Sex Differences in the Relationships Between Electrocardiographic Abnormalities and the Extent of Left Ventricular Hypertrophy by Echocardiography

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Background: Several criteria have been proposed for the electrocardiographic diagnosis of left ventricular hypertrophy (LVH). However, their diagnostic accuracy is questionable. Furthermore, the diagnostic accuracy of abnormalities in ST-T patterns for LVH is known to be uncertain, especially in women. We examined the relationship between electrocardiographic abnormalities and the extent of LVH.

Methods: We studied 76 men and 48 women who satisfied electrocardiographic voltage criteria for LVH (RV_5 or $RV_6 \geq 2.6$ mV, $SV_1 + RV_5$ or $SV_1 + RV_6 \geq 3.5$ mV). They were classified into three groups based on ST-T pattern: normal, early strain, and strain. We defined echocardiographic evidence of LVH as an LV wall thickness ≥ 12 mm.

Results: LVH was identified by echocardiography in 55.3% of men and in 47.9% of women. In strain and early strain groups, the prevalence of echocardiographic LVH was significantly higher in men than in women (strain group: 100 vs 75%, $P < 0.05$, early strain group: 81.8 vs 42.1%, $P < 0.05$), it did not differ significantly between men and women in normal group. In men, QRS voltage values were significantly correlated with echocardiographic indices. In group strain of men, significant good correlations were observed between QRS voltage values and echocardiographic indices. However, in women, there were no significant correlation between QRS voltage values and echocardiographic indices even in strain group.

Conclusions: The combined criteria of both QRS voltage and ST-T classification could provide a greater accuracy in diagnosing LVH compared to the criteria using QRS voltage alone in men rather than in women.

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left ventricular hypertrophy; electrocardiography; sex; ST-T abnormality pattern; LVH strain

Left ventricular hypertrophy (LVH) is a physiological adaptation by which the heart compensates for an increased workload. However, this process can become pathological, as noted by epidemiological studies revealing that LVH is a major risk factor for cardiovascular morbidity and mortality.¹⁻⁴ Thus, the early recognition of LVH is a very important clinical issue.

Electrocardiography is inexpensive, noninvasive, and convenient, and has been widely used in screening for LVH in large populations.⁴⁻⁹ Several criteria have been proposed for the electrocardiographic diagnosis of LVH,¹⁰⁻¹⁵ but their diagnostic accuracy is questionable given that they have been associated with high rates of false-positive and false-negative results.^{5,16-22} An

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Figure 1. Classification of ST-T abnormalities (A) normal ST-T, (B) early strain type of ST-T, and (C) strain type of ST-T.

inherent limitation of the electrocardiography in detecting LVH is its dependence of fixed voltage criteria, which can be substantially influenced by extracardiac factors such as sex, age, weight, and chest-wall configuration.^{4,5,10,23} Furthermore, the diagnostic accuracy of abnormalities in ST-T patterns for LVH is known to be uncertain, especially in women.^{6,10,14,21} Therefore, the relationships between electrocardiographic abnormalities and the extent of LVH in women may differ from that in men.

The purpose of this study was to determine whether there is a sex difference in the relationship between electrocardiographic findings and the extent of LVH as determined by echocardiography.

METHODS

Study Subjects

We studied 76 consecutive men (age 56.2 ± 9.6 years, mean $\pm$ SD) and 48 consecutive women (age 57.6 ± 9.7 years) who satisfied electrocardiographic voltage criteria for LVH. They comprised 23 men and 13 women without any heart disease, 47 men and 23 women patients with hypertension, and six men and 10 women patients with hypertrophic cardiomyopathy and two women with valvular disease. Hypertension was diagnosed according to the WHO/ISH criteria of blood pressures of $>140/90$ mmHg.²⁴ Excluded from the current study were patients with electrocardiographic findings including complete bundle branch block and Wolff-Parkinson-White syndrome, those echocardiographic findings including left ventricular dilation, right ventricular hypertrophy, and abnormal wall motion, and/or those with any history of ischemic heart disease or cerebrovascular accidents. Patients with electrolyte imbalance were also excluded. All of the above factors would interfere with the detection of LVH.²⁵ The study was approved by the appropriate institutional review committee. The subjects were informed of the objectives of the experiment, and the written informed consents were taken from all of them prior to the study.

Electrocardiographic Data

We recorded 12-lead electrocardiograms and used the voltage criteria of Sokolow and Lyon (RV_5 or $RV_6 \geq 2.6$ mV; $SV_1 + RV_5$ and/or $SV_1 + RV_6 \geq 3.5$ mV).¹¹ Subjects were classified into three

Figure 2. Percentages of subjects with echocardiographic evidence of left ventricular hypertrophy in normal type, early strain type, and strain type.

groups according to their ST-T patterns as follows (Fig. 1): (1) normal group: normal ST-T in 12 leads; (2) early strain group: minimal ST depression (of less than 0.05 mV), flat T ($T/R < 1/10$), or biphasic T in V_5 or V_6 (ST-T abnormality not satisfying strain type of ST-T); and (3) group strain: definite ST depression of greater than 0.05 mV ST with asymmetric T wave inversion in V_5 and V_6 .

Echocardiographic Data

The long-axis, short-axis, apical two-chamber, and four-chamber two dimensional echocardiographic views were obtained in each case. The end-diastolic left ventricular internal dimension (LVDd), left ventricular posterior wall thickness (LVPWT), and interventricular septal thickness (IVST) were measured by hand using the Penn measurement convention.²⁶ The LV mass was estimated according to the method of Devereux et al.^{25,26} using the following equation: $LV\ mass = 1.04[(LVDd + LVPWT + IVST)^3 - (LVDd)^3] - 14$. In addition, we calculated the LV mass index as LV mass/body surface area. We defined echocardiographic evidence of LVH as an IVST or LVPWT of ≥ 12 mm.²⁷ Subjects were classified into two groups: (1) the echocardiographic LVH [LVH (+) group] consisting of 65 subjects (42 men, 23 women), and (2) the without LVH [LVH (–) group] consisting of 59 subjects (34 men, 25 women).

Statistical Analysis

We evaluated the echocardiographically determined prevalence of LVH according to the ST-T classification using the chi-square test for

Table 1. QRS Voltage Values and Echocardiographic Findings in Men and Women

	Men (n = 76)	Women (n = 48)	P-Value
Age (years)	56.2 ± 9.6	57.6 ± 9.7	NS
RV ₅ (mV)	3.24 ± 0.98	2.93 ± 0.81	NS
SV ₁ + RV ₅ (mV)	4.69 ± 1.23	4.60 ± 0.97	NS
(IVST + LVPWT)/2 (mm)	11.4 ± 2.7	10.7 ± 2.0	NS
LV mass index (g/m ²)	150.3 ± 54.1	165.9 ± 48.9	NS

Values are mean ± SD. IVST = interventricular septal thickness; LVPWT = left ventricular posterior wall thickness; NS = not significant.

comparison between men and women. Data were analyzed by analysis of variance with Scheffe's test used for multiple comparisons. A probability value of <0.05 was considered indicative of statistical significance. Correlations between electrocardiographic indices (RV₅, RV₆, SV₁ + RV₅, and SV₁ + RV₆) and the echocardiographic indices [IVST, LVPWT, (IVST + LVPWT)/2, and LV mass index] in men and women were assessed by linear regression.

RESULTS

Electrocardiographic Classification and Left Ventricular Hypertrophy

LVH was identified by echocardiography in 55.3% (42 of 76) of men and in 47.9% (23 of 48) of women. There were no significant differences in prevalence of LVH determined by echocardiography between men and women. However, in strain and early strain groups, the prevalence of echocardiographic LVH was significantly higher in men than in women (strain group: 100 vs 75%, $P < 0.05$, early strain group: 81.8 vs 42.1%, $P < 0.05$), it did not differ significantly between men and women in normal group (Fig. 2).

The values of QRS voltages (RV₅ and SV₁ + RV₅) and echocardiographic indices [(IVST + LVPWT)/2, and LV mass index] are listed in Table 1. There

were no significant differences in these parameters between men and women. In men, the values of SV₁ + RV₅ was significantly higher in the LVH (+) group than that in the LVH (−) group. In women, there were no significant differences in QRS voltage values between these two echocardiographic groups (Table 2).

The values of RV₅, and SV₁ + RV₅, were significantly higher in strain group than in normal and early strain groups in men. The values of SV₁ + RV₅ were significantly higher in women in strain group than in normal and early strain groups (Table 3). In men, all echocardiographic indices were significantly higher in strain group than in normal and early strain groups. In women, echocardiographic indices were significantly higher in strain than in normal group (Table 3).

Correlations Between QRS Voltage Values and Echocardiographic Indices

QRS voltage values were correlated with echocardiographic indices in men not in women (Fig. 3). In men of the LVH (+) group, QRS voltage values were significantly correlated with (IVST + LVPWT)/2 ($r = 0.70$, $P < 0.01$) and LV mass index ($r = 0.59$, $P < 0.01$). However, there were no significant correlations between QRS voltage values and echocardiographic indices in women of the

Table 2. Values for QRS Voltage and Echocardiographic Findings in the LVH (+) and LVH (−) Groups

LVH group	Men		Women	
	LVH (−) (n = 34)	LVH (+) (n = 42)	LVH (−) (n = 25)	LVH (+) (n = 23)
RV ₅ (mV)	3.04 ± 0.57	3.40 ± 1.19	2.83 ± 0.59	3.04 ± 0.99
SV ₁ + RV ₅ (mV)	4.30 ± 0.55	5.00 ± 1.51 ^a	4.51 ± 0.51	4.70 ± 1.31
(IVST + LVPWT)/2 (mm)	9.4 ± 0.9	12.9 ± 2.7 ^b	9.3 ± 1.0	12.3 ± 1.6 ^b
LV mass index (g/m ²)	119.1 ± 22.6	175.6 ± 59.1 ^b	158.1 ± 48.0	174.3 ± 49.4

Values are mean ± SD. LVH (−) group versus LVH (+) group; ^a $P < 0.05$, ^b $P < 0.01$.

Table 3. QRS Voltage Values and Echocardiographic Findings in the Three ST-T Groups

Group	Normal (n = 49)	Early Strain (n = 11)	Strain (n = 16)
Men			
RV ₅ (mV)	2.97 ± 0.63	2.89 ± 0.58	3.62 ± 1.39 ^{b,d}
SV ₁ + RV ₅ (mV)	4.31 ± 0.57	4.52 ± 0.75	5.44 ± 1.74 ^{b,d}
(IVST+LVPWT)/2 (mm)	10.1 ± 1.3	11.6 ± 1.1	15.0 ± 3.5 ^{b,d}
LV mass index (g/m ²)	130.5 ± 30.7	154.1 ± 27.1	208.4 ± 79.1 ^{b,c}
Women	(n = 13)	(n = 19)	(n = 16)
RV ₅ (mV)	2.68 ± 0.71	2.74 ± 0.42	3.37 ± 1.05
SV ₁ + RV ₅ (mV)	4.28 ± 0.57	4.35 ± 0.58	5.16 ± 1.34 ^{a,c}
(IVST+LVPWT)/2 (mm)	9.4 ± 1.6	10.9 ± 1.7	11.6 ± 2.0 ^b
LV mass index (g/m ²)	138.4 ± 36.6	161.8 ± 43.4	193.0 ± 51.9 ^b

Values are mean ± SD. Normal group versus strain group, ^aP < 0.05, ^bP < 0.01; early strain group versus strain group, ^cP < 0.05, ^dP < 0.01.

LVH (+) group. There were no significant correlations between QRS voltage values and echocardiographic indices in both men and women in the LVH (–) group (Fig. 4). Strong correlations between QRS voltage values and echocardiographic indices [(IVST + LVPWT)/2 ($r = 0.88$, $P < 0.01$) and LV mass index ($r = 0.79$, $P < 0.01$)] were observed in strain group in men but not in women. There were no significant correlations between QRS voltage values and echocardiographic indices in normal and early strain groups in both men and women (Fig. 5).

DISCUSSION

The findings in the present study can be summarized as follows: (1) the prevalence of echocardiographic LVH in early strain and strain groups were lower in women than in men; (2) in men, the values of QRS voltage were significantly higher in LVH (+) group than in LVH (–) group, whereas there were no differences in the QRS voltage values between women with LVH and without LVH; and (3) QRS voltage values were significantly correlated with echocardiographic parameters in LVH (+) group and in strain group in men. These results are suggestive of sex differences in the relationships between QRS voltage values and echocardiographic LVH.

In our study, there were significant correlations between QRS voltage values and echocardiographic parameters in men with echocardiographic LVH. This finding is consistent with those of Carter and Estes,²² who reported that electrocardiographic voltage values of SV₁ + RV₅ and SV₁ + RV₆ were

correlated with postmortem heart weights in the presence of LVH but not in its absence. This suggests that increased cardiac electromotive force directly reflects the QRS voltage in men with LVH. In contrast, the presence of echocardiographic LVH had no significant effect on QRS voltage values

Figure 3. Relationships between QRS voltage and echocardiographic findings.

Figure 4. Relationships between QRS voltage and echocardiographic findings in the LVH (+) and LVH (-) groups (A and C: in men, B and D: in women).

in women. Additionally, the values of QRS voltage were poorly correlated with LV mass index or LV wall thickness even in women diagnosed with an ST-T abnormality, suggesting that the extent of LVH is not accurately reflected in the QRS voltage in women.

The value of $SV_1 + RV_5$ was significantly higher in men with echocardiographic LVH than in those without echocardiographic LVH. Moreover, the QRS values were significantly higher in strain group than in normal group. Conversely, there were no differences in the QRS voltage values not only in women independently of the presence of echocardiographic LVH. Hence, combining QRS voltage and ST-T wave abnormality criteria could be more reliable in the echocardiographic diagnosis of LVH than using QRS voltage alone in men but not in women. However, in both men and women, values of $(IVST + LVPWT)/2$ was significantly higher in strain group than in normal group. These sex-dependent results are consistent with the findings of Dolgin and coworkers.¹⁴

The frequency of echocardiographic LVH was lower in women than in men, especially in strain and early strain groups. The strict electrocardiographic criteria derived from the voltage criteria combined with ST-T pattern criteria could improve the accuracy of electrocardiographic prediction for LVH in men but not necessarily in women. These findings demonstrate sex differences in the prevalence of echocardiographic LVH in strain and early strain groups. The poor relationships between a high QRS voltage and the extent of LVH in women might be ascribed to lead vectors including the breast tissue, which is rich in subcutaneous fatty tissue,^{4,23} whereas the nonspecific ST-T changes in women reportedly relate to the abnormal oxyhemoglobin dissociation and small-vessel disease.²⁸⁻³⁰ Moreover, electrocardiographic LVH with ST depression and negative T wave changes are the electrocardiographic abnormalities with the greatest prognostic significance for future cardiac events, and the risk is similar for both men and women.³¹ Hence, further evaluation is needed to

Figure 5. Relationships between QRS voltage and echocardiographic findings in the three ST-T groups (A and C: in men, B and D: in women).

rule out ischemia and careful follow-up for early detection and the prevention of progressing cardiac disease in women who have an electrocardiographic LVH with ST-T abnormality.

In conclusion, significant sex differences are present in relation of electrocardiographic parameters and echocardiographic findings in subjects with a high QRS voltage. The combination of QRS voltage criteria and ST-T classification could provide greater accuracy in diagnosing LVH compared to using QRS voltage criteria alone in men rather than in women.

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