Electrocardiographic Criteria of Left Ventricular Hypertrophy in Patients with Morbid Obesity

Justyna Domienik-Karłowicz, M.D.,* Barbara Lichodziejewska, M.D., Ph.D.,*
Wojciech Lisik, M.D., Ph.D.,† Michał Ciurzyński, M.D., Ph.D.,*
Piotr Bienias, M.D., Ph.D.,* Andrzej Chmura, M.D., Ph.D.,†
and Piotr Pruszczyk, M.D., Ph.D.*

From the *Department of Internal Medicine and Cardiology, Warsaw Medical University, Warsaw, Poland; and

†Department of General Surgery and Transplantology, Warsaw Medical University, Warsaw, Poland

Background: Obesity is frequently accompanied by systemic hypertension complicated by left ventricular hypertrophy (LVH). Standard electrocardiography (ECG) is generally accepted screening tool for LVH in systemic hypertension. The aim was to assess currently used ECG criteria in the diagnosis of LVH in morbidly obese patients.

Methods: Ninety-five patients (80 women, 15 men) with body mass index ≥ 40 kg/m², prior to scheduled bariatric surgery were included into the study. All patients underwent standard ECG and transthoracic ECG for LVH assessment.

Results: Echocardiographically LVH (>110 g/m² in women, and >132 g/m² in men) was diagnosed in 54 patients (56.8%). None of the ECG criteria showed satisfactory performance in the diagnosing echocardiographically confirmed LVH. Although, Receiving operating curves (ROC) analysis showed that only Romilht-Estes score and Cornell index $\times$ QRS complex duration were characterized by area under curve >0.6 (0.662; 0.612, respectively), currently recommended values of both tests (Romilht-Estes score and Cornell index $\times$ QRS duration 2436 mm $\cdot$ ms) showed very low sensitivity in morbidly obese patients (0% and 2%, respectively).

Conclusions: Our study showed that none of voltage-based ECG criteria are of value for LVH diagnosis in severely obese patients. Only Romhilt-Estes scale and Cornell indices could be helpful for the identification of LVH in the group of patients with morbid obesity, but their value is far from being satisfactory.

Ann Noninvasive Electrocardiol 2011;16(3):258–262

left ventricular hypertrophy; morbid obesity

It is generally accepted that obesity substantially increases the risk of cardiovascular morbidity and mortality.^{1,2} Obesity is frequently accompanied by systemic hypertension complicated by left ventricular hypertrophy (LVH), which significantly increases the risk of cardiovascular complications, including sudden cardiac death.³ Standard electrocardiography (ECG) is generally accepted screening tool in hypertensive patients for LVH. However, obesity with accumulation of excessive amount of fat tissue can affect ECG parameters such as QRS voltage and therefore potentially can influence the diagnostic criteria of LVH. We assessed the value

of currently used ECG criteria in the diagnosis of LVH in morbidly obese patients.

METHODS

Ninety-five patients (80 women, 15 men) with morbid obesity diagnosed according to World Health Organization recommendations, where body mass index (BMI) ≥ 40 kg/m² were included into the study. They were referred to our department for a medical assessment prior to scheduled bariatric surgery. Patients after myocardial infarction, with atrial fibrillation, left or right bundle branch block or significant valvular lesions, or

Address for correspondence: Justyna Domienik-Karłowicz, M.D., Lindley'a 4, 00-005 Warszawa; Fax: (22)502 13 63; E-mail: jdomienik@tlen.pl

No grant support.

chronic obstructive pulmonary disease were not included into the study.

Electrocardiographic Examination

All patients underwent standard rest 12-lead ECG examinations. Examination were recorded with article speed of 50 mm/s shift and electric signal amplification of 1 mV/cm. All ECG exams were conducted with Philips Page Writer Trim II device (Philips, Andover, MA, USA).

Criteria of Left Ventricular Hypertrophy

Electrocardiographic LVH criteria were used according to European Society of Cardiology criteria that is, RaVL amplitude > 11 mm; RV₅ > 26 mm; RV₆ amplitude > 26 mm; R_{max}+S_{max} > 45 mm; SV₁+RV₅₋₆ > 35 mm, Sokolow-Lyon index; RaVL+SV₃ > 28 mm in men and > 20 mm in women, Cornell criteria; Cornell criteria × QRS duration > 2436 mm · ms; RI+SIII > 25 mm; SV₁ or SV₂ amplitude ≥ 30 mm and Romhill-Estes score > 5 points.⁴

Echocardiography

At the day of electrocardiogram, all patients underwent transthoracic ECG performed according to recommendations of American Society of Echocardiography.⁵ All ECG examinations and measurements were performed with Philips IE33 system (Philips). In two-dimensional parasternal long-axis view, we assessed end-diastolic diameter of left ventricle, thickness of intraventricular septum, and posterior wall. Measurements were done below the level of mitral valve tips and were performed in the late diastole identified by R wave of simultaneously monitored ECG tracing. Left ventricular mass (LVM) was calculated according to the equation proposed by Devereux⁶: $LVM [g] = 1.04 [(IVS + LVDD + LVPW)^3 - LVDd^3] - 13.6$; where:

LVDd = left ventricular diameter diastole,

IVS = intraventricular septal thickness,

LVPW = left ventricle posterior wall thickness.

For the correction of left ventricular mass in the relation to the body surface, the left ventricular mass index was computed according to the following equation:

$$LVMI [g/m^2] = LVM/BSA,$$

where:

LVMI = left ventricular mass index,

LVM = left ventricular mass,

BSA = body surface area calculated according to equation of Mosteller [14].

We regarded less than 110 g/m² in women and less than 132 g/m² in men as reference normal LVMI values.

Statistical Analysis

Statistical analysis included descriptive statistics (quantitative data, means ± standard deviations; qualitative data, counts, and percentages). Receiving operating curves (ROC) were used to assess the diagnostic performance of ECG criteria of LVH diagnosis. We checked sensitivity and specificity of currently accepted ECG criteria. All used tests were two-sided. Data were considered significant at P less than 0.05. For statistical calculations, we used STATISTICA.

RESULTS

Ninety-five patients (80 women, 15 men) aged 39.64 ± 9.23 years with morbid obesity (BMI 48.76 kg/m² ± 9.02) were included to the study. Table 1 shows clinical and ECG characteristics of the patients. LVH was echocardiographically diagnosed in 54 patients (56.8%): 50 women (62.5%) and 4 men (26.7%). The frequency of ECG criteria in the diagnosis of LVH and their diagnostic value is presented in Table 2. In order to assess the diagnostic value of the tested ECG criteria in the patients with morbid obesity, ROC analysis was performed (Table 3). ROC analysis showed that only Romilht-Estes score and Cornell index × QRS duration were characterized by area under curve more than 0.6 (0.662, 95% confidence interval (CI) 0.520–0.723, P = 0.012, 0.612 95% CI 0.500–0.726, P = 0.050). The Cornell index tended to reached statistical significance, with area under curve (AUC) of 0.592 (95% CI 0.490–0.708), P = 0.083. Due to potential relationship between ECG criteria and body mass and body mass index, reanalysis was performed in two subgroups defined according to BMI value. The results of the analysis were presented in Table 4. The results also indicated relatively high predictive value of Romhilt-Estes score, especially in the subgroup of patients with BMI value between 35 and 50 kg/m² as well as RaVL in

Table 1. Basic Clinical and ECG Characteristics of the Patients (mean±SD)

	Women (n = 80)	Men (n = 15)	Total (n = 95)
Body mass (kg)	131.1 ± 19.5	160.5 ± 28.7	135.7 ± 23.6
BMI (kg/m ²)	48.6 ± 9.5	49.7 ± 6.5	48.8 ± 9.1
Hypertension n (%)	80 (100%)	15 (100%)	95 (100%)
Diabetes n (%)	8 (5%)	1 (0%)	1 (6.7%)
LVEDd (mm)	47.0 ± 4.8	49.1 ± 6.9	47.3 ± 5.2
IVS (mm)	11.5 ± 1.2	12.3 ± 0.9	11.6 ± 1.2
LVPW (mm)	11.4 ± 1.1	12.2 ± 0.9	11.6 ± 1.1
LVM	237.34 ± 55.52	281.90 ± 73.62	244.37 ± 60.56
LVMI (g/m ²)	96.5 ± 21.5	99.3 ± 19.5	97.3 ± 1.1
LVH n (%)	50 (62.5%)	4 (26.7%)	54 (56.8%)

Table 2. Value of Various ECG Criteria in the Diagnosis of Left Ventricular Hypertrophy in Obese Patients

Criterion	All Patients n (%)	LVH+ n = 54	LVH- n = 41	Sensitivity (%)	Specificity (%)
RaVL > 11mm n (%)	8 (8.4)	4 (7.4)	4 (9.8)	7	90
RaVL > 7.5mm n (%)	27 (28.4)	18 (33.3)	9 (21.9)	33	78
RV ₅ > 26 mm n (%)	1 (1.05)	0 (0)	1 (2.4)	0	98
RV ₆ > 26 mm n (%)	0 (0)	0 (0)	0 (0)	0	100
R _{max} +S _{max} > 45 mm n (%)	0 (0)	0 (0)	0 (0)	0	100
SV ₁ +RV ₅ /RV ₆ > 35 mm n (%)	2 (2.1)	1 (1.9)	1 (2.4)	2	98
Cornell index n (%)	5 (5.3)	4 (7.4)	1 (2.4)	7	98
Cornell index × QRS duration > 2436 mm · ms n (%)	2 (2.1)	1 (1.9)	1 (2.4)	2	98
RI+SIII > 25 mm n (%)	4 (4.2)	2 (3.7)	2 (4.8)	4	95
SV ₁ lub SV ₂ ≥ 30 mm n (%)	0 (0)	0 (0)	0 (0)	0	100
Romhilt-Estes score > 5 points n (%)	0 (0)	0 (0)	0 (0)	0	100

Table 3. ROC Analysis of ECG Criteria in the Diagnosis of LVH in Patients with Morbid Obesity

Studied Criterion	AUC	95% CI	P
RaVL	0.586	0.463 – 0.702	Ns
RV ₅	0.460	0.470 – 0.658	Ns
RV ₆	0.519	0.456 – 0.644	Ns
Rmax+Smax	0.573	0.443 – 0.692	Ns
SV ₁ +RV ₅ /RV ₆	0.518	0.446 – 0.645	Ns
Cornell index	0.592	0.490 – 0.708	0.083
Romhilt-Estes score	0.662	0.520 – 0.723	0.012
Cornell index × QRS duration	0.612	0.500 – 0.726	0.050
RI+SIII	0.566	0.450 – 0.684	Ns
SV ₁ lub SV ₂	0.537	0.473 – 0.655	Ns

the group of patients with BMI value more than 50 kg/m².

DISCUSSION

Although ECG and especially MRI are sensitive and specific methods of LVH diagnosis, standard ECG is still regarded to be useful in the LVH

diagnosis.⁶ However, there are very limited data on diagnostic value of standard ECG in severely obese patients. However, it is generally accepted that obesity is one of important factors leading to the decreased QRS amplitude.⁷ Therefore, we tried to assess the value of ECG in the diagnosis of LVH in morbidly obese patients. We evaluated consecutive 95 obese patients with BMI >35

Table 4. ROC Analysis for ECG Parameters in Left Ventricular Hypertrophy Recognition in Morbidly Obese Patients Depending on BMI Value

Studied Criterion	BMI < 50 kg/m ² (n = 56) AUC (95% CI)	BMI > 50 kg/m ² (n = 39) AUC (95% CI)
RaVL	0.559 (0.470 – 0.678)	0.621 (0.462 – 0.739)
RV ₅	0.457 (0.342 – 0.534)	0.481 (0.347 – 0.522)
RV ₆	0.503 (0.462 – 0.638)	0.557 (0.465 – 0.691)
Rmax+Smax	0.565 (0.435 – 0.682)	0.613 (0.502 – 0.736)
SV ₁ +RV ₅ /RV ₆	0.536 (0.412 – 0.657)	0.568 (0.476 – 0.698)
Cornell index	0.612 (0.503 – 0.723)	0.573 (0.472 – 0.694)
Romihlt-Estes score	0.715 (0.621 – 0.802)	0.490 (0.373 – 0.531)
Cornell index × QRS duration	0.636 (0.523 – 0.742)	0.589 (0.471 – 0.715)
RI+SIII	0.542 (0.454 – 0.661)	0.587 (0.483 – 0.705)
SV ₁ or SV ₂	0.601 (0.451 – 0.715)	0.458 (0.336 – 0.560)

Figure 1. ROC analysis for Romhilt-Estes score in the prognosis of LVH in morbidly obese patients (AUC 0.622, 95% CI 0.520–0.723). Importantly none of studied obese patients with LVH met Romhilt-Estes score of five points. The group of three patients met Romhilt-Estes score of 2 (sensitivity of 26% and specificity of 83% with PPV and NPV of 67%; 46%, respectively) and the group of 14 patients met Romhilt-Estes score of 3 (sensitivity of 6% and specificity of 100% with PPV and NPV of 100%; 45%, respectively)

assessed before elective bariatric surgery. Eventually LVH was echocardiographically diagnosed in 54 (56.84%) patients. However, current ECG criteria allowed establish the diagnosis in a few patients only. Importantly, majority of voltage criteria (RaVL > 11mm, RV₅ > 26 mm, RV₆ > 26 mm, R_{max}+S_{max} > 45 mm, SV₁+RV₅/RV₆ > 35 mm, Cornell index, SV₁ lub SV₂ ≥ 30 mm, RI+SIII > 25 mm) showed to be of no value for LVH diagnosis. AUC for this parameters was approximately 50%. Only Cornell

index × QRS duration and Romhilt-Estes score were found to have enough good value (AUC 0.612 (95% CI 0.500–0.726) (Fig. 1); AUC 0.662 (95% CI 0.520–0.723), respectively) (Fig. 2). Importantly, commonly used cutoff values for both of them showed very low sensitivity (2% and 0% respectively). Cornell index × QRS duration > 2436 mm · ms correctly identified one patient of 54 LVH subjects, while Romhilt-Estes score > 5 was present in none of obese patients with LVH. Therefore, they were found to be of no clinical value. In

Figure 2. ROC analysis for Cornell index $\times$ QRS duration in the diagnosis of LVH in morbidly obese patients. AUC was 0.612, 95% CI 0.500–0.726, $P = 0.050$. The European Society of Cardiology-recommended value 2436 mm $\cdot$ ms had very low sensitivity of 2% and specificity of 98% with low positive predictive value 1% and negative predictive value 43%.

summary, the current study showed that none of voltage-based ECG criteria are of value for LVH diagnosis.

REFERENCES

1. Poirier P, Giles TD, Bray GA, et al. Obesity and cardiovascular disease. Pathophysiology, evaluation, and effect of weight loss. *Circulation* 2006;113:898-918.
2. WHO. Physical status: the use and interpretation of anthropometry. Report of a WHO expert committee. WHO technical report series 854. Geneva World Health Organization 1995.
3. ESC textbook of cardiovascular medicine recommendations for chamber quantification, JASE Dec 2005.
4. Casale PN, Devereux RB, Milner M, et al. Value of echocardiographic measurement of left ventricular mass in predicting cardiovascular morbid events in hypertensive men. *Ann Intern Med* Aug 1986;105(2):173-178.
5. 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.
6. Recommendations for Chamber Quantification. JASE Dec 2005; 4-12.
7. Masui A, Tsuji H, Tamura K, et al. Effect of body characteristics on the variables of signal-averaged electrocardiograms in healthy subjects. *Chest* May 1994;105(5):1357-1359.