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Frontal QRS-T angle and World Health Organization classification for body mass index

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ABSTRACT

Background: The frontal QRS-T angle, defined as the absolute value of the difference between QRS axis and T-wave axis on 12 lead electrocardiogram (ECG), is the difference in orientation between ventricular depolarization and repolarization. We tested the hypothesis that QRS-T angle is affected by obesity.
Methods: A total of 177 patients undergoing both ECG and echocardiography within one month were recruited from outpatient clinic. Using the World Health Organization (WHO) classification of body mass index (BMI), the patients were classified into the four groups: underweight (<18.5 kg/m^2, $n = 25$), normal weight (18.5–24.9 kg/m^2, $n = 79$), overweight (25–29.9 kg/m^2, $n = 38$) and obese (≥30 kg/m^2, $n = 35$).
Results: Obese patients were significantly younger than those in other groups. As for echocardiographic variables, left ventricular internal dimension and left ventricular mass (LVM) increased with increased WHO classification of BMI. QRS axis and T-wave axis decreased with increased WHO classification of BMI, whereas QRS-T angle increased. Multivariate linear regression analysis showed that BMI ($\beta = 0.23$, $p = 0.01$) and LVM ($\beta = 0.19$, $p = 0.046$) were independent determinants of QRS-T angle.
Conclusions: Our results suggest that BMI is an independent determinant of QRS-T angle.

1. Introduction

The frontal QRS-T angle, defined as the absolute value of the difference between QRS axis and T-wave axis on 12 lead electrocardiogram (ECG), is the difference in orientation between ventricular depolarization and repolarization [1–5]. Abnormal QRS-T angle indicates altered ventricular repolarization possibly associated with underlying functional or structural heart diseases. Recent studies have shown that abnormal QRS-T angle is a strong and independent risk indicator for cardiac morbidity and mortality [3–5].

QRS axis, a constituting factor of QRS-T angle, is affected by some pathophysiological conditions such as obesity [6,7], pregnancy [8] or left ventricular (LV) hypertrophy [9,10]. In the present study, we tested the hypothesis that QRS-T angle is affected by obesity.

2. Methods

2.1. Patients

A total of 177 patients who underwent both ECG and echocardiography within one month in outpatient clinic of our hospital were retrospectively collected. Patients with previous myocardial infarction, cardiomyopathy, significant valvular heart disease, atrial fibrillation, bundle branch block, ventricular pacing or strain pattern on ECG were excluded in this study. Hypertension was defined as systolic blood pressure >140 mm Hg, diastolic blood pressure >90 mm Hg or use of antihypertensive drugs. Diabetes mellitus was defined as a fasting glucose concentration of >7.0 mmol/L or the use of antidiabetic drugs.

2.2. ECG

A standard 12 lead ECG was recorded at a paper speed of 25 mm/s and an amplification of 10 mm/mV. QRS axis and T-wave axis were automatically measured. According to previous reports [2–5,11–13], frontal QRS-T angle was defined as the absolute value of the difference between the frontal plane QRS axis and T-wave axis. When QRS-T angle was >180°, it was adjusted to the minimal angle using (360° - angle).

2.3. Echocardiography

Echocardiographic assessment was undertaken by two experienced sonographers, who had no knowledge of ECG findings, using commercially available ultrasound systems with 3.5 MHz probes (GE Healthcare Vivid 7, Milwaukee, WI; TOSHIBA Medical Artida, Tokyo). Interventricular septal thickness (IVS), posterior wall thickness (PWT) and left ventricular internal dimension (LVID) were measured at end-diastole. 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 following formula [14]:

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

LVM index was calculated by dividing LVM by body surface area.

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2.4. BMI

Weight and height were measured at the time of echocardiography. BMI was calculated by dividing the patient's weight (in kg) by the square of the height (in m). Using the World Health Organization (WHO) classification of BMI [15], the patients were classified into the 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).

2.5. Statistical analysis

Continuous variables are shown as mean ± SD, and categorical variables are shown as frequencies and percentages. Continuous variables were compared by Wilcoxon test. Categorical variables were compared by chi-square test or Fisher's exact test. Correlations between QRS-T angle and clinical variables were assessed by Pearson's correlation test. Multivariate linear regression analysis was performed to determine variables associated with QRS-T angle. 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

Twenty five patients were underweight (<18.5 kg/m^2), 79 patients had normal weight (18.5–24.9 kg/m^2), 38 patients were overweight (25–29.9 kg/m^2), and 35 patients were obese (≥30 kg/m^2). Patient characteristics are shown in Table 1. Obese patients were significantly younger than those in other groups. As for echocardiographic variables, LVID and LVM increased with increased WHO classification of BMI.

3.2. Effects of BMI on frontal QRS-T angle

QRS axis, T-wave axis and frontal QRS-T angle in the four groups are shown in Fig. 1. With increased WHO classification of BMI, QRS axis and T-wave axis decreased. The decrease in QRS axis was more evident compared with the decrease in T-wave axis. Consequently, frontal QRS-T angle increased significantly with increased BMI.

Correlations between QRS-T angle and clinical variables are shown in Table 2. QRS-T angle was associated with BMI ($r = 0.31$, $p < 0.001$), LVM ($r = 0.28$, p < 0.001) and LVM index ($r = 0.19$, $p = 0.01$). Multivariate linear regression analysis showed that BMI (β = 0.23, p = 0.01) and LVM (β = 0.19, $p = 0.046$) were independent determinants of QRS-T angle (Table 3, model 3).

4. Discussion

In the present study, we demonstrated the following: 1) with increased WHO classification of BMI, QRS axis and T-wave axis decreased, whereas QRS-T angle increased; and 2) BMI was an independent determinant of QRS-T angle.

Numerous studies have established that repolarization abnormalities manifested by ST-segment deviation or T-wave inversion were significant predictors of cardiac morbidity and mortality in patients with previous myocardial infarction or hypertension [16,17]. More recently, there has been an increasing interest in the prognostic value of the QRS-T angle [1–5]. Several studies in a large number of population have shown that frontal as well as spatial QRS-T angle is useful in predicting adverse cardiac outcomes [18,19]. In the present study, we demonstrated that frontal QRS-T angle increased with increased WHO classification of BMI.

QRS-T angle consists of QRS axis and T-wave axis. Actually, QRS axis depends on age, LVM index or BMI. Leftward shift of QRS axis with aging is explained by changes on thorax geometry or increased fibrosis and fatty infiltration in the conduction system [20–23]. Leftward shift of QRS axis with LV hypertrophy is well recognized [9,10]. Notably, we have recently found that QRS axis is inversely associated with BMI [7]. This could be explained by the horizontal anatomical position of the heart due to upward shift of the diaphragm [6,7]. In the same way as QRS axis, T-wave axis is affected by LVM index or blood pressures [24]. Given these documented effects on ECG axes, we focused on the association between BMI and QRS-T angle.

In the present study, we showed that QRS axis decreased with increased BMI, being in agreement with previous reports including ours [7]. We also found that T-wave axis decreased less than QRS axis, resulting in increased QRS-T angle with the raising of BMI. BMI and LVM were independent determinants of QRS-T angle. A recent study in the diabetic population have shown that patients with QRS of >90° tend to have higher BMI than those with QRS of <90° [24]. This study may support our findings. Our findings are possibly explained by the following mechanism. A large number of experimental and clinical studies have revealed that the activation of sympathetic nervous system is a hallmark of obesity and contributes to the increased cardiometabolic risk associated with the condition [25]. At the same time, life style modification aimed at reducing calorie intake and increasing physical activity improves sympathetic tone in individuals with obesity [26]. By the way, activation of cardiac sympathetic nerves alters ventricular repolarization. Ramirez et al. examined the effects of stimulation of stellate ganglia on repolarization to identify ECG markers of sympathetic activation, and showed displaced repolarization vector and changes in T-wave morphometrics [27]. Taken together, obesity may enable QRS-T angle to increase through the activation of cardiac sympathetic nerves. Further studies are necessary to clarify the precise mechanism of association between obesity and QRS-T angle.

There were several limitations in this study. First, obese patients were younger than those in other groups. It is noteworthy that BMI was still an independent determinant for QRS-T angle after adjustment for other factors including age. Second, generally, women have a smaller QRS-T angle than men [2]. We could not assess QRS-T angle separately by gender because of small sample size. Third, cardiac sympathetic activity can be assessed by some methods such as iodine 123-

Table 1
Patient characteristics of the four groups according to the World Health Organization classification of body mass index.

Variable	Underweight (n = 25)	Normal weight (n = 79)	Overweight (n = 38)	Obese (n = 35)	p-Value
Age (years)	72 ± 11	71 ± 12	70 ± 11	59 ± 12	<0.001
Male	10 (40%)	52 (66%)	26 (68%)	20 (57%)	0.09
Height (cm)	156 ± 8	161 ± 9	163 ± 10	160 ± 9	0.08
Weight (kg)	42 ± 6	57 ± 7	71 ± 11	87 ± 10	<0.001
BMI (kg/m^2)	17 ± 1	22 ± 2	27 ± 1	34 ± 3	<0.001
Systolic blood pressure (mmHg)	130 ± 17	124 ± 13	125 ± 10	130 ± 17	0.17
Pulse rate (bpm)	69 ± 15	67 ± 12	68 ± 13	70 ± 14	0.74
Hypertension	18 (72%)	63 (80%)	35 (89%)	31 (86%)	0.11
Diabetes mellitus	6 (24%)	15 (19%)	16 (42%)	15 (43%)	0.01
LV interval dimension (mm)	43 ± 5	47 ± 4	49 ± 4	50 ± 5	<0.001
LV ejection fraction (%)	64 ± 6	63 ± 5	63 ± 4	62 ± 8	0.48
LV mass (g)	113 ± 28	140 ± 31	156 ± 31	180 ± 38	<0.001
LV mass index (g/m^2)	82 ± 20	88 ± 18	89 ± 17	95 ± 22	0.14

BMI: body mass index, LV: left ventricle.

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