa Rodriguez-Blanco, Mariano de la Figuera, Josep M. Colomé, Marta Tafalla, Núria Calbet, M Isabel Fernández-San Martin, Judit García-Alonso, Cristina Murillo & Josep Agudo

To cite this article: Ernest Vinyoles, Teresa Rodriguez-Blanco, Mariano de la Figuera, Josep M. Colomé, Marta Tafalla, Núria Calbet, M Isabel Fernández-San Martin, Judit García-Alonso, Cristina Murillo & Josep Agudo (2012) Variability and concordance of Cornell and Sokolow–Lyon electrocardiographic criteria in hypertensive patients, Blood Pressure, 21:6, 352-359, DOI: 10.3109/08037051.2012.686180

To link to this article: https://doi.org/10.3109/08037051.2012.686180

Published online: 16 May 2012.

Blood Pressure, 2012; 21: 352–359

informa
healthcare

ORIGINAL ARTICLE

Variability and concordance of Cornell and Sokolow–Lyon electrocardiographic criteria in hypertensive patients

ERNEST VINYOLES[1], TERESA RODRIGUEZ-BLANCO[2], MARIANO DE LA FIGUERA[3], JOSEP M. COLOMÉ[1], MARTA TAFALLA[1], NÚRIA CALBET[1], M ISABEL FERNÁNDEZ-SAN MARTIN[4], JUDIT GARCÍA-ALONSO[1], CRISTINA MURILLO[1] & JOSEP AGUDO[1]

[1]*La Mina Primary Care Center, University of Barcelona, CIBER Fisiopatologia de la Obesidad y Nutricion (CIBEROBN, Instituto de Salud Carlos III), Barcelona,* [2]*Primary Care Research Institute (IDIAP Jordi Gol) and research associate, Autonomous University of Barcelona (UAB), Barcelona,* [3]*Sardenya Primary Care Center, Barcelona, and* [4]*Barcelona Primary Care Catchment Area, Catalan Health Institute*

Abstract

Aim. To assess the variability and concordance of left ventricular hypertrophy electrocardiographic (LVH-ECG) criteria. *Methods and Results.* Convenience sampling of hypertensive subjects without coronary disease or bundle branch blocks. Two electrocardiograms (ECGs) were performed on each patient. Two investigators carried out two blind-readings of each ECG (Cornell and Sokolow–Lyon criteria). The between-rater and within-rater reliability were assessed (intraclass correlation coefficient, ICC). Poor concordance was defined: mean voltage difference between both ECGs > 2 mm; 824 ECG readings were performed in 103 subjects (58.3% females), aged 66.8 ± 8.8 years, mean blood pressure 141 ± 15.10/78 ± 9.0 mmHg. The between-rater ICCs of the baseline ECG were 0.97(95% CI 0.96–0.98) and 0.98 (95% CI 0.97–0.99) for Cornell and Sokolow–Lyon criteria, respectively. Poor concordance was found in 39.8% and in 41.7% of the cases for Cornell and Sokolow–Lyon criteria, respectively. Systolic blood pressure was found to be significant and positively associated with both criteria. Elderly hypertensive subjects, with higher ECG voltages and lower pulse pressure presented poor concordance of Cornell criteria. *Conclusions.* The between-rater and within-rater reliability of Cornell and Sokolow–Lyon criteria is minimal. Approximately 40% of hypertensive subjects presented poor concordance in a second ECG. Older patients with lower pulse pressure and higher baseline voltages presented poorer reproducibility of LVH-ECG criteria.

Key Words: *electrocardiographic variability, hypertension, left ventricular hypertrophy*

Introduction

Left ventricular hypertrophy (LVH) is an independent cardiovascular risk factor associated with subclinical atherosclerosis (1) and other complications such as ischemic heart disease, arrhythmias (particularly ventricular ectopy, but also atrial fibrillation), heart failure, cerebrovascular disease (2) and sudden death. In addition, LVH in hypertensive patients is indicative of organ involvement (3,4) and its presence and progression is independently associated with increased cardiovascular morbidity and mortality (5–7).

When assessing the cardiovascular risk of hypertensive patients, based on Clinical Practice Guidelines on Hypertension, patients with LVH are considered at high risk. At present, the electrocardiograms (ECGs) are systematically employed in the diagnostic evaluation and follow-up of hypertensive patients because of its accessibility and low cost (8). Compared with echocardiography, ECG has a low sensitivity for detecting LVH, which varies between 8% and el 41%, depending on the criteria used. In contrast, its specificity is over 90% (9). On the other hand, LVH ECG voltage criteria constitute a continuous risk variable that can also be used to monitor the clinical course and progression of hypertensive patients. Generally, the higher the voltage, the higher the cardiovascular

Correspondence: Ernest Vinyoles, CAP La Mina, Carrer Mar s/n, 08930-Sant Adrià de Besòs, Barcelona, Spain. Tel: +34 933 811 593. Fax: +34 933 812 141. E-mail: 23561evb@comb.cat

(Received 12 January 2012; accepted 29 March 2012)

ISSN 0803-7051 print/ISSN 1651-1999 online
DOI: 10.3109/08037051.2012.686180

risk. Moreover, the ECG regression of LVH decreases the cardiovascular risk, independently from other risk factors (10–12).

As in all diagnostic tests, ECG shows a variability that has been long analyzed in the past (13). Such variability is not only dependent on technical factors (electrode placement (14), posture or the actual reading and interpretation of the ECG) but also on biological factors, such as gender, body mass index (BMI), age, skin preparation or respiratory rate (15,16). Specifically, the variability of ECG voltage criteria in LVH should be carefully considered when managing hypertensive patients, especially if such voltage were so high that it considerably decreased the diagnostic reproducibility of the ECG.

The objective of the study was to assess, under standard clinical practice conditions, the variability of Cornell (17) and Sokolow–Lyon (18) ECG voltage criteria in hypertensive patients and to determine which variables are associated with poor concordance of both criteria in two ECGs performed on the same patient.

Subjects and methods

This is a diagnostic intervention study carried out in an urban health center composed of 11 primary care teams, with a catchment adult population of 11,373 patients and a 26.73% proportion of hypertensive patients.

The design and conductance of the study were approved by the IDIAP (Institute for Research in Primary Care) Jordi Gol.

Eleven general practitioners included hypertensive patients aged 18 and over, who had been selected using the convenience sampling method and from whom prior informed consent had been obtained. Patients who required shaving prior to undergoing the ECG, patients with complete right or left bundle branch block, patients with pacemakers, atrial fibrillation, pre-excitation syndromes, and patients with a past history of coronary disease (myocardial infarction, angina), as well as hypertensive patients who had been attended to at the center's emergency department or at home, were excluded from the study. The recruitment period was from July 2007 to November 2008.

Each patient had two 12-lead ECGs (25 mm/s, 1 mV/cm) with the same electrocardiograph device (Cardioline Delta 3 plus), 10 or less days apart. The minimum interval between recordings was 1 day. During this time, antihypertensive therapy was not changed. The two ECGs were randomly performed by 13 experienced nurses. Subsequent to this, two experienced physicians (MF and EV, raters) randomly performed two conventional blind readings of each ECG on different days. Voltages were determined by visual estimation with a precision to the nearest 1 mm. By doing this, each patient had a total of four readings of each of his or her ECGs. Therefore, our data structure presented a cross-classification of ECGs and physicians who made the readings. The following parameters were recorded at the baseline visit: weight, waist circumference and blood pressure taken with the patient in a decubitus position (mean of two consecutive measurements taken under baseline conditions, using the automatic validated sphygmomanometer Omron 705 IT (19) and an arm cuff for obese patients, when necessary).

One hundred and twenty-eight patients were recruited. Of these, seven were excluded due to right bundle branch block and 18 did not keep their appointment for the second ECG. The final analysis was performed on 103 patients and 824 ECG readings.

The variables analyzed included gender, age, BMI, waist circumference, heart rate, arterial blood pressure, a diagnosis of diabetes mellitus (defined as patients with two or more fasting glycemia episodes ≥ 126 mg/dl, based on criteria from the American Diabetes Association (20)), hypercholesterolemia (total cholesterol >250 mg/dl, or low-density lipoprotein-cholesterol >155 mg/dl, or high-density lipoprotein-cholesterol <40 mg/dl in males or <48 mg/dl in women, or the use of lipid lowering drugs (21)), diagnosis of active smoking (defined as a regular daily consumption of any type of tobacco), associated cardiovascular disease (cerebrovascular accident (stroke), chronic renal failure [defined by the estimation of glomerular filtration rate according to Levey's simplified formula, MDRD <60 ml/min] (22), peripheral artery disease or heart failure without coronary disease and antihypertensive therapy. Cornell (males: RaVL + SV3 >2.8 mV; females: RaVL + SV3 >2.0 mV) and Sokolow–Lyon (SV1 + RV5 o V6 >3.5 mV) indexes were defined. Based in our clinical experience, we decided to establish "poor concordance" when the difference in voltage between the baseline and the final ECG was >2 mm, in absolute value in both, the Cornell Index or the Sokolow–Lyon Index (in our opinion differences >2 mm could be clinically relevant because voltage values could regress at least 2 mm a year during antihypertensive therapy (23)). The value of each ECG was calculated based on all readings.

Statistical analysis

Descriptive statistics are presented as means (standard deviation, SD) or as a number (percentage).

The between-rater and within-rater reliabilities were assessed by means of the intraclass correlation coefficient (ICC) (24). Inter-ECG reliability was estimated using the ICC and the paired *t*-test.

The Bland–Altman method and Lin's coefficient were used to determine reproducibility of ECG (25,26).

The coefficients of variation (CV) were used to assess variability between ECG measurements. CV was calculated as the SD of differences between

paired measurements divided by the average value of the means for each set of repeat measurements and quoted as a percentage.

As data were non-hierarchical, cross-classified multilevel linear modeling was employed to assess the associations between patient-level variables and Cornell and Sokolow–Lyon criteria and to investigate the variability of these criteria at rater, ECG and patient level. Rater, ECG and patient were considered random parameters (27). Both models were estimated using full maximum likelihood. The proportion of variance accounted for at each level was calculated with the intraclass correlation coefficient.

The following variables were considered in the initial models: gender (female as reference), age, BMI, blood pressure, diabetes mellitus, hypercholesterolemia, active smoking habit. Age, gender BMI and diabetes were judged epidemiologically as relevant variables, and were included in all the final models.

A logistic regression model was performed in order to assess the factors associated with poor concordance based on Cornell and Sokolow–Lyon criteria. The above variables, as well as Cornell and Sokolow–Lyon baseline voltage values, were considered in the initial models. Age, gender and diabetes were judged epidemiologically as relevant variables, and were included in all the final models.

The alternative models were compared using the partial likelihood ratio test and Akaike's information criterion to determine which model provided the best fit for the data.

All results were expressed along with their 95% confidence intervals (CIs). Statistical significance was set at $p < 0.05$ (two-tailed). The analyses were performed using Stata/SE version 11.1 for Windows (StataCorp. LP).

Table I. Sample characteristics ($n = 103$).

Women	60 ± 58.3
Age (years), mean ± SD	66.8 ± 8.8
BMI, kg/m^2	29.9 ± 4.8
SBP/DBP, mmHg	141.6 ± 15.1/78.7 ± 9.0
Heart rate (beats/min), mean ± SD[a]	72.7 ± 11.2
Waist circumference (cm), mean ± SD[a]	101.9 ± 10.5
Diabetes mellitus	24 ± 23.3
Hypercholesterolemia	42 ± 40.8
Smoking	15 ± 14.6
Associated cardiovascular disease	11 ± 10.7
Antihypertensive therapy	96 ± 93.2

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure. Figures are number (percentage) or mean ± standard deviation, SD. [a]Missing data: Waist circumference 11 (10.7%); heart rate: 15 (14.6%).

Results

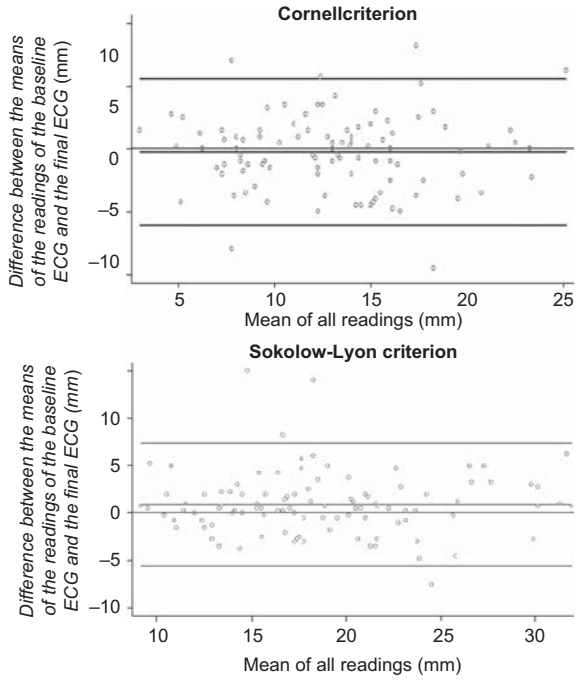
Eight hundred and twenty four ECG readings were performed on 103 hypertensive patients, aged 66.8 ± 8.8 years. Of these, 93.2% were receiving

Table II. Characteristics of electrocardiographic readings.

Number of readings				824
Time between both ECGs (days), mean ± SD				5.58 ± 3.92
ICC, Cornell criterion (within-rater)				
First rater				
Baseline ECG				0.96 (0.94–0.97)
Final ECG				0.98 (0.97–0.98)
Second rater				
Baseline ECG				0.95 (0.93–0.97)
Final ECG				0.92 (0.89–0.95)
ICC, Sokolow–Lyon criteria (within-rater)				
First rater				
Baseline ECG				0.97 (0.96–0.98)
Final ECG				0.99 (0.98–0.99)
Second rater				
Baseline ECG				0.96 (0.94–0.97)
Final ECG				0.98 (0.98–0.99)
ICC, Cornell criteria (between-rater[a])				
Baseline ECG				0,97 (0.96–0.98)
Final ECG				0.97 (0.96–0.98)
ICC, Sokolow–Lyon criteria (between-rater[a])				0.98 (0.97–0.99)
Baseline ECG				
Final ECG				0.99 (0.98–0.99)
	Baseline ECG, mean ± SD of the 4 readings, range	Final ECG, mean ± SD of the 4 readings, range	*p*-value[b]	Mean ± SD of all readings, range
Cornell criteria (mm)	12.91 (4.81), (3–29)	13.16 (4.83), (1–25)	0.381	13.04 (4.89) (1–29)
Sokolow–Lyon criteria (mm)	19.07 (5.74), (8–39)	18.13 (5.75), (6–33)	0.005	18.60 (5.80) (6–39)

Abbreviations: SD: standard deviation; ICC: intraclass correlation coefficient; ECG: electrocardiogram. [a]Degree of agreement between the mean of readings for each rater.

[b]*p*-value was calculated with paired *t*-test, comparing the first with the second ECG.



Concordance measures between baseline ECG and final ECG

	ICC	CV	Lin's coefficient	Mean difference
Cornell	0.81 (0.73–0.87)	13.77%	0.81 (0.74–0.88)	–0.26 (–0.84,0.32)
Sokolow-Lyon	0.84 (0.77–0.89)	9.41%	0.82 (0.76–0.89)	0.94 (0.30,1.59)

ICC: intraclass correlation coefficient, CV: coefficient of variation

The value of each ECG was calculated based on the mean of all its readings.

Figure 1. Bland–Altmann graphs. Difference between the means of the readings of the baseline electrocardiogram (ECG) and the final ECG with regard to the mean of all readings.

pharmacological antihypertensive therapy. Mean blood pressure values were $141.6 \pm 15.1/78.7 \pm 9.0$ mmHg (Table I). Seven patients, all of whom female, met Cornell ECG criteria for LVH (6.5%), and none of the patients met Sokolow–Lyon criteria.

The between-rater and within-rater reliability was very high (ICC $>$ 0.9). Even though the magnitude of the systematic differences between mean Cornell and Sokolow–Lyon voltages were small (Cornell: -0.26 ± 2.97, Sokolow–Lyon: 0.94 ± 3.30, a significant difference was found in the Sokolow–Lyon voltage (Table II, Figure 1). Consistent with ICCs, a lower variation was found in ECGs scores in Sokolow–Lyon voltages compared with Cornell voltages (CV: 13.77% Cornell versus 9.41% Sokolow–Lyon).

Of the total variability in Cornell voltage, 75.4% was among patients, 18.8% between ECGs and 0.6% between raters. The variability for the Sokolow–Lyon voltage was of similar magnitude. In both cases, the variability between raters was small. Systolic blood pressure was significant and positively associated with both criteria, although such association was of little magnitude. In the case of Sokolow–Lyon criteria, having a high BMI was associated with lower voltage (Table III).

Poor concordance was obtained between both ECGs in 39.8% of cases for Cornell criteria and in 41.7% of cases for Sokolow–Lyon criteria.

Hypertensive patients of an older age, with higher voltages in the baseline ECG, lower arterial systolic blood pressure and higher diastolic blood pressure, displayed poorer Cornell concordance between both ECGs. In the case of Sokolow–Lyon criterion, only the highest voltage in the baseline ECG was associated with poorer concordance between ECGs (Table IV).

Discussion

In our sample, the prevalence of LVH, as determined by means of an ECG, was 6.5% (Cornell criteria), and none of the patients fulfilled the LVH criteria according to Sokolow–Lyon. Firstly, the high prevalence of obesity (mean BMI = 29.9 kg/m^2) could be responsible for some attenuation of ECG voltages and hence a lower detection of LVH criteria. On the

Table III. Fixed and random parameters from a cross-classified multilevel linear regression model on Cornell and Sokolow–Lyon criteria (824 electrocardiographic readings).

	Cornell			Sokolow–Lyon		
	Adjusted β[a]	(95% CI)	*p*-value	Adjusted β[a]	(95% CI)	*p*-value
Fixed parameters						
Age, 5 years	0.79	(0.49–1.28)	0.332	0.58	(0.32–1.04)	0.067
Gender (male vs female)	0.53	(−1.24 to 2.30)	0.558	1.03	(−1.01 to 3.07)	0.321
BMI	0.10	(−0.08 to 0.28)	0.281	−0.37	(−0.58 to −0.16)	0.001
Diabetes mellitus	−1.33	(−3.36 to 0.70)	0.200	−1.27	(−3.60 to 1.07)	0.287
SBP	0.07	(0.01 to 0.13)	0.016	0.07	(0.01 to 0.14)	0.035
DBP				−0.04	(−0.17 to 0.08)	0.473
	Variance (SE)	ICC (%)[c]		Variance (SE)	ICC (%)[c]	
Random parameters[b]						
Patient-level	16.45 (2.63)	75.4		21.75 (3.47)	76.9	
ECG-level	4.10 (0.61)	18.8		5.60 (0.81)	19.8	
Rater-level	0.13 (0,06)	0.6		0.08 (0.04)	0.3	
Residual	1.13 (0.07)	5.2		0.86 (0.05)	3.0	

CI, confidence interval; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; SE, standard error; ICC, intraclass correlation coefficient. Final models were adjusted for relevant and significant variables. [a]Adjusted β, regression coefficient of the association between each variable in the model and Cornell or Sokolow–Lyon criteria, controlling for the other variables in the model. [b]Random parameters are multilevel measures of criterion variation. [c]The ICC estimates the proportion of total variance in the Cornell or Sokolow–Lyon criterion that is attributable at each level.

other hand, the fact that they are hypertensive patients from a primary care setting may also explain this result.

This prevalence is slightly lower than that of other studies that also assessed LVH prevalence by means of ECG voltage criteria in samples of hypertensive patients attended to in primary care. In these patients prevalences ranging from 9.8% to 13.7% (28,29) were observed. The real prevalence of LVH in our sample is probably much higher, given the known low sensitivity of ECG to detect this condition (30,31). Despite this, ECG continues to be regarded as a fundamental routine test in the management of hypertensive patients due to its easy accessibility and low cost. In addition, ECG not only provides information on LVH voltage criteria and its clinical course/progression – understood as a continuous variable – but it also provides valuable information on potential arrhythmias, signs of coronary disease, blocks, pre-excitation syndromes or unspecific changes in the ST-T segment. When assessing a hypertensive patient, it is not enough simply to consider the ECG diagnosis of LVH, a quantification of the conditions has to be made (32). Because of this, clinical practice guidelines recommend regular ECG voltage criteria assessment in hypertensive patients, and to monitor the clinical course and progression of these patients over time. A regression of Cornell or Sokolow–Lyon markers implies an improvement in the prognosis of hypertensive patients, independently of the improvement of blood pressure (10–12). Voltage values of LVH are, therefore, continuous variables of cardiovascular risk that are monitored over time, in relation to the control of blood pressure and the pharmacological

Table IV. Factors associated with poor concordance between baseline and final ECG for Cornell and Sokolow–Lyon criteria.

	Cornell Adjusted[a]			Sokolow–Lyon Adjusted[a]		
Logistic regression model ($n = 103$ patients)	OR	(95% CI)	*p*-value	OR	(95% CI)	*p*-value
Sokolow–Lyon baseline ECG	1.20	(1.09–1.32)	<0.001	1.10	(1.01–1.18)	0.020
Cornell baseline ECG	1.11	(1.00–1.24)	0.044			
Age, 5 years	1.49	(1.09–2.05)	0.013	1.15	(0.90–4.47)	0.258
Gender (male vs female)	0.69	(0.26–1.85)	0.463	1.56	(0.66–3.66)	0.308
Diabetes mellitus	0.90	(0.28–2.90)	0.860	0.57	(0.21–1.58)	0.283
SBP	0.94	(0.90–0.98)	0.002			
DBP	1.09	(1.02–1.17)	0.010			

Final models were adjusted for relevant and significant variables. The value of each ECG was calculated based on the mean of all its readings. OR, odds ratio; CI, confidence interval; SBP, systolic blood pressure; DBP, diastolic blood pressure. [a]Adjusted OR represents the association between each variable in the model and Cornell or Sokolow–Lyon criteria, controlling for the other variables in the model. A value greater than 1 indicates positive association with poor concordance.

therapy. The objective is to achieve a reduction of such voltage values, especially in patients who are already presenting high voltages.

The aim of our study was to determine the variability and the concordance of Cornell and Sokolow–Lyon values between the two ECGs performed on the same patient, independently from the ECG diagnosis of LVH. It was observed that in about 40% of the cases there is a poor concordance of LVH voltage criteria between two consecutive ECGs, performed 10 days or less apart. This poor concordance cannot be attributed to the characteristics of the two raters, given that in all cases, the between-rater and within-rater reliability was excellent and the percentage of variability in both criteria due to the raters of the multilevel model was virtually nil. In addition, the study was designed so that its results could be extrapolated to routine clinical practice. As a result, 13 different nurses, with extensive experience in the performance of ECG, were the ones in charge of doing the ECGs. Hence, part of the poor concordance between baseline and final ECG results could be simply owed to the performance of the ECG, i.e. to the usual or standard variability seen in the placement of the electrodes in real clinical practice (about 19% of variability in the criteria was owed to the ECG characteristics). When comparing both criteria (Cornell and Sokolow–Lyon), we observe that there is poor concordance in the Sokolow–Lyon criteria, which is, to a certain extent, understandable, as these criteria are dependent on the localization of precordial electrodes (V1 and V5–V6). In contrast, Cornell criteria are not only dependent on the precordial V3 electrode but on an aVL one, the placement of which would present less variability since it is not a precordial electrode. However, the study design cannot reach the conclusion that the standard variability of electrodes placement is the main responsible of the ECG variability. On the other hand, the variability in the location of the electrodes would not appear to be sufficient to explain fully the poor concordance observed between both ECGs. About 75% of the variability in the scores of both criteria was caused by the patient. Therefore, there may be other characteristics that we have not studied and that pertain to the actual patient, such as possible changes in the skin's electrical conductivity or the actual postural, mechanical or electrophysiological cardiac variability that might explain this variability and poor concordance.

As in the majority of tests in medicine, our results confirm that ECG voltage criteria also bear a non-controllable variability component in real practice, as already described before. One study found variabilities slightly higher than ours, which had only been estimated by means of the variation coefficient: between 18.5% (Sokolow–Lyon) and 24.8% (Cornell) (33). However, other authors describe a variation coefficient for Sokolow–Lyon criteria of 10%, which is very similar to that found in our study (9.4%) (34). Moreover, the reclassification of the presence or absence of LVH in patients varies in the published studies between 3% and 5% (32,35).

Hence, in some instances, it could be advisable not to take diagnostic or therapeutic decisions based solely on one single ECG. There appears to be a group of hypertensive patients with a higher probability of presenting poorer concordance of Cornell or Sokolow–Lyon criteria in two different ECGs. This corresponds to the group of hypertensive patients with elevated voltage values, especially if they are at the borderline of the diagnostic cut-off point for LVH. It appears that in hypertensive patients of an older age, with lower pulse pressures and with elevated voltages in a first ECG, the possibility that a second ECG might show a significant variation in Cornell or Sokolow–Lyon criteria should not be disregarded. An alternative to repeating the ECG could be to apply, in these cases and in the initial ECG, the combination of other ECG criteria for LVH, such as for instance isolated voltage of the R wave in lead aVL $\geq$ 5.7 mm (36). Another option would be to consider the addition of alterations of the terminal segment of the ECG in left ventricular strain patterns and the presence of a negative component of the P wave (which is usually seen in leads DII and V1) (37). These would be ways in which diagnostic sensitivity could be improved.

One of the limitations of the study is the low prevalence of ECG LVH. We do not know if the results would have changed with a sample of hypertensive patients with a higher prevalence of ECG LVH criteria. This could be an interesting aim of future research.

The design of our study does not allow relating neither the variability nor the concordance of LVH ECG criteria to its diagnostic echocardiographic confirmation. However, we can confirm that the variability and electrographic concordance levels of routine clinical practice would call for, in some instances, an additional ECG or for the application of a combination of ECG criteria before making clinical or therapeutic decisions. On the other hand, we should consider, in some cases, ECG changes that occur over time and not to systematically attribute these changes to either a good or poor clinical course of the particular hypertensive patient.

Acknowledgements

The present study was possible thanks to the grant: [1r Ajut per al desenvolupament de projectes de recerca, 2008. Institut Català de la Salut. IDIAP Universitari Jordi Gol.]

Conflict of interest: The authors declare no conflict of interest.

References

1. Mehta SK, Rame JE, Khera A, Murphy SA, Canham RM, Peshock RM, et al. Left ventricular hypertrophy, subclinical atherosclerosis, and inflammation. Hypertension. 2007;49: 1385–1391.
2. Fox ER, Alnabhan N, Penman AD, Butler KR, Taylor HA Jr, Skelton TN, et al. Echocardiographic left ventricular mass index predicts incident stroke in African Americans: Atherosclerosis Risk in Communities (ARIC) Study. Stroke. 2007; 38:2686–2691.
3. Barrios V, Escobar C, Calderón A, Echarri R, González-Pedel V, Ruilope LM, on behalf of the CONTROLRISK Investigators. Cardiovascular risk profile and risk stratification of the hypertensive population attended by general practitioners and specialists in Spain. The CONTROLRISK study. J Hum Hypertens. 2007;21:479–85.
4. Vakili BA, Okin PM, Devereux RB. Prognostic implications of left ventricular hypertrophy. Am Heart J. 2001;141: 334–341.
5. Levy D, Salomon M, D'Agostino RB, Belanger AJ, Kannel WB. Prognostic implications of baseline electrocardiographic features and their serial changes in subjects with left ventricular hypertrophy. Circulation. 1994;90:1786–1793.
6. Verdecchia P, Reboldi G, Angeli F, Avanzini F, de Simone G, Pede S, et al.; on behalf of the HEART Survey. Prognostic value of serial electrocardiographic voltage and repolarization changes in essential. hypertension: The HEART Survey Study. Am J Hypertens. 2007;20:997–1004.
7. Bombelli M, Facchetti R, Carugo S, Madotto F, Arenare F, Quarti-Trevano F, et al. Left ventricular hypertrophy increases cardiovascular risk independently of in-office and out-of-office blood pressure values. J Hypertens. 2009;27:2458–2464.
8. The Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). 2007 Guidelines for the management of arterial hypertension. J Hypertens. 2007; 25:1105–1187.
9. 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;335:711–719.
10. Mathew J, Sleight P, Lonn E, Johnstone D, Pogue J, Yi Q, et al.; for the Heart Outcomes Prevention Evaluation (HOPE) Investigators. Reduction of cardiovascular risk by regression of electrocardiographic markers of left ventricular hypertrophy by the angiotensin-converting enzyme inhibitor ramipril. Circulation. 2001;104:1615–1621.
11. Wachtell K, Okin PM, Olsen MH, Dahlöf B, Devereux RB, Ibsen H, et al. Regression of electrocardiographic left ventricular hypertrophy during antihypertensive therapy and reduction in sudden cardiac death: The LIFE Study. Circulation. 2007; 116:700–705.
12. Okin PM, Devereux RB, Harris KE, Jern S, Kjeldsen SE, Julius S, et al.; LIFE Study Investigators. Regression of electrocardiographic left ventricular hypertrophy is associated with less hospitalization for heart failure in hypertensive patients. Ann Intern Med. 2007;147:311–319.
13. Simonson E. Keys A. Repeat variation of electrocardiogram, blood pressure, and blood cholesterol within one hour and six months. Br Heart J. 1970;32:660–664.
14. Angeli F, Verdecchia P, Angeli E, Poeta F, Sardone M, Bentivoglio M, et al. Day-to-day variability of electrocardiographic diagnosis of left ventricular hypertrophy in hypertensive patients. Influence of electrode placement. J Cardiovasc Med. 2006;7:812–816.
15. Abergel E, Tase M, Menard J, Chatellier G. Influence of obesity on the diagnostic value of electrocardiographic criteria for detecting left ventricular hypertrophy. Am J Cardiol. 1996; 77:739–744.
16. Schijvenaars BJA, van Herpen G, Kors JA. Intraindividual variability in electrocardiograms. J Electrocardiol. 2008;41: 190–196.
17. Casale PN, Devereux RB, Alonso DR, Campo E, Kligfield P. Improved gender-specific criteria of left ventricular hypertrophy for clinical and computer interpretation of electrocardiograms: Validation with autopsy findings. Circulation. 1987;75:565–572.
18. Sokolow M, Lyon TP. The ventricular complex in left ventricular hypertrophy as obtained by unipolar precordial and limb leads. Am Heart J. 1949;37:161–186.
19. Coleman A, Freeman P, Steel S, Shennan A. Validation of the Omron 705 IT (HEM-759-E) oscillometric blood pressure monitoring device according to the British Hypertension Society Protocol. Blood Press. Monit. 2006;11: 27–33.
20. Executive Summary: Standards of Medical Care in Diabetes – 2011. Diabetes Care. 2011;34:S4–10.
21. Maiques-Galán A, Villar-Álvarez F, Brotons-Cuixart C, Torcal-Laguna J, Orozco-Beltrán D, Navarro-Pérez J, et al.; Grupo de Prevención Cardiovascular del PAPPS. Recomendaciones preventivas cardiovasculares. Aten Primaria. 2007;39 Suppl 3:15–26.
22. National Kidney Foundation. K/DOQI clinical practice guidelines for chronic kidney disease: Evaluation, classification, and stratification. Am J Kidney Dis. 2002;39(2 Suppl 1):S1–266.
23. Okin PM, Devereux RB, Jern S, Kjeldsen SE, Julius S, Nieminen MS et al. Regression of electrocardiographic left ventricular hypertrophy during antihypertensive treatment and the prediction of major cardiovascular events. JAMA. 2004;292:2343–2349.
24. Bartko JJ. The intraclass correlation coefficient as a measure of reliability. Psychol Rep. 1966;19:3–11.
25. Lin L. A concordance correlation coefficient to evaluate reproducibility. Biometrics. 1989;45:255–268.
26. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet. 1986;1:307–310.
27. Raudenbush SW, Bryk AS. Hierarchical linear models: Applications and data analysis methods. 2nd ed. Thousand Oaks, CA/London: Sage Publications, Inc.; 2002.
28. De la Figuera M, Vinyoles E, Queijas M J, Castro S, Díaz de Sarralde B, García R. Incidence of electrocardiographic alterations in arterial hypertension. MINACOR Study. Hipertensión. 2001;18:213–217.
29. Martín-Rioboó E, García Criado E, Pérula De Torres LA, Cea-Calvo L, Anguita Sánchez M, López Granados A, et al.; en representación del Grupo de Hipertensión Arterial de la Sociedad Andaluza de Medicina Familiar y Comunitaria (SAMFyC) y de los investigadores del estudio PREHVIA. Prevalence of left ventricular hypertrophy, atrial fibrillation and cardiovascular disease in hypertensive patients of Andalusia, Spain. PREHVIA study. Med Clin (Barc). 2009;132: 243–250.
30. Woythaler JN, Singer SL, Kwan OL, Meltzer RS, Reubner B, Bommer W, et al. Accuracy of echocardiography versus electrocardiography in detecting left ventricular hypertrophy: Comparison with postmortem mass measurements. J Am Coll Cardiol. 1983;2:305–311.
31. Cabezas M, Comellas A, Gómez JR, López L, Casal H, Carrillo N, et al. Comparison of the sensitivity and specificity of electrocardiographic criteria for left ventricular hypertrophy according to the Romhilt–Estes, Sokolow–Lyon, Cornell and Rodríguez Padial methods. Rev Esp Cardiol. 1997; 50: 31–35.
32. Fragola PV, Colivicchi F, Fabrizi E, Borzi M, Cannata D. Assessment of left ventricular hypertrophy in patients with

essential hypertension. A rational basis for the electrocardiogram. Am J Hypertens. 1993;6:164–169.
33. Farb A, Devereux RB, Kligfield P. Day-to-day variability of voltage measurements used in electrocardiographic criteria for left ventricular hypertrophy. J Am Coll Cardiol. 1990;15:618–623.
34. Van Den Hoogen JPH, Mol WH, Kowsoleea A, Van Ree JW, Thien T, Van Weel C. Reproducibility of electrocardiographic criteria for left ventricular hypertrophy in hypertensive patients in general practice. Eur Heart Journal. 1992;13:1606–1610.
35. McLaughlin SC, Aitchison TC, Macfarlane PW. The value of the coefficient of variation in assessing repeat variation in ECG measurements. Eur Heart J. 1998;19:342–351.
36. Verdecchia P, Angeli F, Cavallini C, Mazzotta G, Repaci S, Pede S, et al. The voltage of R wave in lead aVL improves risk stratification in hypertensive patients without ECG left ventricular hypertrophy. J Hypertens. 2009;27:1697–1704.
37. Hsieh BP, Pham MX, Froelicher VF. Prognostic value of electrocardiographic criteria for left ventricular hypertrophy. Am Heart J. 2005;150:161–167.