Abstract  Arterial hypertension is frequently responsible for arteriosclerotic damage in the carotid region. Nevertheless, there is as yet no general agreement that hypertension is correlated with lesions described by noninvasive means in the carotid arteries. We studied, by noninvasive echotomographic technique, 70 uncomplicated primary hypertensive individuals without clinically evident end-organ complications and 30 normotensive matched control subjects to detect early lesions of carotid arteries. The presence of other cardiovascular risk factors was assessed, and heart structure and function were studied by echocardiography. Although hypertensive individuals were comparable to control subjects for other risk factors, they showed a marked increase in the thickness of the intimal-medial complex of the carotid wall (0.71 ± 0.4 versus 0.56 ± 0.2 mm, P <.001 in the right carotid and 0.83 ± 0.3 versus 0.58 ± 0.2, P <.01 in the left), in left ventricular mass (203 ± 52 versus 176 ± 37 g, P <.05), and in the prevalence of definite plaques of the carotid wall, both monolaterally and bilaterally (P <.003 by \( \chi^2 \) test). Among the different factors contributing to the increase in thickness of the carotid artery wall, standing blood pressure, serum triglycerides, and age were found to be the best predictors (they accounted for about 16% of the variability, \( P <.005 \)). These results indicate that carotid arteries of hypertensive individuals undergo degenerative changes, just as shown for hypercholesterolemic and diabetic patients in other studies. This supports the use of B-mode ultrasound imaging to detect early involvement of the carotid region before the appearance of any end-organ damage of hypertension. Moreover, this finding sheds new light on the relationship between arterial wall damage and insulin resistance, since all the main contributors to intimal-medial thickening are particularly altered in the presence of hyperinsulinemia and increased insulin resistance. 

(Arterioscler Thromb. 1994;14:1290-1296.)

Key Words • arterial hypertension • carotid wall thickness • echocardiography • ultrasound imaging • left ventricular hypertrophy

Arterial hypertension is a well-recognized risk factor for early degenerative lesions in the arterial tree. Epidemiological studies have shown that high blood pressure (BP) levels are correlated with increased prevalence and incidence of coronary and cerebrovascular diseases.1-6 Moreover, antihypertensive treatment has been found to reduce the incidence of stroke and myocardial infarction, although in the latter to a smaller extent.7-15

The recent development of noninvasive techniques has allowed investigation of carotid arteries to detect early degenerative changes, to measure plaque dimension, and to follow the progression of arterial lesions.16 In particular, measurement of the thickness of intimal-medial layers, which are portrayed as being limited by a pair of roughly parallel echogenic lines, has attracted the interest of several investigators.17 Poli and coworkers18 found that the thickness of the intimal-medial complex is increased in hypercholesterolemic patients, and Kawamori and coworkers19 detected a similar finding in diabetic patients. Although there is still debate over whether the intimal plus medial thickening might be considered an initial arteriosclerotic lesion, it is noteworthy that the thickness of the intimal-medial complex in the general population is positively related to age, BP, and cigarette smoking and inversely to high-density lipoprotein cholesterol (HDL-C).20

The aim of the present study was to evaluate, by noninvasive echotomographic technique, the carotid arteries of hypertensive patients in an early stage of the hypertensive disease, before the appearance of end-organ damage, in comparison to normotensive control subjects, to assess the following points: (1) detection of possible changes in the thickness of the intimal-medial complex; (2) correlation of the thickness of the intimal-medial complex with the main cardiovascular risk factors and the echocardiographic left ventricular mass (LVM); and (3) evaluation of whether the prevalence of plaques is increased in hypertensive patients, even when clinically asymptomatic, in comparison to normotensive control subjects.

Methods

Seventy patients (34 male, 36 female) seen consecutively in the day hospital service of the Hypertension Clinic of our institution, with arterial hypertension ranging from mild to moderately severe, and 30 age-matched normotensive control subjects (18 male, 12 female) were recruited to participate in this cross-sectional study. The study protocol was fully explained, and informed consent was obtained from each patient before he or she was enrolled for the trial. Exclusion criteria were (1) duration of known hypertension for more than 10 years; (2) clinical evidence of target-organ damage by arterial hypertension (stroke, coronary heart dis-
ease, heart failure, renal impairment, third- or fourth-degree retinopathy; (3) presence of heart disease other than hypertension; (4) presence of liver cirrhosis, chronic lung disease, or renal disease; (5) pregnancy or lactation; (6) use of oral contraceptives; and (7) the impossibility of obtaining high-level echography of the carotid artery that would allow reproducible measurements.

Some of the patients (n=16) had newly discovered hypertension and had never been on antihypertensive treatment; the others (n=54) were asked to discontinue previous drugs for at least 6 weeks before entering the study. The following measurements were taken.

1. Measurements of BP and heart rate (HR) were made at 9 AM by automatic noninvasive technique with a Sentron (Bard Biomedical) instrument and the subject in the supine position and after standing for 2 minutes. Body weight (BW) and height (h) were also measured, and body mass index (BMI= BW/h²) was calculated. Cigarette smoking was investigated by an appropriate questionnaire, and patients and control subjects were divided into three groups: nonsmokers, smokers of 1 to 20 cigarettes/d, and smokers of >20 cigarettes/d. Alcohol intake was evaluated with a questionnaire investigating whether subjects drank wine, beer, or spirits and the amount of daily intake. Physical activity was investigated by a Saltin modified questionnaire.

2. Laboratory assessments of hematology (hematocrit [Hct]) and biochemistry (blood urea, fasting blood glucose [FBG], total proteins), total serum cholesterol (TC), triglyceride (TG), and HDL-C were also made. Blood samples were drawn at 8:30 AM, after an overnight fast. Cholesterol content in low-density lipoprotein cholesterol (LDL-C) was calculated by the Friedewald equation,

\[
LDL-C = TC - (HDL-C + \frac{1}{5}TG)
\]

Whole-blood viscosity was calculated at different shear rates (SRs) from the Hct level and plasma protein determination according to the following equations, where SR-208 is the rate pertaining to larger arteries and SR-104 is similar to the one pertaining to smaller arteries.

\[
SR-104 = 0.12 \times Hct + 0.19 \times Serum \text{ Total Proteins} - 2.13
\]

\[
SR-208 = 0.12 \times Hct + 0.17 \times Serum \text{ Total Proteins} - 2.07
\]

3. A quantitative M-mode echocardiographic study under bidimensional control was performed. The echocardiograms were carried out with the patients in the partial left decubitus position with a 2.5-MHz transducer connected to an SIM 5000 sector imager equipped with a fiber-optic recorder (OTE-Biomedica) to provide a parasternal short-axis view just below the level of the far wall. IMT was measured as the distance from the lumen-intima interface, and the second line is produced by the leading edge of the first echogenic line to the leading edge of the second echogenic line. The images were printed on paper, numerically coded, and read in a random sequence by two physicians, according to the recommendation of the American Society of Echocardiography.

The Penn convention was used only to calculate LVM. Quantitative analysis of M-mode echocardiograms provided the following parameters, allowing the assessment of left ventricular function and anatomy: end-diastolic (d) and end-systolic (s) dimensions (LVIDd and LVIDs) measured from the Teichholz equation; measurements of the internal size of the left ventricle were taken at the level of the chordae tendineae of the mitral valve:

**Ejection Fraction = (EDV - ESV) / EDV x 100%
Fractional Shortening = (LVIDd - LVIDs) / LVIDd x 100 as index of systolic function**

Stroke volume (SV) was calculated as the difference between EDV and ESV; stroke index as the ratio of SV to body surface; cardiac output as the product of SV per HR; cardiac index as the ratio of cardiac output to body surface; end-systolic stress (ESS), as an estimate of myocardial afterload, by the Wilson equation, using cuff BP measured by a random-zero sphygmomanometer after the echocardiogram; LVMI and relative diastolic wall thickness [RWT=(ST+PWT)/LVIDd] as an index of concentric LV hypertrophy. The LVM index was also calculated as the ratio of LVM to both body surface and height.

4. Carotid ultrasound imaging was performed with the Biosound echotomographic system 2000 II SA (Bio Dynamics). The instrument generates wide-band ultrasonic pulses with a middle frequency of 8 MHz. Axial and lateral resolution are about 385 and 500 μm for an ultrasonic speed of 1540 m/s. The reported dynamic range is at least 70 dB. Real-time images are generated on a television monitor connected to the instrument and represent a fourfold magnification of the anatomic structures examined. The procedure was performed by the same observer, unaware of the subjects’ characteristics. The subjects were kept supine until the time-gain compensation curve was steadied and turned contralaterally to the carotid artery being examined; continuous scans were carried out in the anteroposterior and coronal planes from the lower to the higher third of the right and left common carotid arteries. The carotid bifurcation was recognized by visualization of the tip of the flow divider, which identifies the origin of the internal and external carotid arteries and provides the best anatomic landmark.

Criteria for a high-level ultrasonographic examination were (1) presence of the adventitia-media interface and intima-lumen interface in at least two arterial segments and (2) visualization of anterior, posterior, lateral, and medial walls of the common carotid artery, of the bifurcation, and of at least 2 cm of the internal carotid artery.

The carotid artery has been schematically divided into three parts on the basis of the distance from the tip of the flow divider: the 2-cm segment in the internal branch distal to the flow divider is referred to as internal carotid artery; the 1-cm segment proximal to the flow divider is referred to as the bifurcation; and the segment seen below the lowest point of the bifurcation is referred to as the common carotid artery.

The entire extracranial carotid tree was scanned to identify the presence of plaques, recognized as localized lesions of thickness >1.5 mm. Thereafter, the time-gain compensation curve was calibrated to obtain an echo-free lumen limited by two roughly parallel echogenic lines. Lumen size and intima-medial thickness (IMT) of the common carotid arteries were measured 2 cm below the tip of the flow divider. Since the far wall of the common carotid arteries is more echogenic than the near wall visualized with B-mode imaging than the more superficial near wall, determinations of the thickness were carried out only at the level of the far wall. IMT was measured as the distance from the leading edge of the first echogenic line to the leading edge of the second echogenic line (Fig 1). The first line represents the lumen-intima interface, and the second line is produced by the collagen-containing upper layer of the tunica adventitia, close to the media-intima interface. Measurements of the thickness of the arterial wall and of the lumen size were never performed at the level of the plaques. The whole scanning procedure was recorded on a videocassette. Thereafter, the images were printed on paper, numerically coded, and read three times by the same observer: the mean of the three measurements was accepted as the IMT value. The ratio of the IMT-to-lumen diameter was also calculated.

Reproducibility of the measurements was assessed by a repeated scanning 1 week later in a randomly chosen subsample of 40 participants. The rescanning was performed by the same sonographer. The correlation index was 0.994 (p = 0.015; b = 0.978; P < .0001). For each two echographic examinations, the technical error was calculated by the formula (Σ d²/N)² to estimate errors for pairs, where d is the difference between a split pair and N is the number of pairs. The technical error
determined for IMT to evaluate the reproducibility of measurements was <0.1% of the sample mean.

**Statistical Analysis**

The statistical analysis was performed with Statistical Package for Social Sciences (SPSS). Data are given as mean±SD. Two-tailed statistical tests were performed for all the data analyses, with a value of \( P<.05 \) considered significant. Between-group differences were evaluated by unpaired \( t \) test. The strength of the correlation between IMT and some demographic, metabolic, and echocardiographic parameters was assessed by Pearson’s linear correlation and by backward multiple regression analysis.

**Results**

The group of hypertensive individuals and the control group were comparable for age (48.5±7 versus 47.0±7 years, \( P=\)NS, in hypertensive and control groups, respectively) and BMI (27.2±6 versus 27.5±6 kg/m\(^2\)); a slight prevalence of men was observed in the control group compared with the hypertensive group. Both groups were identified as sedentary in the Saltin questionnaire, since none carried out regular daily physical activity.

BP was obviously different (161/99±16/10 versus 127/77±14/5 mm Hg in the supine position; 162/104±13/7 versus 122/82±11/8 mm Hg in the standing position). Also, supine HR was significantly increased in the hypertensive group (75±11 versus 68±9 beats per minute, \( P<.005 \)), whereas it was similar in the standing position (76±11 versus 76±10 beats per minute). Data on SBP, DBP, and mean BP are shown in Fig 2.

With regard to other main risk factors for cardiovascular diseases, no significant differences were observed in lipid parameters (TC, LDL-C, HDL-C, TG, and ratio of LDL-C to HDL-C), blood viscosity in the large and small arteries, and prevalence of cigarette smoking (37% versus 40% in hypertensive individuals and control subjects). Regarding the last point, only two subjects in the control group smoked more than 20 cigarettes/d, the others smoked from 10 to 15 cigarettes/d. With regard to daily alcohol intake, no significant between-group difference was detected. Most of the patients and control subjects drank 1 or 2 glasses of wine daily during lunch or dinner (almost 20 to 25 g alcohol daily); no one claimed to drink spirits. Only FBG was significantly higher in the hypertensive subgroup, but it was still within the normal range. Data on biochemical parameters are shown in Table 1.
TABLE 1. Main Parameters of Lipid and Carbohydrate Metabolism and Whole-Blood Viscosity in the Hypertensive and Control Groups

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Hypertensive Subjects</th>
<th>Control Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cholesterol, mg/dL</td>
<td>209±42</td>
<td>220±52</td>
</tr>
<tr>
<td>Triglycerides, mg/dL</td>
<td>129±53</td>
<td>134±63</td>
</tr>
<tr>
<td>HDL cholesterol, mg/dL</td>
<td>47±12</td>
<td>46±11</td>
</tr>
<tr>
<td>LDL cholesterol, mg/dL</td>
<td>134±43</td>
<td>157±34</td>
</tr>
<tr>
<td>LDL/HDL</td>
<td>3.7±1.5</td>
<td>4.7±1.6</td>
</tr>
<tr>
<td>Fasting blood glucose, mg/dL</td>
<td>90±14</td>
<td>81±15*</td>
</tr>
<tr>
<td>Shear rate-208, s⁻¹</td>
<td>3.8±0.9</td>
<td>3.8±0.7</td>
</tr>
<tr>
<td>Shear rate-104, s⁻¹</td>
<td>4.5±0.5</td>
<td>4.4±0.8</td>
</tr>
</tbody>
</table>

HDL indicates high-density lipoprotein; LDL, low-density lipoprotein. Shear rate-208 is the rate pertaining to larger arteries, and shear rate-104, to smaller.

Twenty-four-hour sodium excretion was slightly increased in the hypertensive group (226±96 versus 169±68 mEq/24 h, P=NS), and so was the 24-hour magnesium excretion (9.2±4 versus 7.3±1 mEq/24 h, P<.05); potassium excretion, on the other hand, was similar in both subgroups (57.7±20 versus 54.1±18 mEq/24 h).

Doppler echocardiographic evaluation of systolic function detected that the hypertensive group had peripheral resistances similar to the normotensive group, without impairment of SV, as shown in Table 2. In particular, ejection fraction (69.6±9% versus 60.8±7%, P<.001) and cardiac output (5.7±1.7 versus 4.6±1.0 L/min) were significantly increased in hypertensive individuals. Among the parameters of cardiac dimensions, LVM was slightly increased in hypertensive individuals (203±52 versus 176±37 g, P<.05). Cardiac afterload was slightly increased in hypertensive individuals, as shown by ESS (71±20×10³ versus 60±11×10³ dynes/cm²).

In all the participants in the study, it was possible to visualize the far wall intima-media boundary to take measurements. Regarding the identification of the plaques, three hypertensive individuals and one control subject did not meet the criteria for a high-level ultrasound examination and were therefore excluded from the study.

Common carotid arteries, studied by high-resolution echotomography, showed a bilateral increase in wall thickness (0.71±0.4 versus 0.56±0.2 mm, P<.001 in the right and 0.83±0.3 versus 0.58±0.2 mm, P<.003 in the left carotid) without significant differences in the respective diameters (Fig 3). The ratio of diameter to wall thickness was also similar (10.2±3 versus 10.9±3). Several demographic, metabolic, and cardiac parameters were correlated with IMT by linear regression analysis, as shown in Table 3. In the whole group, age, BP, and serum TG had a significant correlation matrix, whereas FBG approached statistical significance. In the hypertensive individuals only, age and TG were significantly related to IMT, whereas not one significant correlation was found in the control subjects alone. Stepwise backward multiple regression analysis was performed to evaluate the independent influence of the above-mentioned variables on carotid wall thickness: age, standing BP, and TG were found to predict the development of carotid wall thickening, accounting for 16% of the variability of this parameter (adjusted R² 0.161, F=4.722, P<.005) (Table 4).

The patients recruited for this study were free of clinical evidence of arterial complications. However, the noninvasive study of carotid arteries detected 16 patients with plaques versus only 3 control subjects. Four subjects in the hypertensive group and 1 in the normotensive had two-sided lesions, P<.003. Plaques were never found at the site of IMT measurement. No differences in cardiovascular risk factors, age, BMI, or LVM were detected between the hypertensive subgroup with and the one without carotid lesions; carotid wall thickness was the sole parameter that was significantly different (Table 5).
Discussion

This study compared patients with essential hypertension without end-organ complications and age- and sex-matched normotensive control subjects; its aim was to detect early changes in the cardiovascular system of the hypertensive group before the appearance of clinical signs of hypertension in both the cerebral and the coronary regions.

The subgroups were comparable not only for sex and age but also for BMI, lipid parameters, and blood viscosity in the large and medium-size arteries. FBG alone was slightly but significantly higher in the hypertensive subgroup but still within normal range values.

TABLE 3. Correlation Matrix and Significance of Some Independent Variables With Intimal+Medial Thickness in All Subjects and Separately in the Hypertensive and Control Groups

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>All</th>
<th>Hypertensive Subjects</th>
<th>Control Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>P</td>
<td>r</td>
</tr>
<tr>
<td>SBP (standing)</td>
<td>.289</td>
<td>.01</td>
<td>.039</td>
</tr>
<tr>
<td>DBP (standing)</td>
<td>.247</td>
<td>.04</td>
<td>.005</td>
</tr>
<tr>
<td>MBP (standing)</td>
<td>.276</td>
<td>.02</td>
<td>.025</td>
</tr>
<tr>
<td>HR (standing)</td>
<td>.006</td>
<td>NS</td>
<td>.022</td>
</tr>
<tr>
<td>FBG</td>
<td>.226</td>
<td>.07</td>
<td>.198</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>-.099</td>
<td>NS</td>
<td>-.141</td>
</tr>
<tr>
<td>HDL cholesterol</td>
<td>.025</td>
<td>NS</td>
<td>.070</td>
</tr>
<tr>
<td>Log TG</td>
<td>.289</td>
<td>.02</td>
<td>.431</td>
</tr>
<tr>
<td>LVMI</td>
<td>-.003</td>
<td>NS</td>
<td>-.003</td>
</tr>
<tr>
<td>ESS</td>
<td>.233</td>
<td>NS</td>
<td>.207</td>
</tr>
<tr>
<td>Age</td>
<td>.323</td>
<td>.003</td>
<td>.294</td>
</tr>
<tr>
<td>BMI</td>
<td>.170</td>
<td>NS</td>
<td>.147</td>
</tr>
<tr>
<td>BW</td>
<td>.184</td>
<td>NS</td>
<td>.216</td>
</tr>
</tbody>
</table>

SBP indicates systolic blood pressure; DBP, diastolic blood pressure; MBP, mean blood pressure; HR, heart rate; FBG, fasting blood glucose; HDL, high-density lipoprotein; TG, triglyceride; LVMI, left ventricular mass index; ESS, end-systolic stress; BMI, body mass index; and BW, body weight.

This finding is in agreement with previous observations by other groups and ourselves on impaired glucose metabolism in hypertensive individuals with either normal or increased body weight. With regard to cardiovascular assessment of the two groups, a number of points must be discussed.

First, the hypertensive group had increased cardiac output and ejection fraction, whereas peripheral resistance was similar to that of normotensive control subjects. Accordingly, parameters of ventricular dimension, such as wall thickness and LVM index, were not significantly different from those found in normotensive individuals. These data, even in the absence of controlled information about the onset of hypertension, strongly support the hypothesis that patients were recruited in an early stage of the hypertensive disease, when the damage to target organs was only mild.

A second point, probably the most interesting one of the present study, deals with the echotomographic findings in carotid arteries. In the past two decades, several noninvasive technologies have been developed to image atherosclerosis; however, angiography and Doppler ultrasound allowed estimation of percent stenosis or arterial lumen diameter, whereas arterial wall thickness was overestimated in lumen stenosis. B-mode high-resolution ultrasonography currently appears to provide the most accurate in vivo assessment of early atherosclerosis, allowing visualization and direct measurement of wall thickness and lumen diameter. Ultrasound imaging has some limitations because of the axial resolution, since it does not allow separate measurements of the intima and media; however, as shown under "Methods," the measurement...
TABLE 5. Some Demographic, Metabolic, and Echocardiographic Parameters of Hypertensive Patients With (n=16) and Without (n=54) Carotid Lesions

<table>
<thead>
<tr>
<th>Hypertensive Subjects</th>
<th>Without Carotid Lesions</th>
<th>With Carotid Lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>48.7±7</td>
<td>50.8±6</td>
</tr>
<tr>
<td>BMI, w/h²</td>
<td>27.4±5</td>
<td>28.0±4</td>
</tr>
<tr>
<td>Smoking, %</td>
<td>38</td>
<td>57</td>
</tr>
<tr>
<td>SBP, mm Hg</td>
<td>160±17</td>
<td>161±17</td>
</tr>
<tr>
<td>DBP, mm Hg</td>
<td>100±10</td>
<td>99±9</td>
</tr>
<tr>
<td>MBP, mm Hg</td>
<td>119±12</td>
<td>119±11</td>
</tr>
<tr>
<td>FBG, mg/dL</td>
<td>89±13</td>
<td>94±17</td>
</tr>
<tr>
<td>Cholesterol, mg/dL</td>
<td>209±41</td>
<td>207±36</td>
</tr>
<tr>
<td>HDL cholesterol, mg/dL</td>
<td>47±12</td>
<td>44±10</td>
</tr>
<tr>
<td>TG, mg/dL</td>
<td>125±51</td>
<td>156±56</td>
</tr>
<tr>
<td>LVMi, g/m²</td>
<td>98±25</td>
<td>97±11</td>
</tr>
<tr>
<td>ST, mm</td>
<td>1.0±0.2</td>
<td>1.0±0.2</td>
</tr>
<tr>
<td>PWT, mm</td>
<td>0.99±0.11</td>
<td>1.0±0.1</td>
</tr>
<tr>
<td>SVI, mL/m²</td>
<td>39±11</td>
<td>39±10</td>
</tr>
<tr>
<td>ESS, 10⁵ dynes/cm²</td>
<td>69.8±19</td>
<td>75.0±28</td>
</tr>
<tr>
<td>Carotid wall thickness, mm</td>
<td>0.65±0.2</td>
<td>0.89±0.3*</td>
</tr>
</tbody>
</table>

BMI indicates body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; MBP, mean blood pressure; FBG, fasting blood glucose; HDL, high-density lipoprotein; TG, triglyceride; LVMi, left ventricular mass index; ST, septal thickness; PWT, posterior wall thickness; SVI, stroke volume index; and ESS, end-systolic stress.

*p<.003.

of the intimal-medial complex appears to be well reproducible on separate examinations, and the site of the measurement (far wall, 2 cm below the tip of the flow divider) is easily localized.

There is still some controversy over the meaning of an increased IMT in asymptomatic patients; some authors believe that it may be an adaptive change of the vessel wall due to age.32 On the other hand, increased IMT has been found in the past few years in hypercholesterolemic and diabetic patients,18,19 and it is strongly correlated with the prevalence of stroke,33 thus supporting the hypothesis that IMT is one of the earliest pieces of evidence of atherosclerotic involvement of the carotid artery.34 When the atherosclerotic process advances, local hemodynamic factors (turbulence, etc), via endothelial injury, may start the atherosclerotic process, producing localized lesions such as definite plaques. In the present study, we found a significant increase in IMT in a population of hypertensive patients without detectable signs of end-organ damage compared with normotensive control subjects. This finding is in agreement with some previous studies showing that both SBP and DBP are significantly related to severity of atherosclerosis. This topic, however, is still debated, since the Finnish Study did not find a correlation between BP and carotid lesions in a general population;37 moreover, Lusiani and coworkers,38 using a device with different technical characteristics (a duplex scanner with a 5-MHz mechanical probe), failed to demonstrate any correlation between carotid artery stenosis and duration of hypertension in hypertensive patients free of cardiovascular symptoms, even though arterial hypertension has been well recognized as the main precursor of cerebrovascular disease.3,6 The results of the present study do not support the hypothesis that increased IMT is solely due to aging, since, although the groups were carefully matched for age, IMT was significantly increased in the hypertensive group. The analysis of the slopes of the relationship between age and IMT in hypertensive (b=0.0114) and control (b=0.00469) subjects has shown a statistically significant difference (P<.05).

Regarding the definition of plaque, there is no general agreement: in some studies, plaque has been defined as a focal thickening of the vessel wall from >1.3 to >2 mm and in others as focal thickening without reference to the absolute value of the dimensions.20,29 In this study, we chose 1.5 mm as the lower limit for a focal lesion to be defined as plaque. On this basis, we found that both single-sided and two-sided lesions were found more frequently in hypertensive control subjects. It is noteworthy that in addition to age and BP, serum TG and FBG also were related to IMT in the linear correlation analysis: their independent contribution, particularly that of BP, age, and TG, was still valuable in the multiple regression analysis. Serum TGs were already detected as definite contributors to increased IMT in the Atherosclerosis Risk in Communities (ARIC) study.35 Hypertriglyceridemia, overweight (particularly in patients with central fat accumulation), and hyperglycemia are very often clinical features of insulin resistance and hyperinsulinemia. More recently, arterial hypertension was also found to be frequently correlated with insulin resistance, and this might be a factor linking hypertension to metabolic disorders.40 Since the above-mentioned variables are correlated with IMT in univariate and multivariate analysis, it would be interesting, in the future, to look at the relationships between insulin resistance and IMT and between IMT and alterations of ion transport through plasma membranes, particularly Na-Li countertransport, which is affected by insulin and has already been found to be significantly and positively associated with serum TG, BW, FBG, and arterial hypertension.41

The results of this study therefore strongly support the following conclusions: (1) B-mode ultrasound imaging, despite the obvious limitations of any noninvasive technique, is able to detect increased carotid wall thickening and presence of soft plaques in hypertensive individuals in an early phase of the disease, when no end-organ damage is present; (2) in addition to age, BP and serum TGs seem to be the strongest predictors of carotid wall thickness in this population; and (3) in particular, the slope of the age-IMT relationship sharply increases when hypertension is concomitantly present.

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