Patterns of Left Ventricular Adaptation in Borderline and Mild Essential Hypertension*

Echocardiographic Findings

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To assess patterns of left ventricular adaptation, 38 patients with borderline and 38 with sustained mild essential hypertension, all lacking electrocardiographic and roentgenographic criteria for left ventricular hypertrophy, were compared using systemic hemodynamic values and M-mode echocardiograms. All patients had normal left ventricular function and measurements of wall thickness. Those with borderline hypertension showed no asymmetric increase in the ratio of septal to posterior wall thickness. The ratio of the left ventricular radius to wall thickness remained normal in both groups, indicating no disproportionate hypertrophy or dilatation of chambers during the phase of normal left ventricular function. Neither finding substantiates asymmetric septal hypertrophy in early hypertension. Those with mild essential hypertension demonstrated an augmented mean circumferential fiber shortening rate compared to those with borderline hypertension (P < 0.005), suggesting an early stage of left ventricular hyperfunction in the development and elaboration of hypertensive heart disease.

A progressive increase in ventricular wall thickness and reduced myocardial function due to pressure overload in systemic arterial hypertension are well-known clinical phenomena. The results of the Framingham study indicate that electrocardiographic left ventricular hypertrophy is associated with a significantly greater risk of cardiovascular events within five years if arterial pressure is not adequately treated. This has recently been reinforced by prospective studies.

Adaptation of the left ventricle to the overload from systemic hypertension calls into play a variety of physiologic mechanisms. A recent report indicates that patients with borderline hypertension may have asymmetric septal hypertrophy, possibly due to excessive adrenergic drive. Since asymmetric septal hypertrophy suggests cardiovascular prognostic complications beyond those of hypertension, we evaluated the echocardiographic characteristics of our patients with borderline and mild essential hypertension in the absence of electrocardiographic or chest roentgenographic findings consistent with left ventricular hypertrophy, in order to ascertain the adaptation of the left ventricle during early phases of systemic arterial hypertension.

Materials and Methods

Thirty-eight patients with established essential hypertension (defined as consistent outpatient readings in excess of 140/90 mm Hg for the preceding six months) and 38 patients with borderline hypertension (defined as blood pressure readings greater than 140/90 mm Hg on occasion, interspersed with other readings in the normal range, for six months) are the basis of this study. No patient with borderline hypertension had been treated for those six months, and patients with essential hypertension, if previously treated, were not receiving any antihypertensive therapy for at least four weeks prior to examination. Outpatient blood pressure was recorded at least monthly, if not biweekly. Investigations, including rapid-sequence intravenous pyelogram, urinary catecholamine levels, and assessment of renal function and electrolytes in every instance, prior to entry into the study failed to demonstrate a secondary cause of hypertension. All patients had a standard 12-lead electrocardiogram and a 6-ft posteroanterior and left lateral chest x-ray film.

An M-mode echocardiographic study, either in the supine or left lateral decubitus position (whichever was required for optimal visualization of the cardiac structures in question), was performed. Concomitant mean arterial pressure was determined by electrical integration of continuous intraarterial and intravenous pressures obtained as cardiac output was measured by dye dilution (indocyanine green) in triplicate in the postabsorptive state in the supine position, using a pressure transducer (Statham P-23Db). Heart rate was read from the echocardiogram.

Twenty-four normal subjects were used as controls, and
the mean of three weekly outpatient blood pressure recordings was used. The control subjects were then studied in
the same way as those with essential and borderline hypertension, except that systemic hemodynamic measurements
were not performed.

Standard methods of M-mode echocardiographic study were employed, using an ultrasoundoscope (Smith-Kline
Ekoline 20A) interfaced with a strip chart recorder (Honeywell) using a probe 1.27 cm in diameter. Ultrasonic emission
characteristics were as follows: frequency, 1,000/sec; wave length, 2.25 MHz; and focal length, 10 cm.13 Echocardiographic
electrical fraction was calculated with the formula for end-systolic and end-diastolic volumes developed by Teichholz et al.13 Septal wall thickness and posterior wall thickness were measured in the standard fashion,14 and the ratio of septal-to-posterior wall thickness was determined.

The mean circumferential fiber shortening rate was calculated using the method of McDonald et al.15 with the ejection
time read from the arterial pulse tracing and taken as the average of ten beats. The ratio of the left ventricular radius to wall thickness was determined from the end-diastolic diameter divided by two, and dividing that quotient by the posterior left ventricular wall thickness.14 Comparisons with normal values were made according to the criteria of Caasch.17

Using our previous protocol,1 in order to be classified as left ventricular hypertrophy by chest x-ray film, a cardio-
Thoracic ratio in excess of 55 percent or an Ungerleider index greater than 15 percent (or both) was needed. None of the patients fulfilled these requirements. Electrocardiographic criteria for left ventricular hypertrophy required the following: (1) QRS frontal-plane vector ≤ 30°; (2) tallest precordial R wave plus deepest precordial S wave ≥ 4.5 mV; or (3) left ventricular strain pattern.1 These strict criteria were used to eliminate as many false-positives as possible. No patient was found to have left ventricular hyper-
trophy. Statistical analyses were made using the unpaired Student's t-test, comparing normal subjects with both groups of patients, and the groups of patients with each other.

RESULTS

Clinical and echocardiographic data obtained
The from the normal subjects are detailed in the follow-
ng tabulation (each value represents mean of group± 1 SE):

<table>
<thead>
<tr>
<th>Data</th>
<th>Borderline Hypertension</th>
<th>Essential Hypertension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septal wall thickness, cm</td>
<td>0.78 ± 0.03</td>
<td>0.93 ± 0.05**</td>
</tr>
<tr>
<td>Posterior wall thickness, cm</td>
<td>0.84 ± 0.02</td>
<td>0.91 ± 0.05</td>
</tr>
<tr>
<td>Ratio of septal/posterior wall thickness</td>
<td>0.95 ± 0.03</td>
<td></td>
</tr>
<tr>
<td>End-diastolic dimension, cm</td>
<td>4.68 ± 0.03</td>
<td></td>
</tr>
<tr>
<td>End-systolic dimension, cm</td>
<td>3.25 ± 0.03</td>
<td></td>
</tr>
<tr>
<td>Ejection fraction, percent</td>
<td>66 ± 3</td>
<td></td>
</tr>
<tr>
<td>Mean velocity of circumferential fiber shortening (circumferences/sec)</td>
<td>1.13 ± 0.08</td>
<td></td>
</tr>
<tr>
<td>Ratio of left ventricular radius/wall thickness</td>
<td>2.99 ± 0.20</td>
<td></td>
</tr>
</tbody>
</table>

These data are similar to those in previous reports.1,3 The ultrasonic findings are very much like those observed in our patients with borderline hypertension (Table 1).

Mean arterial pressure was significantly higher in essential hypertension, as compared with borderline hypertension (113 vs 97 mm Hg; P<0.005), whereas heart rate and cardiac index were similar (Table 2). All measurements of wall thickness were within the normal range (<1.2 cm). Compared to borderline hypertension, septal thickness was increased in essential hypertension (0.93 vs 0.78 cm; P<0.05); posterior wall thickness, although increased in essential hypertension, did not reach statistical significance (0.91 vs 0.84 cm). The ratio of septal to posterior wall thickness was increased in essential hypertension (1.04 vs 0.94; P<0.05)

Table 1—Echocardiographic Data in Borderline and
Established Hypertension*

<table>
<thead>
<tr>
<th>Data</th>
<th>Borderline Hypertension</th>
<th>Essential Hypertension</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of subjects</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Age, yr</td>
<td>32 ± 3</td>
<td>42 ± 3</td>
</tr>
<tr>
<td>Male/female ratio</td>
<td>30/8</td>
<td>28/10</td>
</tr>
<tr>
<td>Body surface area, sq m</td>
<td>1.95 ± 0.03</td>
<td>1.96 ± 0.03</td>
</tr>
<tr>
<td>Mean arterial pressure, mm Hg</td>
<td>97 ± 1**</td>
<td>113 ± 3**</td>
</tr>
<tr>
<td>Heart rate, beats per minute</td>
<td>71 ± 2</td>
<td>72 ± 3</td>
</tr>
<tr>
<td>Cardiac index, L/min/sq m</td>
<td>3.26 ± 0.14</td>
<td>3.39 ± 0.15</td>
</tr>
</tbody>
</table>

*Table values are mean of group (±1 SE).
**P<0.005 vs normal subjects or borderline hypertension.
(Table 1). No patient showed a ratio greater than or equal to 1.3.

Left ventricular function assessed echocardiographically by mean circumferential fiber shortening rate and ejection fraction was normal in both groups (normal, ≥0.9 and ≥55 percent, respectively), although those with essential hypertension demonstrated an augmented mean circumferential fiber shortening rate (1.35 ± 0.07) when compared with those with borderline hypertension (1.01 ± 0.02; P<0.005) and with normal subjects (1.13 ± 0.08; P<0.05). Varying degrees of contractility, paralleling mean circumferential fibers shortening rate, were demonstrated by the differences in end-diastolic measurements (borderline vs essential hypertension, 4.28 vs 4.90 cm; P<0.005) and similar end-systolic ventricular dimensions. The ratio of the left ventricular end-diastolic radius to left ventricular posterior wall thickness, (normal, 3.0 ± 0.7) was similar in the two groups.

DISCUSSION

Studies regarding the development of patterns of left ventricular adaptation in patients with hypertension are sparse. This study was undertaken to delineate differences or similarities as hypertension evolves from the intermittent pressure overload of borderline hypertension to the continuous pressure overload of established essential hypertension.

The preselection of patients without left ventricular hypertrophy on the chest x-ray film or ECG by strict criteria assured a group for study that would have rather early changes in left ventricular size and function in response to arterial hypertension. The normal ultrasonic measurements of septal and posterior wall thicknesses strongly corroborate that assumption.

Contrary to a previous report, the ratio of septal to posterior wall thickness was less than unity in borderline hypertension (Table 1). These data strongly militate against asymmetric septal hypertrophy as a common finding in borderline hypertension. Asymmetric septal hypertrophy (ratio of septal to posterior wall thickness ratio ≥1.3) was similarly absent in the group with essential hypertension (ratio of 1.04 ± 0.03), showing further its lack of frequency in hypertensive patients, in accord with the concept of concentric left ventricular hypertrophy in essential hypertension and with previous reports.18-21

Although the ratio of left ventricular radius to wall thickness has been used in a variety of cardiac disorders,18,17,22,28 no previous assessment of this index has been made in uncomplicated hypertension. The data here demonstrate that while normal systolic function exists, no abnormal relationship of chamber to ventricular wall is present, either in intermittent or established pressure overload.

The group of patients with established essential hypertension demonstrated an augmented mean circumferential fiber shortening rate compared with borderline hypertension. This measurement has been used as an accurate index of left ventricular contractility.24 Increased contractility has been reported previously as an early adaptive stage in the development of left ventricular hypertrophy of hypertensive patients.25-27 With similar heart rates and, therefore, ejection times,28,29 this increase in the mean circumferential fiber shortening rate resembles the isometric hyperfunctioning, early hypertrophied ventricle postulated by Meerson.30 One could hypothesize that the intermittent elevations in arterial pressure in borderline hypertension are inadequate to stimulate isometric hyperfunction, whereas the unrelenting pressure overload of established essential hypertension has this capability. Additionally, since heart rate and dye-dilution cardiac index were similar in both groups, this hyperfunction may be necessary in early established hypertension to maintain "normal" systolic performance by the left ventricle.

We believe that the ten-year difference in age between the two groups does not affect the results. If age were a factor, one would have anticipated the mean circumferential fiber shortening rate to decline with age. The reverse was true. Furthermore, we1 and others31 have shown that no significant alteration in echocardiographic ventricular dimensions occurs with aging.

In summary, we have demonstrated with M-mode echocardiograms that neither asymmetric septal hypertrophy nor disproportionate ventricular hypertrophy or dilation of chambers occurs in early hypertension, whether borderline or established. Wall thicknesses of the left ventricle in borderline hypertension are very much like those observed in the normotensive population. Even mild established hypertension appears capable of inducing isometric hyperfunction in a nonhypertrophied left ventricle, perhaps an early adaptation in the elaboration of hypertensive heart disease.

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