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Electrocardiographic characteristics in the underweight and obese in accordance with the World Health Organization classification

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ABSTRACT

Objective: It is clinically important to recognize how the underweight or obese affects electrocardiogram (ECG). We assessed the effects of body mass index (BMI) on QRS axis or R-wave heights.
Methods: From daily outpatient electrocardiograms with sinus rhythm, 203 were selected. The patients were classified into four groups: underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2) and obese (≥30 kg/m^2).
Results: With increasing BMI, QRS axis shifted rightward to leftward. There was a significant inverse correlation between BMI and QRS axis ($r = -0.60$, $p < 0.001$). Multivariate linear regression analysis among age, female, BMI, hypertension, left ventricular internal dimension and left ventricular mass (LVM) revealed that BMI was an independent determinant of QRS axis ($\beta = -0.52$, $p < 0.0001$). Although LVM increased with increasing BMI, R-wave heights in leads V4-5 were similar among the underweight, normal weight and overweight. R-wave heights in leads V4-5 were significantly lower paradoxically in the obese than other groups. With increasing BMI, Sokolow–Lyon index corrected by LVM decreased progressively.
Conclusions: Our results suggest that the underweight or obese is strongly associated with QRS axis or R-wave heights.

1. Introduction

The electrocardiogram (ECG) has been performed as a screening test for detecting left ventricular hypertrophy (LVH) in patients with hypertension because of its established clinical value, broad availability and low cost [1,2]. Previous studies have shown that ECG in the obese appears to have leftward shift of QRS axis and low QRS voltage [3–6]. These studies assessed ECGs in the obese and normal weight, and did not consider the underweight or degrees of the obese. It is clinically important to recognize how the underweight or obese affects ECG systematically. In the present study, we assessed the effects of body mass index (BMI) on QRS axis or R-wave heights. We also evaluated the effects of BMI on the correlation between R-wave heights and left ventricular mass (LVM) assessed by echocardiography.

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2. Methods

2.1. Patients

From daily outpatient electrocardiograms with sinus rhythm, 203 were selected. Patients with strain pattern suggesting LVH were excluded because the main objective of this study was to evaluate the effects of BMI on the ECG. No patients were taking digitalis or antiarrhythmic drugs. Patients with evidence of heart failure, previous myocardial infarction, cardiomyopathy, interventricular conduction delay (QRS duration > 120 ms) or chronic obstructive pulmonary disease were excluded in this study [7]. Hypertension was defined as systolic blood pressure ≥140 mmHg, diastolic blood pressure ≥90 mmHg or use of antihypertensive drugs. Diabetes mellitus was defined as a fasting glucose concentration of >7.0 mmol/L or the use of antidiabetic therapy.

2.2. BMI

Weight was measured with the patient wearing indoor clothing and height was measured without shoes. BMI was calculated by dividing the patient's weight (in kg) by the square of the height

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(in m). In accordance with the World Health Organization classification of BMI [8,9], the patients were classified into four groups: underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2) and obese (≥30 kg/m^2).

2.3. ECG

A standard 12-lead ECG was recorded at a paper speed of 25 mm/s and an amplification of 10 mm/mV in the postprandial state and supine. Heart rate, QRS duration, frontal plane QRS axis, and R-wave and S-wave heights in all leads were automatically measured. Sokolow–Lyon index, which was commonly used for detecting LVH, was calculated as $SV_1 + RV_5$ (mm) [10].

2.4. Echocardiography

In 160 of the 203 patients, echocardiographic assessment was conducted on the same day of ECG by three experienced sonographers, who had no knowledge of the clinical data, using high-quality commercially available ultrasound systems with 3.5 MHz probes (GE Healthcare Vivid 7, Milwaukee, WI; TOSHIBA Medical Artida, Tokyo). Echocardiographic studies were performed in the morning after 30 min rest with the subject in a supine left lateral decubitus position. Interventricular septal thickness (IVS), posterior wall thickness (PWT) and left ventricular internal dimension (LVID) were measured at end-diastole according to established standards of the American Society of Echocardiography (ASE). Left ventricular ejection fraction was obtained using a modified biplane Simpson's method from the apical 2- and 4-chamber views. LVM was calculated according to the ASE-recommended formula [11]:

$$\text{LVM (g)} = 0.8 \times \left\{1.04\left[(\text{IVS} + \text{LVID} + \text{PWT})^3\text{-}(\text{LVID})^3\right]\right\} + 0.6.$$

Relative wall thickness (RWT) was calculated as using the formula:

$$\text{RWT} = (2 \times \text{PWT})/\text{LVID}.$$

To evaluate how Sokolow–Lyon index (in mm) reflect LVM (in g) in each group, Sokolow–Lyon index was divided by LVM.

2.5. Statistical analysis

Continuous variables are shown as mean ± SD, and categorical variables are presented as frequencies and percentages. Continuous variables were compared by Kruskal–Wallis test. Categorical variables were compared by chi-square test or Fisher's exact test. Correlation between BMI and QRS axis was assessed by Pearson's correlation test. Multivariate linear regression analysis was performed among age, female, BMI, hypertension, LVID and LVM to determine factors associated with QRS axis. The ability of RaVF divided by RI (RaVF / RI) to discriminate between the underweight or obese and other groups was evaluated by receiver operating characteristic (ROC) curve analyses. Differences were considered significant if the p value was <0.05. Statistical analysis was conducted using JMP 11 software (SAS Institute, Tokyo, Japan).

3. Results

3.1. Patient characteristics

The 4 groups compromised: underweight, 18 patients; normal weight, 101 patients; overweight, 50 patients; and obese, 34 patients. Patient characteristics are shown in Table 1. Obese patients were significantly younger than those in other groups. With increasing BMI, the incidences of hypertension ($p < 0.0001$) and diabetes mellitus ($p = 0.027$) increased.

3.2. Effects of BMI on QRS axis

With increasing BMI, heart rate increased. There was no significant difference in QRS duration among the four groups. QRS axis was 70.9 ± 13.8° in the underweight, 39.9 ± 25.0° in the normal weight, 23.4 ± 24.1° in the overweight and 2.0 ± 26.1° in the obese (Fig. 1). With increasing BMI, QRS axis shifted rightward to leftward. There was a significant inverse correlation between BMI and QRS axis ($r = -0.60$, $p < 0.0001$) (Fig. 2). A multivariate linear regression analysis including age, female, BMI, hypertension, LVID and LVM was performed in 160 patients undergoing both ECG and echocardiography, and revealed that BMI was an independent determinant of QRS axis ($\beta = -0.52$, $p < 0.0001$) (Table 2).

3.3. Effects of BMI on R-wave heights

In limb leads, with increasing BMI, R-wave heights in leads I and aVL increased, and R-wave heights in leads II, III and aVF decreased (Fig. 3). ROC curve analyses showed that RaVF / RI significantly discriminated between the underweight and other groups, with an area under the curve of 0.94 ($p < 0.0001$) (Fig. 4, left panel). RaVF / RI of 2.13 was the optimal cutoff value for predicting lean, with a sensitivity of 83.3% and a specificity of 91.4%. Also, RaVF / RI significantly discriminated between the obese and other groups, with an area under the curve of 0.82 ($p < 0.0001$) (Fig. 4, right panel). RaVF / RI of 0.62 was the optimal cutoff

Table 1
Patient characteristics.

	Underweight (n = 18)	Normal weight (n = 101)	Overweight (n = 50)	Obese (n = 34)	p value
Age (years)	70.7 ± 14.5	71.5 ± 11.5	69.1 ± 11.0	59.1 ± 12.1	<0.0001
Male	8 (44.4%)	61 (60.4%)	35 (70.0%)	22 (64.7%)	0.27
Height (cm)	159.4 ± 10.5	159.8 ± 9.3	162.3 ± 9.5	161.8 ± 8.3	0.31
Weight (kg)	43.1 ± 7.2	56.6 ± 7.6	70.7 ± 9.7	87.8 ± 11.3	<0.0001
BMI (kg/m2)	16.8 ± 1.3	22.1 ± 1.8	26.7 ± 1.3	33.5 ± 2.8	<0.0001
Hypertension	2 (11.1%)	67 (66.3%)	39 (78.0%)	26 (82.4%)	<0.0001
Diabetes	1 (5.6%)	15 (14.9%)	11 (22.0%)	12 (35.3%)	0.027
Electrocardiogram					
Heart rate (bpm)	64.5 ± 8.4	66.3 ± 10.7	66.7 ± 12.0	72.8 ± 13.1	0.043
QRS duration (msec)	90.1 ± 8.6	89.8 ± 9.3	91.5 ± 10.1	92.3 ± 10.4	0.65
QRS axis (degree)	70.9 ± 13.8	39.9 ± 25.0	23.4 ± 24.1	2.0 ± 26.1	<0.0001
Sokolow–Lyon index (mm)	24.7 ± 6.8	27.2 ± 7.6	25.5 ± 6.9	23.9 ± 7.5	0.091
Echocardiogram	(n = 12)	(n = 83)	(n = 40)	(n = 25)	
LVID (mm)	42.8 ± 4.7	47.1 ± 4.1	49.0 ± 4.5	50.0 ± 5.9	<0.0001
RWT	0.39 ± 0.06	0.38 ± 0.05	0.37 ± 0.05	0.41 ± 0.08	0.34
Ejection fraction (%)	63.7 ± 8.4	63.2 ± 5.3	62.3 ± 5.2	60.7 ± 7.1	0.13
LVM (g)	112.0 ± 28.1	141.1 ± 30.9	160.7 ± 34.7	181.5 ± 47.1	<0.0001

BMI, body mass index; LVID, left ventricular internal dimension; RWT, relative wall thickness; LVM, left ventricular mass.