Long-Term Follow-up in Japanese Public Office Workers of the Influence of Blood Pressure on ECG Changes

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Background The relationship between annual changes in blood pressure (BP) and the electrocardiogram (ECG) was studied to clarify what factors give early detection of complications and predict the outcome of therapy.

Methods and Results The influence of BP on the ECG was assessed in 830 Japanese office workers. Those with hypertension (HT) more frequently developed left atrial and ventricular overload compared with normotensive subjects. In addition, those with borderline HT (systolic pressure 140–160 mmHg and/or diastolic pressure 90–95 mmHg) and even those with lower blood pressure (systolic pressure 130–140 mmHg and/or diastolic pressure 85–90 mmHg) developed left atrial and ventricular overload more frequently than normotensive subjects.

Conclusions Based on these results, BP should be closely followed up when routine systolic and diastolic pressure levels exceed 130 mmHg and 85 mmHg, respectively, in persons in their 40s to 50s and the goal of antihypertensive therapy should be lower than reported previously. (*Circ J* 2004; 68: 563–567)

Key Words: Atrial overload; Blood pressure; ECG; Hypertension; Left ventricular hypertrophy

Left ventricular hypertrophy is a serious complication of sustained elevation of blood pressure (BP); the Framingham study demonstrated the increased risk for mortality, incidence of heart failure and occurrence of cardiovascular complications¹ and epidemiologic studies have shown that BP should be controlled to prevent complications.^{2–5} There is little information on the association between changes in BP and development of ventricular hypertrophy from analysis of the serial changes of the electrocardiograms (ECGs) in Japanese volunteers,⁶ so we studied the relationship between annual changes in BP and the ECG in order to clarify what factors give early detection of complications, and can predict the outcome of therapy. We also studied the influence of borderline or high normal BP on the ECG to determine the goal of antihypertensive therapy.

Methods

This study included 830 subjects aged 35 years or more (564 men and 266 women, mean: 47.6±8.5 years) who underwent the annual check up of office workers in Tokushima City, Japan. We used data from 1985 to 1995 for this retrospective study. Subjects who did not undergo a medical check up because they had moved offices were excluded from the present study. Prior to participation in the study, all subjects gave their written informed consent

and ethical approval. Although dietary and medical treatment was strongly recommended for the hypertensive subjects, BP could not be controlled in some subjects.

Blood pressure was measured from the right forearm once a month using a mercury sphygmomanometer and the averaged BP was used as the representative BP in the fiscal year. The diagnosis of hypertension (HT) was based on the World Health Organization–International Society of Hypertension (WHO/ISH) guideline.⁷ The ECG (FX-323, Fukuda Denshi Co, Ltd, Tokyo, Japan) was recorded in a supine position, and the ECG diagnosis was classified according to Minnesota cords, and the terms ‘left atrial overloading, ST-T change, rhythm abnormality, right bundle branch block and left ventricular hypertrophy’ were used.⁸ The average BP from the initial to the final year of the study and age in the final year are shown in Table 1.

By occupational category, the subjects were engaged in clerical and managerial work. The control group consisted of healthy persons who did not have signs of HT on the ECG or in the urine in their mass screening data for the past 5–10 years. Sixty-four subjects (7.7%) showed elevated BP in the 1985 mass screening (ie, systolic and diastolic pressures were, respectively, 140 mmHg and/or 90 mmHg or more).

The averaged systolic and diastolic BP of each year were investigated retrospectively from the records of the subjects who were then classified according to BP. The Control group (278 cases, 46.9±8.1 years old) had systolic pressure ≤129 mmHg or diastolic pressure ≤84 mmHg. The H-0 group (321 cases, 49.5±5.1 years old) had upper normal BP: average values of systolic and diastolic pressure were 130–140 mmHg and/or 85–90 mmHg, respectively (high-normal BP). This group was specially defined to determine the goal of antihypertensive therapy. The H-1 group (162 cases, 49.1±6.5 years old) had systolic pressures of 140–159 mmHg and/or diastolic pressures of 90–94 mmHg, which corresponds to ‘grade 1 HT’ according to the

(Received June 18, 2003; revised manuscript received March 8, 2004; accepted March 19, 2004)

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Table 1 Incidence of Hypertension by Age and Blood Pressure

	Age (years)					
	≤34	35–39	40–44	45–49	50–54	≥55
No. of subjects	29	206	171	94	201	129
SBP (mmHg)						
≤119	41.4	38.3	33.9	30.9	20.9	21.2
120–139	58.6	48.1	41.5	42.6	50.2	29.7
140–159	0.0	12.1	22.2	23.4	22.4	39.0
≥160	0.0	1.5	2.3	3.2	6.5	10.2
DBP (mmHg)						
≤84	100.0	85.9	70.2	73.4	65.2	59.3
85–89	0.0	4.9	5.8	10.6	9.5	10.2
90–94	0.0	6.3	16.4	11.7	14.9	19.5
≥95	0.0	2.9	7.6	4.3	10.5	11.0

** $p<0.01$ vs each age subject.

SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 2 Incidence of Abnormal ECG Findings by Age in the Final Year of the Study

	Age (years)					
	≤34	35–39	40–44	45–49	50–54	≥55
No. of subjects	29	206	171	94	201	129
No. of abnormal findings per subject	0.38	0.26	0.25	0.31	0.31	0.47
Left atrial overload (%)	3.0	4.9	5.8	8.5	10.4 [†]	10.0 [†]
ST-T changes (%)	0	4.9	4.7	6.4	8.0	14.7
Abnormal rhythm (%)	3.8	2.4	2.3	2.1	3.5	7.0
Right bundle branch block (%)	3.4	3.4	1.2	3.2	3.0	5.4
Left ventricular hypertrophy (%)	3.4	1.5	2.9	2.1	2.5	3.1
Other (%)	6.8	7.2	7.7	6.4	5.4	6.2
No finding	82.4	80.6	75.7	72.3	69.7	55.1

** $p<0.01$, * $p<0.05$ vs each age subject, [†] $p<0.05$ vs subjects under 44 years of age.

WHO/ISH guideline⁷ The H-2 group (69 cases, 50.1±6.8 years old) had systolic pressures ≥160 mmHg or diastolic pressures ≥90 mmHg.

On the day of the 1985 mass screening, the mean age was 48.3±5.3 years in the Control group, 50.8±4.9 years in the H-0 group, 49.9±5.1 years in the H-1 group, and 50.4±6.1 years in the H-2 group. The same subjects were surveyed by questionnaire about the presence or absence of treatment of HT, eating habits, exercise and their health condition in October 1986. Changes in the ECG, past history and body weight were also obtained from the individual mass screening records. The degree of obesity was calculated on the basis of the 1985 standard body weights determined by the Japanese Ministry of Health and Welfare.

There were no differences among the control and 3 hypertensive groups in terms of age in follow-up period (7.4±1.9 years in the control group, 7.8±1.7 years in the H-0 group, 6.9±1.7 years in the H-1 group and 7.3±1.9 years in the H-2 group). The proportion of subjects who had been treated by antihypertensive agents was 16.7% in H-0 group, 33.3% in H-1 group, and 77.8% in H-2 group.

All data are expressed as means±SD. Data obtained at the respective measurement points were compared using ANOVA. A comparison between 2 groups was performed using an unpaired t-test and chi-square test, and $p<0.05$ was considered significant. Data analysis was performed using StatView statistical software (Stat View 5.0, SAS Institute, Inc, Cary, NC, USA).

Results

Incidence of HT

Table 1 shows the distribution of subjects in each BP category. Both systolic and diastolic pressures rose with age and significant differences among the age groups were observed in H-1 group. BP tended to rise step-wise in subjects in their 40s and late of 50s.

Incidence of ECG Abnormalities

Table 2 shows the incidence of ECG abnormalities in each age group. Left atrial overload increased in subjects over 50 years of age, and ST-T changes and arrhythmias were significantly more frequent in subjects in their late 50s or older. The number of abnormal findings per subject increased over 55 years of age.

Relation Between ECG Abnormalities and BP

Table 3 shows the incidence of ECG abnormalities by BP category. Left atrial overload, ST-T changes and left ventricular hypertrophy increased with BP, and significant differences in these findings were noted among the BP groups. The percentages of subjects with no abnormal findings decreased as BP rose.

Annual Changes in the ECG

Table 4 shows the correlation between BP and ECG changes. The ECGs of the hypertensive group tended to show more abnormal findings, even in the initial year. The

Table 3 Incidence of Abnormal ECG Findings by Blood Pressure Level in the Final Year of the Study

	Group			
	Control	H-0	H-1	H-2
SBP/DBP (mmHg)	≤129/≤84	130–139/85–89	140–159/90–94	≥160/≥95
Age (years)	46.9±8.1	49.5±5.1	49.1±6.5	50.1±6.8
No. of subjects	278	321	162	69
No. of abnormal findings per subject	0.26	0.25	0.33	0.64
Left atrial overload (%)	6.1	5.3	11.7	14.5
ST-T changes (%)	4.0	5.3	10.5	20.3
Abnormal rhythm (%)	5.4	3.4	1.2	2.9
Right bundle branch block (%)	3.2	3.7	1.9	2.9
Left ventricular hypertrophy (%)	0.7	1.2	3.7	11.6
Other (%)	7.6	6.5	3.7	11.6
No finding	75.9	78.2	67.3	49.3

***p*<0.01, **p*<0.05 vs each age subject.

SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 4 Correlations Between Blood Pressure and ECG Changes

	<129/84 mmHg	≥130/85 mmHg		
Mean blood pressure level by year (mmHg)	≤129/≤84 (control/group)	130–139/85–89 (H-0 group)	140–159/90–94 (H-1 group)	≥160/≥95 (H-2 group)
Age in final year (years)	48.3±5.3	50.8±4.9	49.9±5.1	50.4±6.1
No. of subjects	278	321	162	69
Blood pressure at initial year				
Systolic pressure (mmHg)	116.0±8.0	120.8±8.6 ^{†††}	132.1±8.8 ^{†††}	138.4±10.0 ^{†††}
Diastolic pressure (mmHg)	68.6±6.7	80.1±6.6 ^{†††}	84.0±6.8 ^{†††}	86.9±6.8 ^{†††}
Blood pressure at final year				
Systolic pressure (mmHg)	118.3±8.3	134.1±9.8 ^{†††}	144.1±9.0 ^{†††}	156.7±18.3 ^{†††}
Diastolic pressure (mmHg)	72.9±6.6	82.3±6.9 ^{†††}	89.1±6.8 ^{†††}	95.2±7.0 ^{†††}
Initial year				
P-II (s)	0.076±0.012	0.085±0.021 [†]	0.087±0.019 [†]	0.084±0.023 [†]
R-V ₅ (mm)	16.7±4.3	16.9±4.6	19.4±4.6 [†]	19.3±4.2 [†]
R-V ₆ (mm)	12.6±3.0	13.8±5.8	15.0±3.9 [†]	15.1±4.4 [†]
S-V ₁ (mm)	10.4±4.1	10.0±3.9	10.4±3.7	11.6±4.2
T-V ₅ (mm)	5.5±1.7	4.0±2.0	5.5±2.8	4.6±2.6
SV ₁ +RV ₅ (mm)	26.6±5.6	29.6±6.7 [†]	29.8±5.4 [†]	30.7±7.1 [†]
T/R V ₅	0.36±1.80	0.24±0.11	0.30±0.15	0.24±0.13
Final year				
P-II (s)	0.080±0.000	0.086±0.023	0.087±0.024	0.089±0.026
R-V ₅ (mm)	15.0±3.4	16.6±5.5	19.3±4.8 ^{†††}	19.0±5.5 [†]
R-V ₆ (mm)	11.0±2.3	13.4±5.2 [†]	14.8±5.0 ^{††}	14.2±4.9 [†]
S-V ₁ (mm)	9.3±3.7	8.2±3.4	10.9±4.7	11.8±4.9
T-V ₅ (mm)	5.0±1.6	3.9±2.4	4.3±2.3	3.5±2.3
SV ₁ +RV ₅ (mm)	24.3±5.9	24.8±6.6	30.2±7.1 ^{†††}	30.9±7.1 ^{††}
T/R V ₅	0.34±0.11	0.24±0.12 ^{††}	0.24±0.09 ^{†††}	0.22±0.10 ^{††}

[†]*p*<0.05, ^{††}*p*<0.01, ^{†††}*p*<0.001 vs control group, **p*<0.05, ***p*<0.01, ****p*<0.001 vs each abnormal blood pressure group.

increases in the amplitude of the R wave in leads V_{5,6}, S wave in lead V₁, and SV₁+RV₅ were greater as the BP rose. The H-1 group showed marked increases in QRS amplitude, and the H-2 group showed flattening of the T wave more frequently. The differences between the normal and H-1 and H-2 groups became more marked in the final year than in the initial year.

The annual changes in the wave patterns of the hypertensive groups were significantly different from those in the control group. The P waves became wider with or without notches as the BP rose in the control and the hypertensive groups. All the values determined in the normal group were lower, except for R waves in lead I, because the ECG trac-

ings became smaller with age.

The annual changes in the amplitude of the T wave and T/R ratio in lead V₅ showed that the T waves were lower in the hypertensive groups than in the control group and there was reduction of the T/R with increased BP. The T wave decreased with age, and the decrease was marked in the H-1 and H-2 groups.

Body Weight and BP

Table 5 shows the average weight at 20 years of age and in the final year of the study in the hypertensive and control groups. The hypertensive subjects were more obese than those in the control group. They had weight gains of 9.3±

Table 5 Averaged Weight at 20 Years of Age and in the Final Year of the Study in the Hypertensive and Control Groups

Group	20 years old	Final year	ΔBW	<i>p</i> value
Control (n=278)				
Body weight (kg)	54.8 $\pm$ 6.7	61.9 $\pm$ 5.7	7.1 $\pm$ 2.4	<0.05
BMI	21.4 $\pm$ 2.6	24.1 $\pm$ 2.9		<0.05
H-0 (n=321)				
Body weight (kg)	56.7 $\pm$ 8.4	64.9 $\pm$ 9.7	8.2 $\pm$ 2.1	<0.05
BMI	22.3 $\pm$ 2.4	25.5 $\pm$ 3.0		<0.05
H-1 (n=162)				
Body weight (kg)	56.4 $\pm$ 8.5	65.4 $\pm$ 9.8	9.0 $\pm$ 3.1	<0.01
BMI	22.9 $\pm$ 2.1	26.6 $\pm$ 3.4		<0.01
H-2 (n=69)				
Body weight (kg)	56.1 $\pm$ 8.1	65.8 $\pm$ 9.4	9.7 $\pm$ 3.9	<0.005
BMI	23.5 $\pm$ 2.5	27.6 $\pm$ 3.3		<0.005

ΔBW (kg) = (body weight in final year) – (body weight at 20 years old).

p value = (20 year old level) vs (Final year level). mean $\pm$ SD.

BMI, body mass index.

4.4 kg and a maximum of 20.0 kg, whereas the control group had a 7.1 $\pm$ 3.2 kg weight gain (p <0.05 vs hypertensive group) and a maximum of 15.0 kg weight change.

Discussion

In a study of Hisayama-cho^{9–12} multivariate analysis of the risk factors for cerebral arteriosclerosis revealed that age was the most significant risk factor, followed by BP and an abnormal ECG. The hypertensive groups in the present study showed ECG changes accompanied by pressure overload of the left ventricle, left atrial overload, and a flattening of the T wave, and these changes were marked in the H-2 group, followed by the H-1 group and the H-0 group, suggesting that left atrial overload and left ventricular hypertrophy seemed to develop as BP rose. The QRS amplitude, however, tended to decreased in the H-0 group, which is a physiological change accompanying aging, as it was also seen in the control group.¹² The analysis of the annual ECG changes revealed that the QRS amplitude in the H-1 and H-2 groups was higher than in the control group. Interestingly, the H-0 group, in particular, showed significant differences from the control group in many findings and showed worsening of the ECG findings with time, although the BP levels were clinically within the normal range. As shown in Table 3, there is no significant difference in age among the BP groups and there is no influence on the ECG changes by aging.

The control group remained at normal BP levels throughout the follow-up period, but the H-0 group had mean levels above the upper limit of normal. There were significant differences between the H-0 group and the control group for many ECG findings and the levels in the H-0 group may not be ideal.

According to the BP classification of the US Joint Committee,² diastolic pressures within the range of 85 to 89 mmHg are classified as 'high normal' and differentiated from normotension. The subjects in the H-0 group had systolic pressures of 130–140 mmHg and diastolic pressures of 80–90 mmHg, but no definite measures to control this condition have been established, partly because there have only been a limited number of epidemiological clinical studies. Our findings, however, strongly suggest the importance of BP control even in these ranges.

Some reports in Western countries, where the eating habits and disease structure are different from those in Japan, have also suggested that BP levels approximately

the same as those stated earlier are normal. The mean degree of obesity was significantly higher in the H-0 and H-1 groups than in the control group. There was no significant difference between the H-2 group and the control group because the H-2 group included both obese and emaciated persons. Obese persons tend to have HT;^{14,15} interestingly, in the present subjects the increase in body weight since their 20s was significantly greater in the hypertensive groups than in the control group.

It is reported that obesity causes HT by increasing the circulating blood volume, creating insulin resistance and acceleration of sympathetic nervous activity by various cytokines from fat cells.¹⁶ Moreover, an excessive intake of salt induces HT. Obesity is a risk factor for various lifestyle related diseases¹⁷ and in the present study, it was closely related with HT. Prevention of obesity can control the progress of HT.

Many clinical studies in Western countries, including a Veterans Affairs study,¹⁸ have confirmed that antihypertensive drugs should be used to prevent the onset and development of cardiovascular complications.^{19–22} However, there have been only a limited number of studies in the Japanese population and in the present study the proportions of subjects who had been treated with antihypertensive drugs were 16.7%, 33.3% and 77.8% in the H-0, H-1 and H-2 groups, respectively.

Although left atrial overloading and left ventricular hypertrophy were increased in subjects with high-normal BP, an increase in the cardiovascular events was not observed. However, it has been suggested that it is necessary to control the BP to a lower value because cardiac overloading is more frequently seen in patients with high-normal BP.²³ In the present study, ECG changes were seen in subjects with high BP, even though hypertensive treatment had been received, suggesting that strict BP control is required.

The goal of antihypertensive therapy is usually approximately 140/90 mmHg, in accordance with the WHO standard⁷ but some have suggested that diastolic pressure should be under 85 mmHg.²⁴ Based on the results from the present H-1 and H-2 groups as well, the goal of antihypertensive therapy should be lowered. The H-0 included some subjects whose BP was improved by hypertensive therapy, but the majority were showing BP elevation and their BP should be controlled as well.

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