International Journal of Cardiology, 28 (1990) 215–221
Elsevier

CARDIO 01100

Electrocardiographic diagnosis of left ventricular hypertrophy in the presence of left bundle branch block: a wasted effort

Pietro Vincenzo Fragola, Camillo Autore, Giancarlo Ruscitti, Antonella Picelli and Dario Cannata

Dipartimento di Medicina Interna, II Università di Roma, Cattedre di Clinica Medica e Semeiotica Medica, Rome, Italy

(Received 6 December 1989; revision accepted 18 March 1990)

Fragola PV, Autore C, Ruscitti G, Picelli A, Cannata D. Electrocardiographic diagnosis of left ventricular hypertrophy in the presence of left bundle branch block: a wasted effort. Int J Cardiol 1990;28:215–221.

We assessed the reliability of multiple electrocardiographic variables for detecting left ventricular hypertrophy in 100 patients (aged 23 to 92 years, mean age 39 ± 14) with complete left bundle branch block and different underlying cardiac diseases. Left ventricular hypertrophy, defined as an echocardiographically evaluated left ventricular mass > 241 g, was present in 66 of the 100 patients. The electrocardiographic parameters with the highest sensitivity were both the Cornell voltage criteria (RaVL + SV3 > 28 mm in men and > 20 mm in women) and the combination of criteria proposed by Kafka (any of these four indexes: RaVL ≥ 11 mm, QRS axis −40° or less, SV1 + RV5 or RV6 ≥ 40 mm, SV2 ≥ 30 mm and SV3 ≥ 25 mm), with a sensitivity of 77%. Both criteria had a very low specificity (32 and 35%, respectively). The high specificities (≥ 88%) of several electrocardiographic criteria were accompanied by ineffective low sensitivities (< 35%). Moreover, the cumulative parameters of Kafka and Cornell voltage criteria achieved a sensitivity of 84 and 89%, respectively, in hypertensive patients and in those with valvar diseases. None of the electrocardiographic indexes tested showed a significative difference in sensitivity when applied in categories of patients with left ventricular hypertrophy and different left ventricular geometry (cavity dilation or concentric hypertrophy). These data indicate that both conventional and recently proposed electrocardiographic criteria for left ventricular hypertrophy in the presence of left bundle branch block poorly recognize an augmented left ventricular mass.

Key words: Electrocardiogram; Echocardiogram; Left bundle branch block; Left ventricular hypertrophy

Introduction

Several studies have demonstrated that anatomic left ventricular hypertrophy is a common finding in patients with left bundle branch block, but disagreement exists as to whether or not the electrocardiogram can be applied for diagnosing left ventricular hypertrophy in these instances [1–13]. Both conventional [1–6] and recently proposed electrocardiographic indexes for left ventricular hypertrophy [7–12] have given conflicting results when tested in patients with left bundle branch block, in both autopsy and echocardiographic studies, and it seems that none of the criteria or

Correspondence to: Pietro Vincenzo Fragola, M.D., Via A. Torlonia 12, 00161, Rome, Italy.

0167-5273/90/$03.50 © 1990 Elsevier Science Publishers B.V. (Biomedical Division)

combination of criteria significantly improve the sensitivity and diagnostic accuracy of the electrocardiogram.

In the present study we evaluated the usefulness of a variety of electrocardiographic criteria for left ventricular hypertrophy in a large series of patients with left bundle branch block using an echocardiographically determined left ventricular mass as the reference standard. We also sought to establish whether the reliability of each electrocardiographic parameter may change when different underlying clinical states and/or left ventricular geometry are considered.

Materials and Methods

Patient population

The study group consists of 100 consecutive hospitalized or out-patients (58 men, 42 women) aged 23 to 92 years (mean 39 ± 14) identified as having complete left bundle branch block on routine electrocardiogram according to the criteria of the Ad Hoc Working Group of the World Health Organization and the International Society and Federation of Cardiology [14], and in whom a technically excellent echocardiogram could be performed within 15 days of the electrocardiogram.

Clinical diagnosis was established by a medical history, complete physical examination, clinical records when available, M-mode and cross-sectional echocardiographic evaluation; cardiac catheterization was performed in 15 undefined cases. Twenty-seven patients were considered to have systemic arterial hypertension, 10 valvar heart disease, 22 coronary arterial disease, 19 dilated cardiomyopathy, 4 hypertrophic cardiomyopathy. Eighteen subjects had no clinical evidence of associated cardiovascular diseases and their left bundle branch block was judged an isolated cardiac abnormality.

Electrocardiographic analysis

All patients had a satisfactory 12-lead electrocardiogram correctly standardized (paper speed 25 mm/sec; sensitivity 1 mV/10 mm) and recorded using a Hewlett-Packard 4760A Cardiograph. All electrocardiograms were analyzed by two independent investigators without knowledge of the echocardiographic results. Measurements of the deflections were made manually to the nearest millimeter, QRS duration (msec) from any lead and the mean QRS axis in the frontal plane were also calculated (averaged, if necessary). Finally, the presence or absence of a left atrial abnormality was evaluated. The following criteria for left ventricular hypertrophy were then analyzed: the Sokolow-Lyon criteria ($SV1 + RV5$ or $V6 \geq 35$ mm); the "Cornell voltage" criteria ($RaVL + SV3 > 28$ mm in men and > 20 mm in women and $RaVL + SV3 > 35$ mm in men and > 25 mm in women [12,15]; $RI + SIII > 25$ mm; $RaVL > 11$ mm; SV1 or $V2 + RV6 > 40$ mm; RV6 : RV5 voltage ratio ($RV6 > RV5$); Deepest S + tallest R in precordial leads ≥ 40 mm;

Furthermore, the indexes proposed by Klein et al. [7] ($SV2 + RV6 > 45$ mm or the combination of QRS duration ≥ 160 msec and left atrial enlargement) and those proposed by Kafka et al. (8) (any of these four parameters: $RaVL \geq 11$ mm, QRS axis $-40°$ or less, $SV1 + RV5$ or $V6 \geq 40$ mm, $SV2 \geq 30$ mm and $SV3 \geq 25$ mm) were tested in all cases.

Echocardiography

All subjects were studied using cross-sectional M-mode echocardiograms from short-axis view with corrected angulation of short-axis plane defined in long-axis view [16]. Measurements techniques were consistent with the American Society of Echocardiography Convention using leading edge to leading edge methodology [17]. Measurements of left ventricular end-diastolic internal dimension (LVID), posterior wall thickness (PWT), interventricular septum tickness (IVST) were made during the expiratory phase by two independent observers; differences were resolved by joint review. Relative wall thickness (Th/r) was evaluated using the formula:

$$(IVST + PWT)/LVID$$

Because the methods for measuring the echocardiograms were consistent with the recommendations of the American Society of Echocardiography, the corrected formula: left ventricular mass

$$(g) = 0.80\{1.04 \times [(IVST + LVID + PWT)^3 - LVID^3]\} + 0.6,$$

described by Devereux et al. [18] was used to calculate left ventricular mass. Left ventricular hypertrophy was considered a echocardiographic left ventricular mass (or mass index) > two standard deviations of the mean of a group of 54 subjects (our healthy reference group) providing the normal values of our laboratory (162 ± 39.5 g or 94 ± 13 g/m^2). Accordingly, patients were considered to have left ventricular hypertrophy when the left ventricular mass was > 241 g or > 120 g/m^2. Moreover, since electrocardiographic voltages have been known to be dependent on changes in cardiac volume size and shape, we compared the sensitivity of the different electrocardiographic criteria in patients with left ventricular hypertrophy of concentric type (left ventricular mass greater than 241 g and relative wall thickness > 0.55, excluding patients with hypertrophic cardiomyopathy) and left ventricular hypertrophy with cavity dilation (internal diameter in diastole > 56 mm).

Statistical analysis

The sensitivity, specificity, positive predictive value and accuracy of each electrocardiographic criteria in diagnosing left ventricular hypertrophy were calculated by standard formulas [19].

Results

The clinical diagnoses of the 100 patients with left bundle branch block are listed in Table 1; the overall incidence of echocardiographically evaluated left ventricular hypertrophy was 66%. The sensitivity, specificity, positive predictive value and accuracy of each electrocardiographic index used in diagnosing left ventricular hypertrophy are given in Table 2. Only the Cornell voltage criteria (RaVL + SV3 > 28 mm in men and > 20 mm in women) showed, as a single parameter, a good sensitivity (77%) although had a low specificity (32%); its diagnostic accuracy was 62%. The combination of the four criteria proposed by Kafka et al. [8] gave similar results (sensitivity = 77%; specificity = 35%; accuracy = 63%). The high specificity (≥ 88%) of several electrocardiographic indexes was accompanied by an ineffective low sensitivity (< 35%).

TABLE 1

Clinical diagnosis of patients (pts) with and without left ventricular hypertrophy (LVH) at echocardiogram.

Diagnosis	No. of pts	LVH	Echo mass (g)	No LVH	Echo mass (g)
Systemic arterial hypertension	27	20	range 243–380 mean 296–47.7	7	range 149–210 mean 179 ± 26.7
Valvar heart disease	10	9	range 243–487 mean 367 ± 95.6	1	178
Coronary arterial disease	22	14	range 245–557 mean 323.4 ± 89.1	8	range 135–217 mean 186 ± 26.7
Dilated cardiomyopathy	19	18	range 279–500 mean 381 ± 68.3	1	225
Hypertrophic cardiomyopathy	4	4	range 374–551 mean 449.7 ± 78	0	–
No detectable cardiovascular disease	18	1	274	17	range 120–230 mean 174.8 ± 29.6
Total	100	66	range 243–557 mean 343.4 ± 84.7	34	range 120–230 mean 180 ± 28

TABLE 2

Sensitivity (Sn), specificity (Sp), positive predictive value (Ppv) and accuracy (Acc) of ECG criteria for left ventricular hypertrophy.

	Men		Women		All			
	Sn (%)	Sp (%)	Sn (%)	Sp (%)	Sn (%)	Sp (%)	Ppv (%)	Acc (%)
SV1 + RV5/V6 ≥ 35 mm	31	88	33	69	32	88	84	51
SV3 + RaVL (12) > 28 mm in men > 20 mm in women	64	44	100	22	77	32	69	62
SV3 + RaVL (15) > 35 mm in men > 25 mm in women	33	69	83	39	52	53	68	52
RI + SIII > 25 mm	12	94	17	100	14	97	90	42
RaVL > 11 mm	12	94	29	94	18	94	86	44
SV1/SV2 + RV6 > 40 mm	48	81	54	72	50	77	80	59
RV6 > RV5	62	13	96	17	74	15	63	54
Deepest S + tallest R in precordial leads ≥ 40 mm	27	100	46	94	35	97	96	56
QRS duration ≥ 160 msec	31	100	8	89	23	94	88	47
Left atrial abnormality	19	88	17	78	18	82	71	40
Klein [7]	19	100	21	100	20	100	100	47
Kafka [8]	69	38	92	33	77	35	70	63

When the electrocardiographic criteria were tested in subsets of patients with different underlying cardiac diseases (Table 3) a slight increase in sensitivity was observed for the cumulative parameters of Kafka et al. [8], the RV6 > RV5 index and Cornell voltage criteria [12] who all achieved a value of 84% in hypertensive patients and a value of 89% in those affected by valvar heart disease. The sensitivity of the remaining criteria, although improved in some instances, never achieved a satisfactory value (Table 3). Between the 66 patients with left ventricular hypertrophy, 40 had a left ventricular dilation and 10 a left ventricular hypertrophy of concentric type at echo; when we compared the effectiveness of the electrocardiographic indexes of left ventricular hypertrophy in these two categories of patients we found a significative difference in sensitivity only for the Cornell voltage criteria [12] who demonstrated a value of 90% in patients with left ventricular hypertrophy of concentric type versus 30% in those with cavity dilation ($P < 0.001$).

Discussion

Most currently employed electrocardiographic criteria in the assessment of left ventricular hypertrophy have generally demonstrated low sensitivity and limited utility in the presence of left bundle branch block [1–13]. Thus, several studies proposed the use of various new voltage electrocardiographic indexes [7–12] as individual parameters or in relatively complex formula, demonstrating an improvement in sensitivity without adverse effects on the specificity in estimating left ventricular hypertrophy. This was not true in our study. The results of our series revealed that neither voltage nor non-voltage criteria were valid in the face of left bundle branch block in recognizing those patients with an augmented left ventricular mass. The best voltage criteria were those proposed by Casale et al. [12] and Kafka and colleagues [8] that achieved a sensitivity of 77% but a very low specificity and diagnostic accuracy. Furthermore, when these two indexes were applied in

TABLE 3

Sensitivity % (Sn) and specificity % (Sp) of the ECG criteria for left ventricular hypertrophy in the different clinical settings

		HP	VD	CAD	DC	HCM	NDC
SV1 + RV5/V6 ≥ 35 mm	Sn	11	33	33	44	75	0
	Sp	86	100	63	100	NV	100
SV3 + RaVL > 28 mm men SV3 + RaVL > 20 mm women	Sn	84	89	73	78	25	100
	Sp	43	0	25	100	NV	29
SV3 + RaVL > 35 mm men SV3 + RaVL > 25 mm women	Sn	53	89	47	44	25	0
	Sp	57	0	50	100	NV	53
RI + SIII > 25 mm	Sn	11	33	0	17	25	0
	Sp	100	100	100	100	NV	94
RaVL > 11 mm	Sn	21	33	7	17	25	0
	Sp	100	100	88	100	NV	94
SV1/V2 + RV6 > 40 mm	Sn	42	67	47	50	75	0
	Sp	86	100	63	100	NV	77
RV6 > RV5	Sn	84	89	67	72	25	100
	Sp	14	0	25	100	NV	6
Deepest S + tallest R in precordial leads ≥ 40 mm	Sn	37	33	27	44	25	0
	Sp	86	100	100	100	NV	100
QRS ≥ 160 msec	Sn	11	33	27	22	50	0
	Sp	100	100	88	100	100	94
Atrial enlargement	Sn	16	33	13	22	0	0
	Sp	71	100	88	100	NV	82
Klein [7]	Sn	0	44	13	28	50	0
	Sp	100	100	100	100	NV	100
Kafka [8]	Sn	84	89	73	78	50	100
	Sp	71	100	13	100	NV	24

HP = hypertension; VD = valvar disease; CAD = coronary arterial disease; DC = dilated cardiomyopathy; HCM = hypertrophic cardiomyopathy; NDC = no evidence of cardiovascular disease. NV = not valuable.

subsets of patients with different cardiovascular diseases, a slight increase in sensitivity was observed only in systemic hypertension and valvar diseases, likely not related to the higher prevalence of left ventricular hypertrophy in these two categories of patients. In fact, the same indexes showed even a lower sensitivity when tested in other clinical states, like dilated or hypertrophic cardiomyopathy with nearly 100% prevalence of left ventricular hypertrophy (Table 1).

In our study, as in others [10], QRS duration > 155 msec, predicted left ventricular hypertrophy in a good proportion of patients (positive predictive value = 88%). We had better results with some voltage criteria (Table 2).

Regarding the suggested influence of left ventricular geometry (wall thickness or cavity volume predominance in the hypertrophic ventricle) on electrocardiographic voltages [20,21], from our data we are unable to determine which was the anatomic variable that plays a greater role in augmenting potentials; however, the RaVL + SV3 index showed a higher sensitivity when tested in subjects with left ventricular hypertrophy of concentric type.

Left ventricular hypertrophy has been established as a predictor of major cardiovascular events [22–25], especially in patients with left bundle branch block: hence, its recognition and quantification has a great relevance in diagnostic assessment and in deciding an appropriate therapeutic intervention. In this regard the unaffectiveness of electrocardiogram in detecting left ventricular hypertrophy, mainly related to a low sensitivity, requires an echocardiographic evaluation. In our study the poor performance of the various electrocardiographic criteria for left ventricular hypertrophy seems to be affected by factors other than the prevalence of left ventricular hypertrophy of the sample population.

Acknowledgment

We express our gratitude to Dr. Anna Maria Maccari for excellent technical assistance and data analysis.

References

1 Scott RC, Norris RJ. Electrocardiographic-pathologic correlation study of left ventricular hypertrophy in the presence of left bundle branch block. Circulation 1959;20:766–767.

2 Petersen GV, Tikoff G. Left bundle branch block and left ventricular hypertrophy: electrocardiographic-pathologic correlations. Chest 1971;59:174–177.

3 Cokkinos DV, Demopoulos JN, Heimonas ET, Hallios C, Papazoglou N, Vorides EM. Electrocardiographic criteria of left ventricular hypertrophy in left bundle branch block. Br Heart J 1978;40:320–324.

4 Zmyslinski RW, Richeson JF, Akiyama T. Left ventricular hypertrophy in presence of complete left bundle branch block. Br Heart J 1980;43:170–175.

5 Havelda CJ, Sohi GS, Flowers NC, Horan LG. The pathologic correlates of the electrocardiogram: complete left bundle branch-block. Circulation 1982;65:445–451.

6 Noble LM, Humphrey SB, Monaghan GB. Left ventricular hypertrophy in left bundle branch block. J Electrocardiol. 1984;17:157–160.

7 Klein RC, Vera Z, De Maria AN, Mason DT. Electrocardiographic diagnosis of left ventricular hypertrophy in the presence of left bundle branch block. Am Heart J 1984;108:502–506.

8 Kafka H, Burgraff GW, Milliken JA. Electrocardiographic diagnosis of left ventricular hypertrophy in the presence of left bundle branch block: an echocardiographic study. Am J Cardiol 1985;55:103–106.

9 Fournier C, Blondeau M, Picandet B. Bloc complet de la branche gauche et diagnostic electrocardiographique de l'hypertrophie ventriculaire gauche. Arch Mal Coeur 1986; 79:184–190.

10 Haskell RJ, Ginzton LE, Laks MN. Electrocardiographic diagnosis of left ventricular hypertrophy in the presence of left bundle-branch block. J Electrocardiol 1987;20:227–232.

11 Koito H, Spodick D. Accuracy of the RV6 : RV5 voltage ratio for increased left ventricular mass. Am J Cardiol 1988;62:985–987.

12 Casale PN, Devereux RB, Alonso DR, Campo E, Kligfield P. Improved sex-specific criteria of left ventricular hypertrophy for clinical and computer interpretation of electrocardiograms: validation with autopsy findings. Circulation 1987;75:565–572.

13 Ruscitti G, Fragola PV, Borzi M, Autore C, Maccari AM, Cannata D, Sangiorgi M. Left ventricular hypertrophy in left bundle branch block. Electrocardiographic-echocardiographic correlations. 6th International Congress on Echocardiography, Rome, 23–25 June, 1988.

14 Willems JL, Robles De Medina EO, et al. Criteria for intraventricular conduction disturbances and pre-excitation. J Am Coll Cardiol 1985;5:1261–1275.

15 Casale PN, Devereux RB, Kligfield P, et al. Electrocardiographic detection of left ventricular hypertrophy: development and prospective validation of improved criteria. J Am Coll Cardiol 1985;6:572–580.

16 Devereux RB, Liebson PR, Horan MJ. Recommendations concerning use of echocardiography in hypertensive and general population research. Hypertension 1987;9(suppl. 2):97–104.

17 Sahn DJ, De Maria A, Kisslo J, Weyman A. The Committee on M-mode standardization of the American Society of Echocardiography. Recommendations regarding quantitation on M-mode echocardiography: results of a survey of echocardiographic measurements. Circulation 1978;58: 1072–1083.

18 Devereux RB, Alonso DR, Lutas EM, et al. Echocardiographic assessment of left ventricular hypertrophy: comparison to necropsy findings. Am J Cardiol 1986;57:450–458.

19 Vecchio TJ. Predictive value of a single diagnostic test on unselected population. N Engl J Med 1966;274:1171–1173.

20 Devereux RB, Phillips MC, Casale PN, Eisenberg RR, Kligfield P. Geometric determinants of electrocardiographic left ventricular hypertrophy. Circulation 1983;67:907–911.

21 Antman EM, Greene LH, Grossman W. Physiologic determinants of the electrocardiographic diagnosis of left ventricular hypertrophy. Circulation 1979;60:386–396.

22 Kannel WB. Prevalence and natural history of electrocardiographic left ventricular hypertrophy. Am J Med 1983;75(suppl. 3A):4–11.

23 Casale PN, Devereux RE, Milner M, et al. Value of echocardiographic measurements of left ventricular mass in predicting cardiovascular morbid events in hypertensive men. Ann Intern Med 1986;105:173–178.

24 Kreger BE, Cupples LA, Kannel WB. The electrocardiogram in prediction of sudden death: Framingham study experience. Am Heart J 1987;113:377–382.

25 Rautaharju PM, La Croix AZ, Savage DD, et al. Electrocardiographic estimate of left ventricular mass versus radiographic cardiac size and the risk of cardiovascular disease mortality in the epidemiologic follow-up study of the First National Health and Nutrition Examination and Survey. Am Heart J 1987;113:377–382.