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Left ventricular mass and hypertrophy assessment by means of the QRS complex voltage-independent measurements

Maciej Sosnowski*, Barbara Korzeniowska, Michał Tendera

3rd Division of Cardiology, Silesian Medical School, Ziolowa Street 47, 40-635 Katowice, Poland

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Abstract

ECG QRS-complex voltage-based criteria are relatively insensitive for detection of increased left ventricular mass (LVM). We developed and evaluate a new ECG index for LV hypertrophy (LVH) detection regardless of the QRS voltage.

Methods: Study population consisted of 106 patients (73 m, 33 f, aged 60±10 years) with established coronary artery disease (CAD). All patients had LVM assessed echocardiographically and indexed to BSA ($LVMI_{ECHO}$). LVH was diagnosed if $LVMI_{ECHO} > 117$ g/m^2 in men and >104 g/m^2 in women. LV geometry was also determined. Analysed ECG variables, obtained from 12 leads recorded simultaneously, were: the QRS complex duration (QRSd, ms), the average 12-lead time to maximal deflection (TMD, ms), the average 12-lead QRS complex voltage (12QRSV, mV), the average product of 12 lead QRS voltage and duration (12QRSVd, mV ms), Sokolow–Lyon voltage and V–d product (SLV, SLVd), Cornell voltage and V–d product (CV, CVd). A newly developed index, LVM_{ECG}, was calculated, as $LVM_{ECG} = [(2 \times TMD + QRSd/\pi)^3 - (QRSd/\pi)^3] * 0.0001$ (ms^3), and indexed to BSA ($LVMI_{ECG}$, ms^3/m^2).

Results: Means of the QRS voltage-related parameters were similar in patients with LVH and normal LVM. Greater differences existed between both groups when the QRS voltage–duration products were compared. $LVMI_{ECG}$ was most powerful in distinguishing between groups (130±33 LVH vs 91±21 normal LVM, $p < 0.001$). $LVMI_{ECG}$ correlated with $LVMI_{ECHO}$ better ($r = 0.77$, $p < 0.001$) than other indices (r coefficients between 0.24 for SLV and 0.49 for CVd). None of the examined indices allowed for distinction between eccentric and concentric LVH. The new index showed better statistical performance (area under ROC = 0.861) compared to the other indices (AUC range 0.545–0.697, $p < 0.001$ vs $LVMI_{ECG}$). At the specificity level of 92%, the value of $LVMI_{ECG} > 120$ ms^3/m^2 had the sensitivity of 64% for detection of increased LVM. The sensitivities of the other parameters were significantly lower (sensitivity range 18–42%). Relative intra- and interobserver errors and correlation coefficients for $LVMI_{ECG}$ calculation were 0.4% and 1.6% and $r = 0.94$ and 0.98, respectively.

Conclusions: In patients with CAD an assessment of LV mass and detection of hypertrophy using the QRS complex time-dependent index is feasible. The new index correlated well with echocardiographically-determined LVM and showed better statistical performance than indices which include QRS-voltage measurements. The results are promising and warrant further studies to evaluate the utility of the new index as a risk predictor.

Keywords: Left ventricular mass; Left ventricular hypertrophy; Electrocardiography; QRS complex; Echocardiography; Coronary artery disease

1. Introduction

The resting electrocardiogram (ECG) is a simple, non-invasive and widely applicable method, useful for diagnosing of left ventricular hypertrophy (LVH) in different populations [1–5]. Numerous studies have documented electrocardiographic LVH to be a harbinger of greater morbidity and mortality, especially in patients with coronary artery disease [6]. Early observations indicated that in general population the risk attributable to the presence of LVH equals that related to the presence of ECG signs of myocardial infarction [7]. The risk of all-cause mortality associated with LVH on ECG is even greater than that of single or multivessel CAD or reduced left ventricular ejection fraction [1].

* Corresponding author. Tel.: +48 32 252 39 30; fax: +48 32 252 3930.
E-mail address: msos@poczta.onet.pl (M. Sosnowski).

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Different ECG studies have used a variety of criteria to define LVH, conventionally including the QRS complex voltage measurements [4,5,8–16]. For clinical purposes voltage-based ECG criteria, like Sokolow–Lyon or Framingham, have relatively low sensitivity for detection of increased left ventricular mass (LVM) [8,11,13,17]. However, despite their limitations, these indices are still employed in recent studies, especially in hypertensive patients [4,16].

The sensitivity of ECG for LVH detection has been greatly improved by addition of the QRS complex duration (QRSd), either as voltage–duration product and integral, or in combined LVH score systems or multivariate regression equations [17–24]. Nevertheless, factors influencing voltage-related criteria, i.e., age, body weight, lung disease and amount of subcutaneous and pericardial fat, continue to limit their performance [18,25–28].

These factors, however, have no influence on time-dependent measurements of the QRS complex, like QRSd and intrinsic deflection (ID), for which the relationships with left ventricular mass have been documented [17,29–32].

Therefore, we performed this study to develop and evaluate a new ECG index which allows for LVM determination and LVH detection solely from time-related QRS complex measurements, without taking any notice of the QRS voltage.

2. Methods

2.1. Study population

Study population consisted of 106 patients, 73 men and 33 women, at mean age 60±10 years with established coronary artery disease (CAD), who had been examined between November 2003 and May 2004. A diagnosis of CAD was confirmed by either history of myocardial infarction or presence of a significant coronary stenosis on coronary angiography. Patients with non-sinus rhythm, QRS complex duration >120 ms, implanted pacemaker, advanced heart failure or a need for a continuous intravenous therapy or inadequate echocardiograms were not included. Characteristics of the study patients with and without LVH are presented in Table 1.

Table 1
Characteristics of patients with and without LVH on echocardiography

Characteristic	LVH+	LVH−
Number (%)	55 (52)	51 (48)
Age (years)	61±9	58±12
Age ≥ 65 years (%)	22	17
Males (%)	38 (69)	40 (78)
Weight (kg)	81±14	81±12
Body mass index (kg/m^2)	28.2±4.3	27.7±3.8
Obese (>30 kg/m^2, %)	18 (33)	15 (29)
Heart rate (bpm)	74±14	76±13
Systolic blood pressure (mm Hg)	133±18*	126±14
Diastolic blood pressure (mm Hg)	81±8	79±8
History of myocardial infarction (%)	18 (33)	15 (29)
Hypertension (%)	48 (87)***	27 (53)
Diabetes (%)	20 (39)	14 (28)
Hypercholesterolemia (%)	47 (92)*	39 (76)
Current smoking (%)	18 (33)	12 (24)
Stroke/transient Ischemic attack (%)	6 (12)	3 (6)
Coronarography (%)	50 (90)	51 (100)
Coronary stenoses >75%		
1 vessel	14 (28)	18 (36)
2 vessel	18 (36)	21 (42)
≥3 vessels	18 (36)	11 (22)
Coronary interventions	44 (80)	47 (92)
CABG	12 (22)	5 (10)
PTCA+stenting	29 (53)	33 (65)
PTCA alone	2 (4)	4 (8)
CABG+PTCA/stenting	1 (2)	5 (10)
Medications		
Beta-blockers (%)	44 (80)	45 (88)
ACEIs/ARBs (%)	39 (71)	29 (57)
Statins (%)	48 (87)	50 (98)
Calcium antagonists (%)	14 (25)	11 (22)
Diuretics (%)	21 (38)	6 (12)
Acetylsalicylic acid (%)	52 (95)	51 (100)

Abbreviations: LVH—left ventricular hypertrophy, CABG—coronary artery by-pass grafting, PTCA—percutaneous transluminal coronary angioplasty, ACEIs—angiotensin converting enzyme inhibitors, ARBs—angiotensin receptor blockers.
Statistics (Chi-square test): *$p<0.05$, ***$p<0.001$.

2.2. Electrocardiography

Standard 12-lead electrocardiograms (ECGs) were recorded in all patients with a commercially available equipment (GE Medical Systems, CASE v.4.1). The median cardiac cycle complexes were collected automatically and displayed on a screen using the magnifying function with a gain up to 8 cm/1 mV and a paper speed of 200 mm/s. The QRS complex parameters were measured manually with a caliper to the nearest 1 ms and its voltage to the nearest 4 μV. All measurements were performed in accordance with the Common Standards in Electrocardiography Working Party recommendations [33] by an experienced investigator (MS) who had no knowledge of the patients' clinical data and echocardiographic findings. The following ECG variables and indices were obtained from 12 simultaneously recorded leads: the QRS complex duration (QRSd, ms), the average 12-lead time to maximal deflection (TMD, ms), the average 12-lead QRS complex voltage (12QRSV, mV), calculated as a sum of absolute voltages of all deflections within twelve QRS complexes divided by the number of leads, and the average product of 12-lead QRS voltage and duration (12QRSVd, mV ms). Commonly recommended ECG criteria were also calculated: Sokolow–Lyon voltage (SLV, mV) as a sum of the S-wave voltage in V_1 or V_2 leads and the R-wave voltage in V_5 or V_6 (whichever higher), Cornell voltage (CV, mV) as a sum of the R-wave voltage in the lead aVL and the S-wave voltage in the lead V_3. A correction for female gender