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Prevalence of electrocardiographic left ventricular hypertrophy among patients with coronary artery disease and diabetes mellitus

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ABSTRACT

Introduction. Electrocardiography (ECG) is a widely used non-invasive diagnostic method for assessment of patients with cardiovascular diseases. Numerous different electrocardiographic criteria exist for detection of left ventricular hypertrophy (LVH). LVH is an important risk factor in patients with coronary artery disease (CAD) or diabetes mellitus and its presence is associated with increased cardiovascular morbidity and mortality. The aim of this study was to evaluate the prevalence of the most frequently used electrocardiographic left ventricular hypertrophy (ECG-LVH) criteria among patients with CAD and diabetes.

Methods. A cross-sectional, multicenter study was conducted in outpatient clinics across Poland. Family physicians performed physical examinations and collected relevant information about: onset of CAD and diabetes, presence and onset of hypertension, dyslipidemia, heart failure, diabetic complications, history of acute coronary syndrome and pharmacotherapy. In order to detect LVH, we used seven ECG criteria: 1) the Sokolow-Lyon voltage, 2) the Gubner voltage, 3) the criterion of the R wave amplitude on the leads V5–V6 and 4) aVL, 5) the gender specific Cornell voltage and 6) product, and 7) the Romhilt-Estes point score. Centralized manual assessment of the obtained ECG tracings were performed.

Results. We enrolled 1001 patients (48.5% women, 51.5% men, mean age 65 ± 11 years) into the study. At least one ECG-LVH criterion was met in 20.0% (n = 200) of the study participants. The ECG-LVH diagnosis was the most common when using the Romhilt-Estes point score (n = 138; 13.8%). The corresponding prevalence rates for the Cornell voltage, the Cornell product, the R wave amplitude on the lead aVL, the Sokolow-Lyon voltage, the Gubner voltage and the R wave amplitude on the leads V5-V6 criteria were 5.5% (n = 55), 5.2% (n = 52), 3.2% (n = 32), 2.2% (n = 22), 1.9% (n = 19) and 1.3% (n = 13) respectively. Subsequently, the prevalence of the three most frequently used in clinical practice electrocardiographic criteria for LVH (the Sokolow-Lyon voltage, the Cornell voltage and the Romhilt-Estes point score) was analyzed. At least one of them was fulfilled in 185 ECGs. All three criteria at the same time were met only in 5 ECGs (2.7% of 185). Two and only one out of three criteria were fulfilled in 20 (10.8%) and 160 (86.5%) ECGs respectively.

Conclusions. The co-occurrence of all assessed ECG-LVH criteria, including the three most frequently applied in clinical practice, is very low in diabetic CAD patients. The Romhilt-Estes point score identifies the highest number of ECG-LVH cases in this setting. However, it seems reasonable to use routinely several ECG criteria for detection of LVH. Further studies are needed to compare diagnostic values of ECG-LVH criteria with imaging methods and to assess prognostic values of various ECG-LVH criteria.

Key words: electrocardiography, left ventricular hypertrophy, coronary artery disease, diabetes mellitus

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Introduction

Electrocardiography (ECG) is over 100 years old, but due to its simplicity, non-invasiveness, significant prognostic value and wide availability still remains routinely used for assessment of patients with suspected and diagnosed cardiovascular diseases. Numerous different electrocardiographic criteria exist for detection of left ventricular hypertrophy (LVH), but only several methods are used in clinical practice. Electrocardiographic evidence of LVH is a powerful and independent predictor of increased cardiovascular morbidity and mortality [1–6].

LVH often coexists with coronary artery disease (CAD) and diabetes mellitus. Additionally, the latter is considered a major cardiovascular risk factor associated with accelerated atherosclerosis and increased risk of micro- and macroangiopathies in subjects with and without diagnosed CAD [7–11]. As LVH progresses, myocardial oxygen demand increases, which may cause exacerbation of CAD and potentially lead to acute cardiovascular events. Interestingly, several studies have suggested that diabetes may be associated with left ventricular structural and functional abnormalities [12–14]. Diabetic patients exhibit higher left ventricle wall thickness, mass and more concentric geometry than those without diabetes. Importantly, cardiovascular morbidity and mortality increase progressively with left ventricular muscle mass [15–20].

The aim of this study was to evaluate the prevalence of the most frequently used electrocardiographic left ventricular hypertrophy (ECG-LVH) criteria among patients with CAD and diabetes mellitus.

Methods

Study design and conduct

A cross-sectional, multicenter study was conducted among patients with CAD and diabetes by family physicians in primary care centers in Poland in 2009. Inclusion criteria were: 1) previous angiographically proven clinical diagnosis of CAD, 2) previous diagnosis of type 2 diabetes mellitus according to the American Diabetes Association criteria, and 3) provision of informed consent for the study participation, while exclusion criteria included: 1) the presence of ventricular pacing, 2) the presence of left or right bundle branch block, 3) the presence of left anterior or posterior hemiblock, and 4) inability of adequate ECG assessment and interpretation caused by technical reasons. For each patient, a thorough history was taken and detailed physical examination was performed. Blood pressure was measured by a physician with a mercury sphygmomanometer or an automated device in the outpatient clinic in a quiet and relaxed environment, with the subject seated for at least 10 minutes. The average of two measurements was used for the analysis. Collected information from the medical history included: history of hypertension, dyslipidemia, gout, heart failure, diabetic complications (diabetic foot, retinopathy, nephropathy and neuropathy), previous stroke and acute coronary syndrome as well as duration of hypertension, diabetes and CAD. Hypertension was defined as systolic blood pressure $\geq$ 140 mm Hg and/or diastolic blood pressure $\geq$ 90 mm Hg or treatment with anti-hypertensive drugs. Measured laboratory parameters included: fasting plasma glucose, *glycated* hemoglobin (HbA_{1c}), total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol and triglycerides. The aforementioned results were taken from patient documentation when measured within 12 months. Detailed information on participants' pharmacological treatment during the last 6 months was recorded, including the use of metformin, sulfonylurea derivatives, insulin, acetylsalicylic acid, clopidogrel, statins, fibrates, angiotensin-converting enzyme inhibitors, angiotensin II receptor blockers, beta-adrenolytics, diuretics and calcium channel antagonists.

The study protocol was approved by the Local Ethics Committee in accordance with the Declaration of Helsinki.

Electrocardiography

Standard supine 12-lead electrocardiograms were registered at a 25 mm/s speed and 10 mm/mV gain. ECGs were read according to the AHA/ACCF/HRS Recommendations for the Standardization and Interpretation of the Electrocardiogram [21]. Centralized measurements were performed in all ECGs manually, questionable cases were resolved by consensus of experienced cardiologists. In order to detect LVH, we used seven methods, including various voltage criteria and point score system. Electrocardiographic criteria for the LVH diagnosis were as follows: 1) the Sokolow--Lyon voltage — sum of the S wave in lead V1 and the largest R wave in the lead V5 or V6 $\geq$ 3.5 mV [22], 2) the criterion of the R wave amplitude in the lead V5 or V6 $\geq$ 2.6 mV [22], 3) the criterion of the R wave amplitude in the lead aVL $\geq$ 1.1 mV [23], 4) the Gubner voltage — sum of the R wave in the lead I and the S wave in the lead III $\geq$ 2.5 mV [24], 5) the gender specific Cornell voltage — sum of the R wave in the lead aVL and the S wave in the lead V3 $\geq$ 2.0 mV in women and $\geq$ 2.8 mV in men [25], 6) the gender specific Cornell product — sum of the R wave in the lead aVL and the S wave in the lead V3 (for women, added 8 mm), all multiplied by the mean QRS interval, result $\geq$ 2436 mm was considered positive for LVH [26], and 7) the Romhilt and Estes point score [27]. The latter comprises amplitudes of

the R or S waves > 20 mm in the limb leads (1 point) or > 30 mm in precordial leads (1 point), ST-T segment strain pattern in V5 or V6 (3 points, but when using digitalis — it is only 1 point), the P wave amplitude > 1mm and duration > 40 ms in the lead V1 (3 points), QRS electrical axis > –30 degrees (2 points); QRS duration > 90 ms in the lead V6 (1 point) and initial time of the intrinsicoid deflection of the QRS > 50 ms in V5 or V6 (1 point). In the Romhilt-Estes point score, LVH is diagnosed when the score is ≥ 5 points.

We prespecified an additional analysis including the three most frequently applied in clinical practice ECG criteria for detection of LVH — the Sokolow-Lyon voltage, the Cornell voltage and the Romhilt-Estes point score.

Statistical analysis

Results are shown as mean ± standard deviation (SD) for continuous variables and as number and percent for categorical variables. Continuous data were checked for normal distribution by means of Shapiro--Wilk W test. Differences in clinical characteristics between patients with and without ECG-LVH were assessed using the Chi-square test for categorical variables and the Student's t-test for normally distributed continuous variables. The non-parametric Mann-Whitney U test and the ANOVA Kruskal-Wallis test were applied for comparisons of continuous variables whose distribution deviated from normality. Spearman's rank correlation coefficient was used to determine strength of relationship between tested variables. A two-sided difference was considered significant at p < 0.05. The statistical analysis was carried out using the Statistica 9.1 package (StatSoft, Tulsa, OK, USA).

Results

Out of 1116 potentially eligible patients, 1001 subjects (485 women and 516 men) were enrolled into the study. We excluded 115 participants due to: paced rhythm in the assessed ECG (n = 18 cases), the presence of left or right bundle branch block (n = 76) or inability of adequate ECG assessment and interpretation caused by technical reasons (n = 21). The clinical characteristic of the study population is reported in Table 1.

There were 200 patients (20.0%) who met at least one ECG criteria for LVH. In details, we found electrocardiographic evidence of LVH fulfilling at least 1 criterion in 99 women (20.4%) and in 101 men (19.6%). The prevalence of LVH varied widely due to the criteria used. There was no patient fulfilling all seven LVH criteria. The prevalence of LVH was the highest when using the

Romhilt-Estes point score (13.8%) and the lowest when using the criterion of the R wave amplitude in the lead V5 or V6 (1.3%) (Tab. 2).

At least one of the three most frequently used criteria, the Sokolow-Lyon voltage, the Cornell voltage and the Romhilt-Estes point score, was met in 185 patients (18.5% of all 1001 patients), while all three criteria at the same time were fulfilled only in 5 patients (2.7% of 185 patients with at least one of the three above listed criteria). Two out of the three above mentioned criteria at the same time were met in 20 patients (10.8%): the Sokolow-Lyon voltage and the Cornell voltage in 3 patients (1.6%), the Sokolow-Lyon voltage and the Romhilt-Estes point score in 6 patients (3.2%) and the Cornell voltage and the Romhilt-Estes point score in 11 patients (6.0%). Only one criterion was met in the large majority of patients — 160 (86.5%): the Sokolow-Lyon voltage in 8 patients (4.3%), the Cornell voltage in 36 patients (19.5%) and the Romhilt-Estes point score in 116 patients (62.7%) (Fig. 1).

Differences in clinical characteristics among patients meeting commonly used ECG criteria for LVH (the Sokolow-Lyon voltage, the Cornell voltage and the Romhilt-Estes point score) are presented in Table 3.

We found a trend showing positive correlation between duration of hypertension and magnitude of the Sokolow-Lyon voltage criterion (r = 0.38, p = 0.095) but no correlation with either systolic or diastolic blood pressure. There were no correlations between either blood pressure levels or duration of hypertension and magnitude of the Cornell voltage criterion.

Discussion

Large amount of research evidence indicates that sensitivity of traditional electrocardiographic criteria for LVH is relatively poor when compared with the reference standard for LVH assessment – echocardiography [28–34]. However, Verdecchia et al. and Schillaci et al. suggest that using the combination of three highly specific criteria: the Romhilt-Estes point score, left ventricular strain and Cornell criteria in a cumulative score can produce a rise in sensitivity without excessive deterioration of specificity [35, 36]. Importantly, even single electrocardiographic criteria for LVH are highly specific, with specificity exceeding 90% [37].

In a population of patients with CAD and concomitant diabetes, we found that the prevalence of LVH detected by ECG was 20% and ranged widely from 1% to 14%, depending on the criterion used. The LIFE study demonstrated that diabetes is associated with an increased prevalence and severity of ECG-LVH assessed according to the Cornell criteria [38]. In contrast, in high-

Table 1. Clinical characteristics of patients with electrocardiographic left ventricular hypertrophy (ECG-LVH) diagnosed with at least one criterion and without any evidence of ECG-LVH

Clinical feature	All patients with LVH (n = 200)	All patients without LVH (n = 801)	p	Women with LVH (n = 99)	Women without LVH (n = 386)	p	Men with LVH (n = 101)	Men without LVH (n = 415)	p	p (men with LVH vs. women with LVH)
Age (years)	65.3 ± 9.6	64.5 ± 11.0	0.26	67.0 ± 8.5	66.2 ± 11.2	0.48	63.6 ± 10.4	63.2 ± 10.2	0.47	< 0.05
Height [cm]	168.1 ± 8.3	168.4 ± 8.5	0.58	162.4 ± 6.6	162.2 ± 5.7	0.66	173.2 ± 5.8	174.1 ± 6.3	0.12	< 0.000001
Weight [kg]	86.0 ± 13.9	86.7 ± 14.9	0.68	82.8 ± 15.0	81.4 ± 13.8	0.45	89.3 ± 12.0	91.7 ± 14.1	0.15	< 0.001
BMI [kg/m^2]	30.6 ± 5.0	30.6 ± 4.9	0.78	31.4 ± 5.8	31.0 ± 5.3	0.63	29.7 ± 3.7	30.3 ± 4.4	0.32	< 0.05
Waist circumference [cm]	98.6 ± 13.0	98.6 ± 13.3	0.95	95.9 ± 14.5	95.1 ± 13.7	0.65	101.4 ± 10.6	102.0 ± 12.0	0.67	< 0.002
Hips circumference [cm]	107.1 ± 13.1	105.0 ± 12.3	0.11	110.0 ± 14.1	106.9 ± 11.8	0.08	104.0 ± 11.3	103.1 ± 12.4	0.31	< 0.01
Heart rate [beats/min]	74.6 ± 14.5	73.7 ± 12.9	0.79	73.7 ± 11.9	73.3 ± 11.6	0.94	75.6 ± 16.7	74.1 ± 13.9	0.78	0.96
Systolic blood pressure [mm Hg]	140.1 ± 15.3	140.2 ± 16.8	0.91	139.3 ± 14.9	139.4 ± 15.9	0.96	140.8 ± 15.7	140.9 ± 17.6	0.93	0.67
Diastolic blood pressure [mm Hg]	83.2 ± 10.8	83.1 ± 11.1	0.87	83.4 ± 10.7	82.2 ± 15.9	0.38	83.1 ± 10.9	84.0 ± 12.0	0.55	0.90
Previous acute coronary syndrome	89 (45%)	371 (46%)	0.64	38 (38%)	151 (39%)	0.89	51 (51%)	219 (53%)	0.66	0.08
Previous stroke	34 (17%)	108 (13%)	0.20	21 (21%)	55 (14%)	0.09	13 (13%)	61 (15%)	0.63	0.12
Duration of CAD (years)	6.3 ± 5.7	5.9 ± 5.5	0.35	6.8 ± 5.9	6.0 ± 5.7	0.16	6.0 ± 4.7	5.8 ± 5.3	0.96	0.22
Duration of diabetes (years)	9.7 ± 7.3	9.0 ± 6.8	0.27	10.4 ± 8.1	9.2 ± 6.9	0.24	9.1 ± 6.5	8.9 ± 6.7	0.69	0.40
Duration of hypertension (years)	12.0 ± 7.8	11.8 ± 7.6	0.87	12.3 ± 8.1	12.4 ± 7.9	0.91	11.7 ± 7.6	11.4 ± 7.3	0.74	0.66
Duration of dyslipidemia (years)	10.2 ± 6.7	9.4 ± 6.7	0.13	11.4 ± 7.6	9.1 ± 6.4	< 0.05	9.2 ± 5.7	9.7 ± 6.5	0.81	0.09
Duration of microangiopathy (years)	6.3 ± 5.7	5.9 ± 5.5	0.15	7.0 ± 5.9	5.6 ± 4.6	0.28	5.5 ± 3.5	5.1 ± 3.7	0.37	0.57
Duration of heart failure (years)	5.6 ± 4.4	5.6 ± 4.1	0.87	5.9 ± 4.2	5.8 ± 4.1	0.94	5.4 ± 4.7	5.3 ± 4.1	0.88	0.57
Tests results:										
Fasting plasma glucose [mg/dL]	128.5 ± 91.1	124.7 ± 46.0	0.24	131.6 ± 42.7	126.7 ± 36.0	0.44	124.9 ± 26.1	122.7 ± 28.1	0.39	0.71
HbA$_{1c}$ (%)	7.0 ± 1.1	7.3 ± 3.9	0.72	7.0 ± 1.1	7.3 ± 4.0	0.87	7.1 ± 1.1	7.3 ± 3.8	0.74	0.66
Total cholesterol [mg/dL]	216.6 ± 91.1	206.4 ± 45.9	0.72	216.1 ± 81.8	206.2 ± 44.6	0.79	217.1 ± 99.9	206.6 ± 47.3	0.83	0.99
HDL cholesterol [mg/dL]	49.4 ± 16.7	50.3 ± 17.9	0.84	51.9 ± 17.4	52.7 ± 18.0	0.63	46.9 ± 15.7	48.2 ± 17.6	0.95	0.12

LDL cholesterol [mg/dL]	117.1 ± 36.4	120.5 ± 41.2	0.43	122.4 ± 35.5	119.1 ± 42.7	0.32	112.1 ± 36.9	121.6 ± 39.9	< 0.05
Triglycerides [mg/dL]	171.7 ± 86.6	162.3 ± 76.6	0.40	165.5 ± 84.2	157.4 ± 68.7	0.60	177.4 ± 88.9	166.9 ± 83.2	0.42
Treatment:									
Acetylsalicylic acid	164 (82%)	656 (82%)	0.97	80 (81%)	315 (82%)	0.86	84 (83%)	341 (82%)	0.66
Clopidogrel	40 (20%)	134 (17%)	0.27	16 (16%)	51 (13%)	0.45	24 (24%)	83 (20%)	0.18
Statins	179 (90%)	668 (83%)	< 0.05	90 (91%)	313 (81%)	< 0.05	89 (88%)	354 (85%)	0.52
Fibrates	46 (23%)	163 (20%)	0.41	18 (18%)	73 (19%)	0.87	28 (28%)	90 (22%)	0.11
ACEI	157 (79%)	632 (79%)	0.90	75 (76%)	300 (78%)	0.68	82 (81%)	331 (80%)	0.35
ARB	47 (24%)	185 (23%)	0.90	19 (19%)	90 (23%)	0.38	28 (28%)	95 (23%)	0.15
Beta-adrenolytics	181 (91%)	683 (85%)	< 0.05	87 (88%)	322 (83%)	0.28	94 (93%)	360 (87%)	0.21
Diuretics	106 (53%)	401 (50%)	0.46	50 (51%)	201 (52%)	0.78	56 (55%)	199 (48%)	0.48
CCA	71 (36%)	253 (32%)	0.29	36 (36%)	129 (33%)	0.58	35 (35%)	124 (30%)	0.80
Metformin	133 (67%)	565 (71%)	0.27	75 (76%)	275 (71%)	0.37	58 (57%)	290 (70%)	< 0.01
Sulfonylurea derivatives	86 (43%)	346 (43%)	0.96	46 (46%)	171 (44%)	0.70	40 (40%)	175 (42%)	0.33
Insulin	73 (37%)	283 (35%)	0.76	36 (36%)	132 (34%)	0.69	37 (37%)	150 (36%)	0.99

Data presented are mean values ± standard deviations or numbers (percentages). ACEI — angiotensin-converting enzyme inhibitors; ARB — angiotensin II receptor blockers; BMI — body mass index; CAD — coronary artery disease; CCA — calcium channel antagonists; HbA_{1c} — glycated hemoglobin; HDL — high-density lipoprotein; LDL — low-density lipoprotein

Table 2. Prevalence of left ventricular hypertrophy based on seven assessed electrocardiographic criteria

Criterion	All analyzed patients (n = 1001) n (%)	Men (n = 516) n (%)	Women (n = 485) n (%)
The R wave amplitude on the lead V5 or V6 criterion	13 (1.3)	8 (1.6)	5 (1.0)
The Gubner voltage criterion	19 (1.9)	10 (1.9)	9 (1.9)
The Sokolow-Lyon voltage criterion	22 (2.2)	14 (2.7)	8 (1.6)
The R wave amplitude on the lead aVL criterion	32 (3.2)	17 (3.3)	15 (3.1)
The Cornell product criterion	52 (5.2)	24 (4.7)	28 (5.8)
The Cornell voltage criterion	55 (5.5)	18 (3.5)	37 (7.6)
The Romhilt-Estes point score	138 (13.8)	78 (15.1)	60 (12.4)

-risk patients in the HOPE study, there was no difference in the prevalence of diabetes between patients with and without ECG-LVH determined using the Sokolow-Lyon criterion [39]. In our population of diabetic patients with CAD, the prevalence of the Cornell voltage criterion was about 6%, while the prevalence of the Sokolow-Lyon voltage criterion was only 2%.

Bruno et al. investigated ECGs of 965 patients with type 2 diabetes mellitus and assessed the prevalence of ECG-LVH and its relationship with clinical and metabolic variables [40]. Patients with ECG-LVH were older than those without it, but there were no further differences in terms of body mass index, duration of diabetes, diabetes treatment, systolic and diastolic blood pressure, presence of CAD or hypertension. Interestingly, the comparison of patients with and without ECG-LVH in our study revealed that the former subjects were more often treated with beta-adrenolytics and statins.

According to our observations, it seems insufficient to use only one ECG criterion for detection of LVH in patients with CAD and DM, because each criterion identifies a different group of patients. In our study, 86.5% of subjects met only one out of the three most frequently used electrocardiographic criteria. It suggests the criteria are complementary and should be used in combination in order to detect ECG-LVH. González-Juanatey et al. indicated that the Cornell and Sokolow-Lyon diagnostic criteria enable us to identify hypertensive patients with LVH with different epidemiologic and cardiovascular risk profiles [41]. In men, LVH was preferably diagnosed using the Sokolow-Lyon criterion, whereas women more frequently fulfilled the Cornell criterion. In our study, the Sokolow-Lyon criterion was fulfilled in 2.7% of men and in 1.6% of women, while the Cornell criterion was met in 3.5% of men and in 7.6% of women.

The severity of ECG-LVH may be assessed by determining the magnitude of the voltage criteria. González-Juanatey et al. found positive correlations
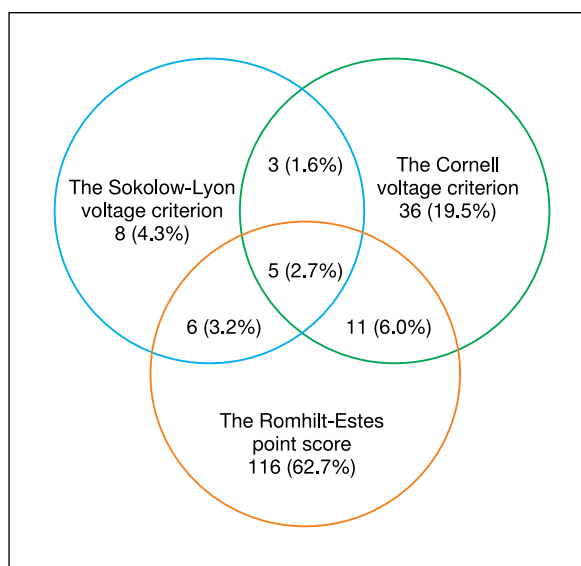

Figure 1. Coexistence of the three most frequently used ECG-LVH criteria; ECG-LVH — electrocardiographic left ventricular hypertrophy. Percentages are calculated out of all patients who fulfilled at least one of the three assessed ECG-LVH criteria (n = 185)

between systolic and diastolic blood pressure levels and severity of both the Sokolow-Lyon and the Cornell voltage criteria [41]. We also analyzed the severity of ECG-LVH reflected by the magnitude of the Sokolow-Lyon and the Cornell voltage criteria. In our study, there was a trend showing that the severity of LVH due to the Sokolow-Lyon criterion positively correlated with the duration of hypertension. However, we failed to find any correlations between the severity of the Cornell voltage and blood pressure levels or duration of hypertension. Importantly, a large majority of our study participants were treated with antihypertensive drugs.

There are some limitations of the study that deserve attention. First of all, ECGs were recorded in our study using analog, but not digital, systems and therefore

Table 3. Clinical characteristics of patients meeting the three most frequently used electrocardiographic criteria of left ventricular hypertrophy

Clinical feature	The Sokolow-Lyon criterion (n = 8)	The Cornell voltage criterion (n = 36)	The Romhilt-Estes point score (n = 116)	p
Age (years)	68.1 ± 6.3	65.6 ± 9.3	65.0 ± 9.6	0.54
Height [cm]	169.5 ± 8.1	166.4 ± 6.8	167.7 ± 8.8	0.53
Weight [kg]	81.4 ± 15.2	86.7 ± 18.3	85.1 ± 12.1	0.62
BMI [kg/m^2]	28.3 ± 4.7	31.3 ± 6.8	30.3 ± 4.1	0.39
Waist circumference [cm]	96.1 ± 11.4	100.1 ± 16.0	98.2 ± 12.6	0.61
Hips circumference [cm]	106.0 ± 10.7	110.0 ± 14.8	106.3 ± 12.9	0.53
Heart rate [beats/min]	65.5 ± 13.9	75.5 ± 13.1	74.4 ± 14.5	0.08
Systolic blood pressure [mm Hg]	146.6 ± 15.1	142.0 ± 15.1	138.2 ± 14.2	0.11
Diastolic blood pressure [mm Hg]	86.1 ± 10.6	83.3 ± 8.6	82.6 ± 11.0	0.70
Duration of CAD (years)	2.6 ± 2.8	7.8 ± 5.4	6.2 ± 6.2	< 0.05
Duration of diabetes (years)	8.4 ± 5.8	13.7 ± 9.2	8.5 ± 6.6	< 0.01
Duration of hypertension (years)	14.9 ± 9.1	14.9 ± 10.1	10.8 ± 7.0	0.06
Duration of dyslipidemia (years)	9.6 ± 5.6	13.4 ± 7.7	9.3 ± 6.7	0.09
Duration of microangiopathy (years)	1.5 ± 1.0	6.6 ± 4.3	7.0 ± 6.0	< 0.05
Duration of heart failure (years)	4.8 ± 4.3	7.8 ± 6.1	5.3 ± 4.1	0.49
Duration of ACEI treatment (years)	6.8 ± 2.6	9.2 ± 5.3	7.8 ± 4.4	0.33
Fasting plasma glucose [mg/dL]	114.2 ± 16.0	135.6 ± 44.9	127.3 ± 31.2	0.62
HbA$_{1c}$ (%)	6.0 ± 0.0	7.1 ± 1.2	7.1 ± 1.1	0.51
Total cholesterol [mg/dL]	206.3 ± 24.6	210.2 ± 61.3	213.6 ± 100.0	0.83
HDL cholesterol [mg/dL]	39.8 ± 7.5	52.7 ± 14.2	48.9 ± 18.4	0.07
LDL cholesterol [mg/dL]	97.3 ± 25.3	122.8 ± 40.2	115.2 ± 33.4	0.34
Triglycerides [mg/dL]	137.0 ± 11.0	152.0 ± 61.8	174.9 ± 95.2	0.40
Treatment:				
Acetylsalicylic acid	8 (100%)	28 (78%)	93 (80%)	0.14
Clopidogrel	2 (25%)	5 (14%)	25 (22%)	0.44
Statins	8 (100%)	35 (97%)	103 (89%)	0.63
Fibrates	2 (25%)	4 (11%)	28 (24%)	0.30
ACEI	4 (50%)	30 (83%)	94 (81%)	< 0.05
ARB	4 (50%)	6 (17%)	23 (20%)	< 0.05
Beta-adrenolytics	8 (100%)	33 (92%)	103 (89%)	0.40
Diuretics	4 (50%)	19 (53%)	62 (53%)	0.89
CCA	3 (38%)	9 (25%)	39 (34%)	0.47
Metformin	6 (75%)	27 (75%)	69 (59%)	1.00
Sulfonylurea derivatives	3 (38%)	11 (31%)	58 (50%)	0.70
Insulin	2 (25%)	15 (42%)	37 (32%)	0.38
Previous incidents:				
Previous acute coronary syndrome	3 (38%)	15 (42%)	50 (43%)	0.83
Previous stroke	1 (13%)	8 (22%)	19 (16%)	0.54

Data are presented as mean values ± SD or numbers (percentages). ACEI — angiotensin-converting enzyme inhibitors; ARB — angiotensin II receptor blockers; BMI — body mass index; CAD — coronary artery disease; CCA — calcium channel antagonists; HbA$_{1c}$ — glycated hemoglobin; HDL — high-density lipoprotein; LDL — low-density lipoprotein

they were analyzed manually. Secondly, we were not able to use the same electrocardiographic devices for all patients in different regions of Poland. Thirdly, some subgroup analyses in our study were underpowered. Fourthly, we did not assess left ventricular mass or wall thickness by echocardiography or magnetic resonance imaging and therefore we could not calculate the specificity or sensitivity of the compared ECG-LVH criteria. Finally, further studies are needed to verify the prognostic values of various ECG-LVH criteria.

Conclusions

The co-occurrence of all assessed ECG-LVH criteria, including the three most frequently applied in clinical practice, is very low in diabetic CAD patients. The Romhilt--Estes point score identifies the highest number of ECG-LVH cases in this setting. However, it seems reasonable to use routinely several ECG criteria for detection of LVH. Further studies are needed to compare diagnostic values of ECG-LVH criteria with imaging methods and to assess prognostic values of various ECG-LVH criteria.

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