Effect of Body Characteristics on the Variables of Signal-averaged Electrocardiograms in Healthy Subjects*

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Late potentials have been reported to be affected by body size or left ventricular mass. To our knowledge, however, the effect of subadipose tissue, which is known to influence QRS amplitudes of the surface ECG on the variables of late potentials, has not been evaluated. The relationships between the variables of late potentials and various obesity indices were assessed in 45 men, aged 24 to 38 years, without structural heart disease and bundle branch blocks. QRS duration (DUR), root mean square voltage in the last 40 ms (RMS), and low-amplitude signals <40 μV (LAS) were obtained by signal-averaged ECG. Left ventricular mass (LV mass) was determined by echocardiography. The DUR and RMS had no correlation with body height, weight, body mass index (BMI), sum of skin folds (triceps and subcapsular), or LV mass. Positive linear correlations were found between LAS and weight ($r=0.48$, $p<0.002$), BMI ($r=0.54$, $p<0.002$), sum of skin folds ($r=0.57$, $p<0.002$), and percent BMI ($r=0.54$, $p<0.002$). Subadipose tissue may shift the onset of the 40-μV point of LAS to the left with a consequent prolongation of LAS by attenuation of the QRS complex. These data suggest that the use of LAS alone or as a combination in an obese population for the definition of positive late potentials is inappropriate.

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Ventricular late potentials are high-frequency, low-amplitude signals in the terminal portion of the QRS complex obtained by signal averaging of surface electrocardiograms. Late potentials have been demonstrated to be related to the occurrence of spontaneous or induced sustained ventricular tachycardia. Although late potentials are thought to represent delayed and inhomogeneous conduction, quantitative variables that define late potentials have been reported to be affected by gender, body size, or echocardiographically estimated left ventricular mass. To our knowledge, however, the effect of subadipose tissue, which is well known to influence QRS amplitude of surface electrocardiograms, on late potentials has not been evaluated. The present study assessed the relationship between late potentials and various obesity indices evaluated by body weight, body height, skin folds, and left ventricular mass.

**Methods**

**Study Population**

Forty-five healthy Japanese male volunteers, aged 24 to 38 years (28±3 years) were studied. They were medical residents and physicians. None had a history of heart disease, metabolic disease, or systemic hypertension. They all had normal results of a physical examination, standard 12-lead electrocardiogram, and echocardiogram.

**Signal-Averaged Electrocardiogram**

Signal averaging was performed using a system (Corazonix). Standard orthogonal leads X, Y, and Z were used to record the signal-averaged electrocardiograms. At least 150 beats were averaged to obtain a sound of 0.3 μV or less. Bidirectional filtering and a high-pass filter at 40 Hz were employed. Three signal-averaged electrocardiogram parameters were obtained including (1) filtered QRS duration, (2) low-amplitude signal duration less than 40 μV in the terminal QRS, and (3) root mean square voltage in the terminal 40 ms in microvolts.

**Clinical Variables**

Echocardiography was performed with an ultrasound system (Aloka SSD), with a 3.5-MHz transducer. Left ventricular mass was calculated according to the formula of Devereux et al: left ventricular mass (g) = 1.04 ([left ventricular internal dimension + ventricular septal thickness + posterior wall thickness] - [left ventricular internal dimension]) + 3.6. Skinfold thickness was measured in subcapular and triceps regions and the sum of the thickness of these two regions was used as a sum of skinfolds. Body mass index was calculated according to the following formula: weight (kg)/height (m)$^2$. As 25 is considered as the upper limit of normal body mass index, (personal body mass index – 25) × 100/25 was calculated as percent body mass index.

**Statistical Analysis**

Values are expressed as means±SD. Pearson's correlation coefficient was used to determine the relation between the variables, and $p<0.05$ was considered statistically significant.

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Table 1—Clinical and Signal-Averaged Electrocardiographic Characteristics and Left Ventricular Mass in 45 Healthy Men

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean±SD</th>
</tr>
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<tbody>
<tr>
<td>Age (years)</td>
<td>28±3</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.71±0.05</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71±12</td>
</tr>
<tr>
<td>Body mass index</td>
<td>24±4</td>
</tr>
<tr>
<td>Sum of skin folds (mm)</td>
<td>40±10</td>
</tr>
<tr>
<td>Left ventricular mass</td>
<td>178±31</td>
</tr>
<tr>
<td>DUR (ms)</td>
<td>106±8</td>
</tr>
<tr>
<td>RMS (µV)</td>
<td>37±26</td>
</tr>
<tr>
<td>LAS (ms)</td>
<td>32±10</td>
</tr>
<tr>
<td>Percent BMI</td>
<td>-2.4±15</td>
</tr>
</tbody>
</table>

Means±SD. DUR=filtered QRS duration; RMS=root mean square voltage in the last 40 ms; LAS=low-amplitude signal duration <40 µV; percent BMI=(personal body mass index−25)×100/25.

RESULTS

Means±SD of clinical and signal-averaged electrocardiographic characteristics are listed in Table 1. The correlation coefficients between clinical characteristics and the variables of signal-averaged electrocardiograms are shown in Table 2. QRS duration and root mean square voltage had no correlation with body height, weight, body mass index, sum of skinfolds (triceps and subcapular), or left ventricular mass. There were positive correlations between low-amplitude signals and body weight (r=0.48, p<0.002), body mass index (r=0.54, p <0.002), sum of skin folds (r=0.57, p<0.002), and percent body mass index (r=0.54, p<0.002). In 16 obese subjects with body mass index greater than 25,7 had prolonged low-amplitude signals greater than 40 ms, and 77 percent of subjects had prolonged duration of low-amplitude signals.

DISCUSSION

QRS duration, root mean square voltage, and low-amplitude signals are the variables used frequently for the quantitative definition of late potentials. Among these variables, low-amplitude signals are the only variable that employs voltage criteria for the measurement. In our study, low-amplitude signals were the only variable that was affected by body weight, body mass index, and sum of skinfolds. Among the variables related to obesity, sum of skinfolds had the biggest correlation coefficient (Fig 1). Subadipose tissue can attenuate the amplitude of the QRS complex on a surface electrocardiogram. The point of 40 µV for the calculation of low-amplitude signals may be shifted to the left with a consequent prolongation of low-amplitude signals due to the attenuation of the QRS complex related to the thickness of subadipose tissue. QRS duration also could have been influenced by the modification of onset and offset of the filtered QRS complex through the attenuation of QRS amplitudes, but in our data, shortening of QRS duration in proportion to subadipose tissue was not observed. The 40 µV points are higher than the onset and offset points. Subsequently, the influence of the attenuation by subadipose tissue might be greater in the 40-µV point, and hence affect only the low-amplitude signals (Fig 2).

QRS duration in signal-averaged electrocardiograms has been related to body characteristics.7 Danford et al5 demonstrated that QRS duration was longer in male than in female subjects. Raineri et al5,7 reported positive linear correlations between QRS duration and weight, height, or left ventricular mass. However, we could not find any of those

Figure 1. Correlation between the duration of low-amplitude signals <40 µV (LAS) and weight, body mass index (BMI), skin folds thickness, and percent BMI.
correlations. Female subjects are obviously different from male subjects in body characteristics, heart size, and proportion of subadipose tissue. To evaluate the accuracy of subadipose tissue on the variables of signal-averaged electrocardiograms, we studied a very homogeneous population, ie, normal young Japanese men.

Therefore, the range of body weight, height, and left ventricular mass was restricted compared with their results. The high homogeneity of our study population may explain the difference in the results.

In addition to the correlation between low-amplitude signals and obesity indices, the present study showed a substantial number of normal subjects with prolonged low-amplitude signals in an obese population. Although the effect of obesity was unclear in previous studies, Raineri et al reported that 16 percent of normal subjects had prolonged low-amplitude signals of more than 38 ms in their study, in which obese subjects were excluded. Surprisingly, a high incidence (78 percent) of prolonged low-amplitude signals of more than 38 ms in control subjects reported by Woelfel et al may be explained by the high incidence of obese subjects.

At the present time, there are no absolute criteria to define late potentials in signal-averaged electrocardiograms. Many studies used one or various combinations including QRS duration, root mean square voltage, and low-amplitude signals for the definition in the method of Simson. However, our study suggests that the use of low-amplitude signals alone or as a combination in an obese population for the definition of positive late potential is inappropriate.

REFERENCES

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8 Devereux RB, Alonso DR, Lutas EM, Gottlieb GJ, Reichek N. Echocardiographic assessment of left ventricular hypertrophy: comparison to necropsy findings. Am J Cardiol 1986; 57:450-58