Sex and Age Differences in Ventricular Gradient

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Sex and age differences of ventricular gradient ($\hat{G}$) were analyzed and normal ranges were determined in normal Japanese subjects (120 men and 74 women), whose resting heart rate was within the range of 65 to 75 beats/min. Women showed a larger Z component in $\hat{A}T$ and a smaller Y and larger Z component in $\hat{G}$ than men. The common trend in age differences was a decrease in Y component of $\hat{G}$ in both men and women. The ranges obtained in the present study can be applied in automatic VCG analysis, in particular for the differentiation of primary and secondary ST-T changes.

Key words: Frank VCG, Primary ST-T changes, Secondary ST-T changes, Normal ranges, Automatic VCG analysis

Ventricular gradient ($\hat{G}$), a vectorcardiographical concept proposed by Wilson et al (1), has been applied to distinguish primary and secondary ST-T changes. Recently, it was reported that $\hat{G}$ is useful for the detection of the severity of coronary artery disease (2). Although the usefulness of $\hat{G}$ has been noted, few reports discussed sex or age differences or normal ranges in the normal Japanese population (3). The present study was designed to evaluate the sex and age differences of $\hat{G}$ and establish the normal ranges in the Japanese population.

MATERIALS AND METHODS

The Japanese population studied consisted of 194 apparently healthy Japanese volunteers (120 men and 74 women) evaluated at Nagoya University Hospital. On the basis of history and routine physical and laboratory examinations, they were screened for detectable disease which might have an affect on ventricular gradients. They were grouped into 8 groups according to sex and age: the third decade (M-20: 30 men, F-20: 30 women), the fourth decade (M-30: 30 men, F-30: 23 women), the fifth decade (M-40: 30 men, F-40: 13 women), and the

sixth decade (M-50: 30 men, F-50: 8 women).

Frank X • Y • Z scalar ECGs were recorded on a magnetic tape, which was reproduced and converted to 10-bit digital form at 500-Hz sampling frequency and stored in the core memory of JEC-6 computer. For measurements, the P-P line was designated as the baseline, and beats with a preceding R-R interval of 800 to 925 ms [heart rate of 65 to 75 beats/min (bpm)] were selected.

The beginning of P, and the end of QRS and T were automatically recognized using the spatial velocity and magnitude curves, and incorrect point recognition was corrected manually. The orthogonal components of $\hat{A}QRS$, $\hat{A}T$ and $\hat{G}$ were calculated (Fig. 1), where $\hat{A}QRS$ and $\hat{A}T$ are three-dimensional vectors with a magnitude given by the area between the respective deflection and the baseline, and $\hat{G} = \hat{A}QRS + \hat{A}T$ (4). The beginning and end of QRS complex and T wave were taken as the earliest or latest deflection from the baseline in any one of the 3 orthogonal leads. In rectilinear coordinate axes of the body, posterior (Z), downward (Y), and leftward (X) directions were designated as positive.

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Fig. 1. Measurements of ventricular gradient. $\hat{A}_{QRS}$, area of the ventricular depolarization (including the P wave and PQ interval); $\hat{A}_T$, area of the repolarization (including the ST interval); ventricular gradient ($\hat{G}$), the sum of $\hat{A}_{QRS}$ and $\hat{A}_T$. The integral of the area was calculated on a digital computer according to the equation: $\hat{A} = \int f(t)dt$

STATISTICAL ANALYSIS

Data were expressed as the mean $\pm$ SD. Sex and age differences of the three orthogonal components of $\hat{A}_{QRS}$, $\hat{A}_T$ and $\hat{G}$ were assessed by univariate one-way layout analysis of variance. Sex and age differences in $\hat{A}_{QRS}$, $\hat{A}_T$ and $\hat{G}$ between 8 groups were assessed by multivariate one-way layout analysis of variance. Sheffé's method (5) was employed when the analysis of variance indicated that there was an inter-group difference.

RESULTS

The means and SDs of heart rate for 8 groups were 70 ± 3 bpm for M-20, 70 ± 2 bpm for M-30, 71 ± 2 bpm for M-10, 69 ± 3 bpm for M-50, 70 ± 3 bpm for F-20, 70 ± 4 bpm for F-30, 69 ± 4 bpm for

F-40, 69 ± 5 bpm for F-50. There was no difference in heart rate among the 8 groups. Tables 1 to 3 list the means, SDs and ranges for the three orthogonal components of $\hat{A}_{QRS}$, $\hat{A}_T$ and $\hat{G}$. In Table 4, the means, SDs and ranges of the three polar coordinates in $\hat{G}$ are given. Significant sex and age differences in the three orthogonal components for $\hat{A}_{QRS}$, $\hat{A}_T$ and $\hat{G}$ are indicated in Table 5, and those in the vectors $\hat{A}_{QRS}$, $\hat{A}_T$ and $\hat{G}$ are in Table 6.

1. Sex differences

There was no significant sex difference in the three components of $\hat{A}_{QRS}$ (Table 5). In X and Y components of $\hat{A}_T$, there was no sex difference, but in Z component of $\hat{A}_T$ women showed larger mean values ranging from -24.3 to $-4.5 \mu V$ s compared to -41.3 to $-47.0 \mu V$ s in men (Table 2). There was also no sex difference noticed in X component of $\hat{G}$. However, Y and Z components of $\hat{G}$ (Table 5) showed a significant sex difference, the former being from 61.0 to $40.5 \mu V$ s in women and 70.9 to $54.1 \mu V$ s in men, and the latter being -23.5 to $2.3 \mu V$ s in women and -37.7 to $-29.5 \mu V$ s in men (Table 3). As a vector, there was significant sex difference noticed in $\hat{A}_{QRS}$, $\hat{A}_T$ and $\hat{G}$ (Table 6).

2. Age differences

In men there was no significant age difference in the three orthogonal components of $\hat{A}_{QRS}$, $\hat{A}_T$ and $\hat{G}$ (Table 5). However, as a vector, an age difference was noticed in $\hat{A}_{QRS}$ between 20 and 50 yr, in $\hat{G}$ between 20 and 50 yr, and between 30 and

Table 1. Means, Standard Deviations and Ranges of Three Orthogonal Components of $\hat{A}_{QRS}$ (μV s)

Items		Men					Women				
		M-20	M-30	M-40	M-50	Total	F-20	F-30	F-40	F-50	Total
ÂQRSX	M	19.1	21.4	20.8	19.8	20.3	15.9	21.3	21.3	21.8	19.2
	SD	10.2	9.6	10.0	8.7	9.5	7.7	8.2	8.0	8.0	8.2
	Range	−2–42	5–45	8–36	5–47	−2–47	1–32	−1–32	6–32	6–29	−1–32
ÂQRSY	M	26.3	25.4	23.5	19.0	23.6	22.8	24.0	17.7	16.6	21.6
	SD	11.6	11.3	11.8	8.4	11.0	9.7	9.3	7.6	10.0	9.5
	Range	5–52	4–50	3–56	−2–33	−2–56	1–47	11–39	3–30	2–29	1–47
ÂQRSZ	M	13.3	8.2	9.3	6.0	9.2	5.5	0.6	2.6	6.6	3.6
	SD	10.4	8.4	13.6	12.8	11.6	6.7	7.0	10.0	7.8	7.9
	Range	−8–32	−8–24	−22–30	−19–31	−22–32	−10–18	−12–14	−14–18	−4–18	−14–18

$\hat{A}_{QRSX}$, $\hat{A}_{QRSY}$ and $\hat{A}_{QRSZ}$ are X, Y and Z components of $\hat{A}_{QRS}$, respectively.

Table 2. Means, Standard Deviations and Ranges of the Orthogonal Components of $\hat{A}T$ (μV s)

Items		Men					Women				
		M-20	M-30	M-40	M-50	Total	F-20	F-30	F-40	F-50	Total
$\hat{A}TX$	M	48.1	42.7	41.9	40.9	43.4	34.9	41.9	31.3	41.9	37.2
	SD	21.0	15.6	14.2	17.2	17.1	11.7	18.0	14.0	12.3	14.8
	Range	-2-100	10-76	8-63	10-87	-2-100	11-55	10-75	13-59	26-61	10-75
$\hat{A}TY$	M	43.0	45.4	43.3	35.0	41.8	36.7	37.0	22.9	32.1	33.9
	SD	17.8	15.8	22.0	18.0	18.7	9.3	17.0	9.9	7.1	13.0
	Range	5-77	21-84	1-89	-4-61	-4-89	18-59	-4-64	4-38	19-43	-4-64
$\hat{A}TZ$	M	-42.8	-46.7	-47.0	-41.3	-44.4	-13.7	-24.3	-17.7	-4.5	-16.7
	SD	24.3	23.0	25.2	20.2	23.0	11.1	11.0	20.8	20.1	15.3
	Range	-108-1	-81-1	-102-8	-78-2	-108-2	-40-6	-38-0	-58-29	-31-26	-58-29

$\hat{A}TX$, $\hat{A}TY$ and $\hat{A}TZ$ are X, Y and Z components of $\hat{A}T$, respectively.

Table 3. Means, Standard Deviations and Ranges of Three Orthogonal Components of $\hat{G}$ (μV s)

Items		Men					Women				
		M-20	M-30	M-40	M-50	Total	F-20	F-30	F-40	F-50	Total
$\hat{G}X$	M	63.3	64.4	62.8	60.8	62.8	50.7	63.0	52.8	63.6	56.3
	SD	23.1	21.9	19.3	20.8	21.0	15.9	21.1	16.9	12.1	18.2
	Range	12-118	21-112	22-98	16-115	12-118	21-87	31-97	31-79	48-82	21-97
$\hat{G}Y$	M	69.3	70.9	66.5	54.1	65.3	59.4	61.0	40.5	48.7	55.5
	SD	20.0	18.5	27.2	19.9	22.8	13.7	18.3	14.3	15.0	16.9
	Range	11-111	41-112	9-122	1-84	1-122	30-91	31-91	13-61	24-73	13-91
$\hat{G}Z$	M	-29.5	-37.7	-37.5	-35.3	-35.0	-8.2	-23.5	-15.2	2.3	-13.1
	SD	30.0	26.3	25.0	24.9	25.3	13.7	11.3	19.3	24.5	17.4
	Range	-78-14	-89-10	-76-3	-83-14	-89-14	-36-12	-41-1	-49-27	-26-44	-49-44

$\hat{G}X$, $\hat{G}Y$ and $\hat{G}Z$ are X, Y and Z components of $\hat{G}$, respectively.

Table 4. Means, Standard Deviations and Ranges of Three Polar Coordinates in $\hat{G}$

Items	Men					Women				
	M-20	M-30	M-40	M-50	Total	F-20	F-30	F-40	F-50	Total
Azimuth (degree)										
M	23.5	29.4	29.3	26.3	27.1	8.3	20.3	12.6	−2.5	11.6
SD	20.8	18.8	16.4	20.6	19.1	13.3	10.9	21.5	19.7	16.4
Range	−16–69	−18–57	−3–59	−41–59	−41–69	−18–35	1–42	−40–47	−28–24	−40–47
Elevation (degree)										
M	46.3	47.3	49.5	53.1	49.0	41.4	47.8	55.4	53.0	47.0
SD	12.6	10.6	12.3	11.9	12.0	10.0	9.1	7.9	5.8	10.5
Range	20–81	18–65	27–79	21–89	18–89	15–57	31–59	43–73	46–61	15–73
Magnitude (μ Vs)										
M	105.3	107.3	103.3	92.5	101.7	80.7	92.6	71.3	79.6	82.6
SD	25.0	23.0	30.0	27.1	26.7	16.2	24.4	20.2	27.5	21.9
Range	64–163	52–137	35–165	56–147	35–165	55–112	60–138	43–99	21–109	21–138

Table 5. Sex and Age Difference in Three Orthogonal Components of $\hat{A}QRS$, $\hat{A}T$ and $\hat{G}$

Item	Contrast	Significance probability
$\hat{A}TZ$	1 men < women	near 0
$\hat{G}Y$	1 men > women	0.0298
$\hat{G}Z$	1 men < women	near 0

$\hat{A}TZ$, Z component of $\hat{A}T$; $\hat{G}Y$, Y component of $\hat{G}$; $\hat{G}Z$, Z component of $\hat{G}$

Table 6. Sex and Age Difference in $\hat{A}QRS$, $\hat{A}T$ and $\hat{G}$

Item	Contrast	Significance probability
$\hat{A}QRS$	1. Men vs Women	0.0017
	4. M-20 vs M-50	0.0012
	9. F-20 vs F-40	0.0259
	10. F-20 vs F-50	0.0315
$\hat{A}T$	1. Men vs Women	near 0
$\hat{G}$	1. Men vs Women	near 0
	4. M-20 vs M-50	0.0127
	5. M-30 vs M-50	0.0147
	8. F-20 vs F-30	0.0303
	9. F-20 vs F-40	0.0110
	10. F-20 vs F-50	0.0380
	11. F-30 vs F-40	0.0293
	12. F-30 vs F-50	0.0191

50 yr (Table 6).

In women there was a significant age difference in $\hat{A}QRS$ between 20 and 40 yr, and 20 and 50 yr, although no difference was seen in $\hat{A}T$. A significant age difference was noticed in $\hat{G}$ except between 40 and 50 yr (Table 6).

DISCUSSION

1. Sex differences

The present study demonstrated a significant sex difference. Women had a larger Z component or $\hat{A}T$ and a smaller Y and larger Z component of $\hat{G}$ than men (Table 5). $\hat{A}QRS$, $\hat{A}T$ and $\hat{G}$ showed significant sex differences, women having smaller anterior and inferior components of $\hat{G}$ than men. $\hat{A}T$ also showed the same tendency as seen in $\hat{G}$, indicating that $\hat{G}$ was affected by $\hat{A}T$. The results presented here were similar to observations reported by Mashima et al

(3). They demonstrated that $\hat{A}QRS$ in men is more posterior, and $\hat{A}T$ and $\hat{G}$ more anterior, and that the magnitude of $\hat{G}$ is larger in men than in women.

Many previous studies have shown a significant sex difference in various VCG parameters. Women are reported to have QRS and T loops of smaller magnitude than men (6–9). The mechanisms of sex differences in ECG and VCG have not yet been fully elucidated. This must be studied from the difference in the various factors affecting the cardiac generator and the lead vector (6). The smaller magnitude of the QRS and T loops in women might be explained by the smaller heart size, absolute as well as relative to the body weight (10, 11). Breast adipose tissues or the shape of the female torso may be some of the factors accounting for the smaller ECG magnitude in women. However, differences in chest configuration are less likely to be the cause of the smaller ECG magnitude according to Simonson et al who demonstrated sex differences in QRS complexes in V2, V5 and V6 (12). Higher skin impedance may be one reason for the smaller Y components of $\hat{G}$ in women (13). However, the reason why Z component of $\hat{G}$ was larger and $\hat{G}$ was oriented less anteriorly in women than men is unclear.

2. Age differences

Although there tended to be some age differences in $\hat{G}$ between men and women, the common trend was a decrease in Y components of $\hat{G}$. This may correspond with the finding of a leftward shift of $\hat{G}$. As suggested by some investigators, increasing relative body weight (14) and a leftward shift of the heart with age seems to be the main factor in the decrease of the Y component of $\hat{G}$.

3. Normal ranges

The present study showed that sex and age differences were more clearly demonstrated by a vector than by vector components. $\hat{G}$, which is originally a vector, must be analyzed as a vector. However, the age difference was not noticed as orthogonal components, so in clinical use the combined ranges from 20 to 50 yr could be applied.

$\hat{G}$ has been used to diagnose myocardial ischemia. In spite of a significant sex difference, sex-adjusted ranges have not yet been used in clinical practice. Diagnostic accuracy for primary ST-T changes will likely be improved with sex-adjusted normal criteria for $\hat{G}$. In many reports, spatial polar

coordinates have been used to analyze $\hat{G}$. In the present study, means, SDs and normal ranges for the three polar coordinates were also presented (Table 4).

Since the orthogonal components of $\hat{G}$ were reported to decrease as the heart rate increases (3, 15), the data presented can only be applied when the heart rate is within the range of 65 to 75 bpm. These ranges are expected to be useful as normal ranges for more reliable VCG diagnosis.

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