Relation of Circulating Blood Volume to Left Ventricular Geometry in Essential Hypertension

Kotaro YASUMOTO, Masanobu TAKATA, Hitoshi UENO, Fumihiro TOMODA, and Hiroshi INOUE

To investigate whether circulating blood volume contributes to left ventricular (LV) geometry, 60 outpatients with untreated, mild to moderate essential hypertension and 45 normotensives were studied. Based on echocardiographic LV mass index and relative wall thickness, four patterns of LV geometry, i.e., normal left ventricle, concentric remodeling, eccentric hypertrophy and concentric hypertrophy, were identified. Plasma volume and blood volume were measured by the $^{131}$I labeled human serum albumin technique. LV end-diastolic volume was greater in patients with eccentric hypertrophy than in the groups of patients with normal left ventricles, concentric remodeling, or concentric hypertrophy or in normotensive subjects. No differences were found in systolic function among the five groups. Both plasma volume and blood volume were decreased in the concentric remodeling group as compared with the other four groups. However, there were no differences in plasma volume or blood volume among the normal left ventricle, eccentric hypertrophy and concentric hypertrophy groups. These data indicate that a small LV chamber in cases of “concentric remodeling” may be related to decreased plasma and blood volumes, but an enlarged LV chamber in cases of “eccentric hypertrophy” is not likely to be related to either plasma or blood volume levels in mild to moderate untreated essential hypertension. (Hypertens Res 2002; 25: 703–710)

Key Words: blood volume, left ventricular geometry, essential hypertension

Introduction

Hypertensive left ventricular hypertrophy (LVH) is generally thought to be an important adaptive response to chronic pressure overload (1, 2). The left ventricular (LV) wall thickening compensates for the elevated arterial pressure and maintains a normal wall stress, thus enabling the left ventricle to eject a normal stroke volume against a high peripheral resistance (3). According to this model of the response to pressure overload, it is expected that the change in LV geometry would be uniform among hypertensive patients. However, hypertensive patients show a variety of forms of LV geometry, including normal LV geometry, concentric remodeling, eccentric hypertrophy and concentric hypertrophy, suggesting that not only pressure load but also other hemodynamic or nonhemodynamic factors may contribute to the LV geometry. A recent study has shown that abnormal LV geometries, especially concentric hypertrophy, are associated with a higher level of cardiovascular morbidity and mortality as compared with normal LV geometry (4). Therefore, it seems important to elucidate the determinants of the LV geometric pattern in the management of patients with hypertension.

A variety of hemodynamic and nonhemodynamic stimuli have been suggested to play a role in hypertension-associated LVH, including: arterial pressure or volume load (1), arterial stiffness (5), catecholamines (6), the renin-angiotensin system (7), genetic background (8), insulin sensitivity (9), and body size or obesity (10, 11). These hemodynamic and nonhemodynamic stimuli may contribute to the wide spectrum of LV geometric patterns in hypertension. Though LV geometric patterns are generally identified by echocarbo-
graphic LV mass index (LVMI) and relative wall thickness (RWT) (4), both LVMI and RWT could be affected by LV wall thickness and/or LV chamber size. Previous studies have shown that LV chamber size and LV mass are associated with volume load. For example, intravascular volume was found to be a major discriminator for LV chamber volume and LV mass (12). LV mass has shown a better correlation with LV end-diastolic volume than with systolic blood pressure (13), and plasma volume and systolic blood pressure have been shown to be independent determinants of LV mass (14). However, little is known about the relation of circulating blood volume to LV geometric patterns in hypertension. Recently, we observed that production of plasma brain and atrial natriuretic peptides, an indicator of LV hypertrophy and LV dysfunction due to pressure and/or volume overload, and myocardial ischemia were increased in hypertensive patients with concentric hypertrophy, but not in patients with eccentric hypertrophy in whom LV chamber size was enlarged and LV systolic function was decreased (15). The present study was therefore designed to investigate whether circulating blood volume would contribute to LV geometric patterns in essential hypertension.

Subjects and Methods

Patients

Sixty outpatients with untreated essential hypertension were studied after giving their informed consent. Patients were entered into the study if their systolic blood pressure (SBP) was >160 mmHg and/or their diastolic blood pressure (DBP) ranged from 90 to 114 mmHg on three separate occasions. There were 31 men and 29 women ranging in age from 27 to 71 years (mean ± SD: 48 ± 10 years). Patients with heart failure, valvular disease, hepatic disease, renal disease or diabetes mellitus were excluded from the study. All patients underwent routine investigations, including assays of serum electrolytes, serum creatinine, blood urea nitrogen, and fasting blood glucose level, a liver function test, urinalysis, chest roentgenography, and electrocardiography. All patients had serum creatinine <1.2 mg/dl and a normal urinalysis. The diagnosis of essential hypertension was made by physical examination, routine laboratory investigations, and endocrinological studies according to the WHO guidelines (16). Blood pressure was measured using a standard cuff and sphygmomanometer after resting for 5 to 10 min in the sitting position.

Forty-five age- and gender-matched normotensive subjects served as controls (26 men and 19 women; age range, 27 to 68 years; mean age, 46 ± 19 years).

Protocol

Prior to the study, patients were instructed to eat a normal diet (NaCl 8–10 g daily), avoiding either very high or very low sodium intake. On the day of the study, patients ate a light breakfast 3 h before the investigation and abstained from caffeine, alcohol, or smoking for 12 h prior to the investigation. After patients had rested for 10 min in the supine position, conventional transthoracic echocardiography was performed. After an additional 30 min of rest, a blood sample for measurements of plasma renin activity and plasma aldosterone concentration was taken from an indwelling antecubital venous canula. The blood sample was immediately transferred into a chilled tube containing EDTA. After centrifugation at 4°C, plasma was stored at -80°C until assayed.

Echocardiography

M-mode echocardiography was performed with two-dimensional monitoring using an SSH-160A phased array ultrasonic sector scanner and LSR-20B recorder (Toshiba, Tokyo, Japan). All patients were studied in the supine or left lateral position in a quiet room. Tracings used to determine LV dimensions were recorded at or just below the tip of the mitral leaflets with transducer placement in the 3rd to 5th intercostal space at the left sternal border. Echocardiograms were read blindly by two independent observers according to the recommendation of the American Society of Echocardiography (17). LV mass (LVM) was calculated according to the formula of Devereux and Reichek (Penn convention) (18):

$$\text{LVM(g)} = 1.04[(\text{LVIDd} + \text{PWTd} + \text{IVSTD})^3 - \text{LVIDd}] - 13.6$$

where LVIDd is the LV internal dimension in diastole, PWTd is the LV posterior wall thickness in diastole, and IVSTD is the interventricular septal thickness in diastole. LVMI was derived by dividing the calculated LVM by the patient’s body surface area (BSA). RWT was calculated as

$$\text{RWT} = (\text{IVSTD} + \text{PWTd})/\text{LVIDd}$$

LV percent fractional shortening (%FS) and ejection fraction (EF) were obtained as markers of LV systolic function. %FS was calculated as

$$\%\text{FS} (%) = 100 \frac{\text{LVIDd} - \text{LVIDs}}{\text{LVIDd}}$$

where LVIDs is the LV internal dimension in systole. EF was calculated as

$$\text{EF} = (\text{LVEDV} - \text{LVESV})/\text{LVEDV},$$

where LVEDV is the LV end-diastolic volume and LVESV is the LV end-systolic volume in which volume (V) was calculated as

$$V (\text{ml}) = 7 \frac{D^3}{(2.4 + D)},$$

where D is the LV dimension (19). Stroke volume (SV) was calculated by subtracting LVESV from LVEDV. The LVEDV index (LVEDVI), LVESV index (LVESVI) and SV index (SVI) were derived by dividing the calculated LVEDV, LVESV and SV by the patient’s BSA, respectively. Cardiac output (CO) was calculated as

$$\text{CO (l/min)} = \text{SV} \times \text{HR}/1,000.$$  

The cardiac index (CI) was derived by dividing the calculated CO by the patient’s BSA. Total peripheral resistance (TPR) was calculated as

$$\text{TPR (dyn·s/cm}^5) = \text{mean BP} \times 60 \times 1.332/\text{CO},$$
where mean BP was estimated as

\[ \text{mean BP} = \text{DBP} + (\text{SBP} - \text{DBP})/3. \]

Four different patterns of LV geometry were identified by categorizing patients according to the values of LVMI and RWT (4). The cut-off values for LVMI were 111 g/m² for men and 106 g/m² for women (the upper normal limits for LVMI were estimated as 2 SD above the mean values in 45 normotensive subjects), and that of RWT was 0.44 for both genders (20, 21). These LV geometric patterns (4) consisted of a “normal left ventricle” pattern in which both LVMI and RWT were normal, a “concentric remodeling” pattern in which RWT was increased and LVMI was normal, an “eccentric hypertrophy” pattern in which LVMI was increased and RWT was normal, and a “concentric hypertrophy” pattern in which both LVMI and RWT were increased.

**Blood Volume Measurements and Assay of Neurohumoral Parameters**

Plasma volume (PV) was measured by intravenous injection of ¹³¹I human serum albumin. Blood samples were collected from an antecubital venous canula before and 10, 20 and 30 min after injection of the radio labeled albumin. Radioactivity was counted on standard and plasma samples, the background was subtracted, and PV was calculated as

\[ \text{PV (ml)} = (\text{net standard count} \cdot 4,000)/\text{net plasma count}. \]

The PV calculated for each sample was plotted against time, and the volume at zero time was measured by semi logarithmic extrapolation. Blood volume (BV) was calculated as

\[ \text{BV (ml)} = \text{PV} \cdot 100/(100 - \text{hematocrit}). \]

The PV index (PVI) and BV index (BVI) were derived by dividing PV and BV by the patient’s BSA. The plasma renin activity and plasma aldosterone concentration were determined by radioimmunoassay.

**Statistical Analysis**

Data are expressed as the means ± SD. Differences between the groups were analyzed by one-way analysis of variance followed by Bonferroni’s test. Relationships between variables were assessed using linear regression analysis. Values of \( p < 0.05 \) were considered to indicate statistical significance.

**Results**

**Clinical and Echocardiographic Characteristics**

The average SBP and DBP among the hypertensive patients were 160 ± 12 and 99 ± 7 mmHg, respectively. LVMI ranged from 63 to 215 g/m² (mean: 127 ± 30 g/m²), and RWT ranged from 0.29 to 0.67 (mean: 0.43 ± 0.09). Of the 60 patients with essential hypertension, 17 patients (28%) were included in the normal left ventricle group, 9 patients (15%) in the concentric remodeling group, 16 patients (27%) in the eccentric hypertrophy group and 18 patients (30%) in the concentric hypertrophy group (Table 1). With the exception of blood pressure, there were no differences in clinical characteristics between the four study groups and the normotensive subjects. In hypertensive patients, there were no significant differences in age, gender distribution, BSA, DBP, heart rate, hematocrit level, serum creatinine or plasma aldosterone concentration among the four groups. Plasma renin activity was suppressed, but not significantly, in the eccentric hypertrophy group. However, SBP was significantly higher in the concentric hypertrophy group than in the normal LV group (168 ± 16 vs. 153 ± 13 mmHg, \( p < 0.05 \)).

Table 2 shows echocardiographic data for the four LV geometric groups and normotensive subjects. Compared with normotensive subjects, IVSTd and PWTh were increased in

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**Table 1. Clinical Characteristics in Normotensive Subjects and Essential Hypertensive Patients with Different LV Geometries**

<table>
<thead>
<tr>
<th></th>
<th>Normotensive subjects</th>
<th>Hypertensive patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal left ventricle</td>
<td>Concentric remodeling</td>
</tr>
<tr>
<td>Numbers</td>
<td>45</td>
<td>17</td>
</tr>
<tr>
<td>Age (year)</td>
<td>46 ± 19</td>
<td>44 ± 11</td>
</tr>
<tr>
<td>Gender (male/female)</td>
<td>26/19</td>
<td>8/9</td>
</tr>
<tr>
<td>Body surface area (m²)</td>
<td>1.63 ± 0.18</td>
<td>1.66 ± 0.20</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>116 ± 22</td>
<td>153 ± 13*</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>74 ± 9</td>
<td>98 ± 10*</td>
</tr>
<tr>
<td>Mean BP (mmHg)</td>
<td>88 ± 11</td>
<td>116 ± 9*</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>71 ± 13</td>
<td>71 ± 8</td>
</tr>
<tr>
<td>Hematocrit (%)</td>
<td>41.4 ± 3.4</td>
<td>41.4 ± 4.9</td>
</tr>
<tr>
<td>Serum creatinine (mg/dl)</td>
<td>0.7 ± 0.1</td>
<td>0.8 ± 0.2</td>
</tr>
<tr>
<td>Plasma renin activity (ng/ml/h)</td>
<td>1.0 ± 1.1</td>
<td>1.2 ± 1.1</td>
</tr>
<tr>
<td>Plasma aldosterone concentration (ng/dl)</td>
<td>6.0 ± 2.2</td>
<td>8.0 ± 3.4</td>
</tr>
</tbody>
</table>

Values are mean ± SD; * \( p < 0.01 \) vs. normotensive subjects; ** \( p < 0.05 \) vs. normal left ventricle. BP, blood pressure.
Table 2. Echocardiographic Data in Normotensive Subjects and Essential Hypertensive Patients with Different LV Geometries

<table>
<thead>
<tr>
<th></th>
<th>Normotensive subjects</th>
<th>Hypertensive patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal left ventricle</td>
<td>Concentric remodeling</td>
</tr>
<tr>
<td>IVSTd (mm)</td>
<td>9.1 ± 1.5</td>
<td>10.4 ± 0.5*</td>
</tr>
<tr>
<td>PWTd (mm)</td>
<td>9.1 ± 1.3</td>
<td>10.0 ± 0.7*</td>
</tr>
<tr>
<td>LVIDd (mm)</td>
<td>45 ± 5</td>
<td>42 ± 2</td>
</tr>
<tr>
<td>LVMI (g/m²)</td>
<td>85 ± 14</td>
<td>100 ± 14</td>
</tr>
<tr>
<td>RWT</td>
<td>0.39 ± 0.06</td>
<td>0.36 ± 0.04</td>
</tr>
<tr>
<td>LVEDVI (ml/m³)</td>
<td>84 ± 18</td>
<td>93 ± 8</td>
</tr>
<tr>
<td>LVESVI (ml/m³)</td>
<td>35 ± 11</td>
<td>39 ± 7</td>
</tr>
<tr>
<td>SVI (ml/m³)</td>
<td>50 ± 13</td>
<td>53 ± 10</td>
</tr>
<tr>
<td>%FS (%)</td>
<td>35.5 ± 7.3</td>
<td>34.0 ± 5.6</td>
</tr>
<tr>
<td>EF</td>
<td>0.58 ± 0.10</td>
<td>0.57 ± 0.07</td>
</tr>
<tr>
<td>CI (l/min/m²)</td>
<td>3.5 ± 1.2</td>
<td>3.7 ± 0.7</td>
</tr>
<tr>
<td>TPR (dyn·s/cm²)</td>
<td>1.350 ± 420</td>
<td>1.570 ± 410</td>
</tr>
</tbody>
</table>

Values are mean ± SD; *p < 0.05, **p < 0.01 vs. normotensive subjects; *p < 0.05, **p < 0.01 vs. normal left ventricle; *p < 0.05, **p < 0.01 vs. concentric remodeling; †p < 0.05, ‡p < 0.01 vs. eccentric hypertrophy. IVSTd, interventricular septal thickness in diastole; PWTd, posterior wall thickness in diastole; LVIDd, left ventricular internal diameter in diastole; LVMI, left ventricular mass index; RWT, relative wall thickness; LVEDVI, left ventricular end-diastolic volume index; LVESVI, left ventricular end-systolic volume index; SVI, stroke volume index; %FS, percent fractional shortening; EF, ejection fraction; CI, cardiac index; TPR, total peripheral resistance.

![Fig. 1](image-url)  
Left ventricular end-diastolic volume index (LVEDVI), left ventricular end-systolic volume index (LVESVI), plasma volume index (PVI), and blood volume index (BVI) in normotensive subjects and hypertensive patients with four different left ventricular geometric groups. Values are mean SD. *p < 0.05 and **p < 0.01 vs. normotensive subjects; *p < 0.05 and **p < 0.01 vs. normal left ventricle; †p < 0.05 and ‡p < 0.01 vs. concentric remodeling; and *p < 0.05 and **p < 0.01 vs. eccentric hypertrophy. NT, normotensive subjects; N, normal left ventricles; CR, concentric remodeling; EH, eccentric hypertrophy; CH, concentric hypertrophy.

The concentric remodeling, eccentric hypertrophy and concentric hypertrophy groups. LVIDd, LVEDVI and SVI were increased in the eccentric hypertrophy group, and were smaller in the concentric remodeling group than in the other hypertensive groups. LVESVI was higher in the eccentric hypertrophy group than in normotensive subjects. There
were no significant differences in %FS or EF among the five groups. CI was significantly lower in the concentric remodeling group than in the normotensive, normal left ventricular geometry and eccentric hypertrophy groups. TPR was significantly higher in the concentric remodeling group than in the other four groups.

Blood Volume and LV Geometry

The average PVI and BVI values for the entire group of hypertensive patients were similar to those in normotensive subjects ($1,680 \pm 210$ vs. $1,630 \pm 190$ ml/m$^2$ and $2,850 \pm 390$ vs. $2,800 \pm 420$ ml/m$^2$, respectively), a finding consistent with those of previous studies (14, 22, 23). PVI was significantly lower in the concentric remodeling group than in the other four groups (Fig. 1; $1,540 \pm 190$ vs. $1,630 \pm 190$, $1,680 \pm 230$, $1,720 \pm 180$ and $1,720 \pm 200$ ml/m$^2$; p < 0.05). BVI was also lower in the concentric remodeling group than in the other four groups. There were no significant differences in PVI or BVI among the normal left ventricular geometry, eccentric hypertrophy, concentric hypertrophy, and normotensive control groups. There were no correlations between BVI and plasma renin activity or plasma aldosterone concentration ($r = 0.02$ and $0.14$, respectively; Fig. 2).

Figure 3 summarizes the correlations between LV volume and circulating blood volume in hypertensive patients of the four LV geometric groups and normotensive subjects. Compared with normotensive subjects, the area of correlation between LVEDVI and BVI shifted to the upper right in patients of the normal left ventricle and concentric hypertrophy groups, and shifted more directly to the right in the eccentric hypertrophy group.

Discussion

This study was the first to show the relation of circulating BV to LV geometry in mild to moderate, untreated essential hypertension, and obtained the following major findings. First, circulating PV and BV were decreased in the concentric remodeling group characterized by normal LVMI with increased RWT, decreased LV volume and CI, and increased TPR. Secondly, PV and BV were not increased in the eccentric hypertrophy group characterized by increased LVMI with normal RWT, and increased LV volume.

Blood Volume and LV Geometry

It is well recognized that both volume load and pressure load play an important role in determining the LV adaptation to hypertension (1). However, previous studies have shown that the circulating PV in patients with hypertension was virtually the same (14, 22, 23) or decreased (24, 25) compared with that in normotensive subjects. Ganau et al. reported that PV was related to SV, left atrial and LV dimensions, and LVM, and suggested that LV volume load due to contraction or expansion of the circulating fluid volume might induce parallel modification in LVM and LV geometry in hypertension (14). In the present study, although the average PV and BV among all hypertensive patients were similar to those in the normotensive subjects, the concentric remodeling group showed different PV and BV levels than the other three LV geometric groups.

Hypertension with concentric remodeling is characterized by decreased CO with increased peripheral resistance. Previous studies have shown that aging induces concentric remodeling (26), and that elderly individuals with isolated systolic hypertension have a high prevalence of concentric remodeling (27). In this study, however, there was no significant difference in age between normotensive subjects and subjects of the concentric remodeling group, and none of the patients of the concentric remodeling group had isolated systolic hypertension. PV and BV were lower in the concentric remodeling group than in the other three study groups or...
the normotensive controls, which finding was consistent with that of Ganau et al. (14). In a recent experimental study by Di Segni et al., transient concentric LV remodeling was commonly seen during hypovolemia, and may have further enhanced the echocardiographic estimation of LV preload (28). However, the mechanism of the development of concentric remodeling in essential hypertension remains unclear. One plausible hypothesis is that concentric remodeling occurs as a result of natriuresis-induced contraction of the intraventricular fluid volume (underfilling). Hypertensive patients with concentric LV remodeling might have a reduced LV volume caused by pressure natriuresis-induced blood volume depletion and increased LV wall thickness against increased afterload.

Previous studies have suggested that either LV systolic dysfunction (29) or obesity (30) is the main determinant of eccentric hypertrophy. Obesity did not account for the eccentric hypertrophy in the present study, since the BSA did not differ among normotensive subjects and the four-hypertensive LV geometric groups. It is generally recognized that eccentric hypertrophy is found in conditions associated with volume overload of the left ventricle, such as aortic and mitral regurgitation, ventricular septal defect, arteriovenous fistula, chronic isotonic exercise (31), and hypertension (32). However, the present study showed that both PV and BV levels in the eccentric hypertrophy group were identical to those in the normotensive subjects, despite an enlargement of LV chamber size. These results indicated that circulating fluid volume did not contribute to the genesis of eccentric hypertrophy in mild to moderate essential hypertension. Ganau et al. reported that PV was significantly related to LV SV in hypertensive patients (14). However, subjects in their study had higher serum creatinine levels (<1.8 mg/dl) than those in the present study (<1.2 mg/dl). Differences in fluid volume excretion due to differences in renal function may account for the variation in PV among patients with eccentric hypertrophy. Ulrych et al. showed that the distribution of BV in the central and peripheral circulation affects CO (32). Therefore, not only the “systemic” but also the “regional” volume overload to the left ventricle may play a role in the enlargement of LV chamber size in eccentric hypertrophy.

SBP in the concentric hypertrophy group was the highest among the four hypertensive LV geometric groups, and both PV and BV in the specific LV geometry group were the same as those in the normotensive subjects. These results indicate that appropriate LV wall thickening in response to pressure overload and inappropriate enlargement of LV chamber size against a normal BV for maintaining a normal CO may occur during the development of concentric hypertrophy.

Although the hypertensive patients with normal LV geometry have normal LVMI and normal RWT, the LV chamber size in these patients was larger than that in the normotensive subjects, indicating that the patients with normal LV geometry also had an abnormal LV anatomy, as did the other three hypertensive LV geometric groups. This finding was consistent with previous reports (33). It is possible that neither volume overload nor LV dysfunction was involved in enlargement of the LV chamber in the group of patients with normal LV geometry, since BV, PV and LV systolic function were the same as in the normotensive subjects.

**Blood Volume and Neurohumoral Factors**

In the present study, hypertensive patients with eccentric hypertrophy tended to have decreased plasma renin activity but not increased PV. Hypertensive patients with concentric remodeling had decreased PV, but not increased plasma renin activity. Neither plasma renin activity nor plasma aldosterone concentration was correlated with BV in the full group of hypertensive outpatients, all of whom were instructed to eat a normal diet (NaCl 8–10 g daily). Previous studies have reported that the inverse correlation was found between plasma renin activity and BV in the steady state of untreated essential hypertensives (34–36). However, other studies failed to show the inverse relationship between PV and plasma renin activity after salt restriction, suggesting that the unidentified sodium-retaining steroid might be responsible for volume expansion (37). We speculate that the inverse correlation between plasma renin activity and BV might occur under condition of a more vigorous control of dietary sodium intake.

**Blood Volume and LV Volume**

The relationship between LV volume and circulatory BV did not evolve in parallel due to a lack of increase in BV in the eccentric hypertrophy group. In the concentric remodeling group, the area of correlation between LVEDVI and BVI shifted downward. The difference in the correlation between ventricular function and fluid volume excretion, myocardial performance, and distribution of blood volume in the central and peripheral circulation between our subjects and others (14) may have contributed to the difference between these studies in the correlation between BV and LV volume in the concentric remodeling and eccentric hypertrophy groups.

**Natural Course of Plasma Volume and LV Geometric Changes in Hypertensive Patients**

To date, there have been no longitudinal studies on PV and LV geometric changes in untreated essential hypertension. Adaptation to pressure overload may increase the wall to lumen ratio of the left ventricle. It is known that some patients develop eccentric hypertrophy when volume expansion is loaded due to renal dysfunction. A recent experimental study has also reported that Dahl salt-sensitive rats show eccentric hypertrophy of LV during the development of hypertension (38). However, the natural course of LV geometric change in untreated essential hypertension may not be uniform, since
LV hypertrophy is affected by not only elevated blood pressure but also other factors such as salt sensitivity, genetic factors, circadian rhythm of blood pressure, neurohumoral factors or renal function. A long-term follow-up study may be needed to assess the natural course of PV and LV geometry.

Limitations of the Study
The present study was limited for several reasons. First, the water and sodium intake was not standardized, because the subjects in the present study were outpatients. Although we cannot rule out the possibility of inaccuracies in the measurement of BV level in this study, there were notable features in the relation between the BV levels and LV volumes in the different LV geometry groups. Second, the number of subjects in this study was kept small in order to thoroughly investigate the relation of circulating BV levels to different LV geometric patterns.

Despite these limitations, the present results clearly suggest that a small LV chamber in cases of “concentric remodeling” may be related to decreased PV and BV (volume underload), but an enlarged LV chamber in cases of “eccentric hypertrophy” is not likely to be related to either PV or BV levels (systemic volume overload) in mild to moderate untreated essential hypertension. Differences in myocardial response to arterial hypertension and/or changes in BV through pressure-natriuresis might be involved, at least in part, in the genesis of the different LV geometries seen in patients with mild to moderate essential hypertension.

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