Experimental studies have reported that common antihypertensive drugs such as diuretics, beta-blockers, and methyldopa have adverse effects on plasma lipids and lipoproteins. To investigate whether such effects can be observed in the general population, plasma lipid and lipoprotein levels were compared in subjects receiving antihypertensive treatment, subjects with untreated high blood pressure, and subjects with normal blood pressure in a random sample of 5603 subjects screened in a national study of risk factor prevalence in Australia. In both sexes, high density lipoprotein (HDL) cholesterol was lower in the group receiving treatment than in the others ($p < 0.001$). In men, triglycerides (TG) ($p < 0.001$) and the ratio of total cholesterol to HDL cholesterol (TC/HDL cholesterol) ($p < 0.05$) were higher in the group receiving treatment. In both sexes, the differences in plasma lipids and lipoproteins between treated and untreated hypertensive groups were independent of age, body mass index, alcohol consumption, and smoking. More than 40% of the treated or untreated hypertensive men and women had elevated total cholesterol (TC > 252 mg/dl) or an elevated TC/HDL cholesterol ratio (>6.0). In men receiving antihypertensive treatment, the prevalence of an elevated TC/HDL cholesterol ratio was significantly greater than in men with untreated high blood pressure ($p < 0.01$). The results of this study suggest that the effects of antihypertensive treatment on plasma lipids and lipoproteins can be observed in population lipid and lipoprotein levels. Even before treatment, a large proportion of high blood pressure patients have a significant plasma cholesterol abnormality, which may be aggravated by conventional antihypertensive therapy. (Arteriosclerosis 5:391-396, July/August 1985)
volved small numbers of subjects and short follow-up intervals. In the Multiple Risk Factor Intervention Trial, however, there were significant reductions in HDL cholesterol and increases in TG in a large group of subjects treated with the beta-blocker propranolol after 72 months of treatment. These results suggest that in populations in which beta-blockers are used widely to treat hypertension, the plasma lipid and lipoprotein changes associated with treatment may be of sufficient duration and magnitude to affect mean plasma lipid and lipoprotein levels and the population risk of CAD in community hypertensive groups.

In the present study, we examined a random sample of men and women living in Australian urban communities who were receiving antihypertensive therapy and compared their plasma lipid and lipoprotein levels with those of normotensive and untreated hypertensive subjects from the same population. We took account of factors such as age, body mass index, alcohol consumption, and smoking that might confound the comparison. National statistics on pharmaceutical prescriptions indicate that in 1980, the year of this study, approximately 35% of prescriptions for antihypertensive treatment were for beta-blockers, 15% were for methyldopa, and 40% were for diuretics. The changes in plasma lipids and lipoproteins reported in studies of regimens using these drugs suggest that a random sample of Australian patients receiving antihypertensive therapy would have lower HDL cholesterol and higher TG levels than comparable groups not receiving therapy. Depending on the frequency of diuretic monotherapy and the duration of the therapy's effects on plasma lipids and lipoproteins, there might also be higher TC and LDL cholesterol levels in the treated group.

### Methods

The Risk Factor Prevalence Study was conducted from May to November 1980 in the six state capital cities of Australia. The study population was a random sample from the electoral rolls of people aged 25 to 64 years. Informed consent was given by all participants. There were 5603 subjects, 2765 men and 2838 women, representing a response rate of 75.7%. Comparison of the demographic characteristics and age structure of the study population with census data for the same age group in the same geographic locations revealed few differences. A full account of the methods and a preliminary analysis of the data has been published.

All subjects filled out a dietary and medical history questionnaire and a medical examination. Subjects were asked whether or not they were receiving antihypertensive therapy, but information about the specific type of treatment was not recorded. Blood pressure was measured by observers using standard mercury sphygmomanometers and cuffs who had been trained in a common protocol similar to that of the Lipid Research Clinics Prevalence Study. Systolic and diastolic (phase V) blood pressures were defined as the mean of two readings taken consecutively in the seated position after a 5-minute rest with the cuff on the right arm. High blood pressure was arbitrarily defined as a diastolic blood pressure of 95 mm Hg or more and/or a systolic blood pressure of 150 mm Hg or more. Resting heart rate in beats per minute (bpm) was recorded from the radial pulse.

Plasma lipids and lipoproteins were also measured by the Lipid Research Clinics method. All participants had fasted for at least 12 hours. Using the criteria of the National Heart Foundation of Australia, we defined hypercholesterolemia as a TC of 252 mg/dl (6.5 mmol/liter) or greater; in both men and women, this level approximated the 80th percentile in the distributions of TC. On the basis of the Framingham Study data, elevated TC/HDL cholesterol was defined as a ratio of 6.0 or more.

Adiposity was assessed by using Quetelet's body mass index [weight(kg)/height(m)^2]. Alcohol intake was assessed from the subjects' estimate of the usual frequency of drinking (number of days per week) and the usual number of drinks consumed on each day. Subjects were asked whether they currently smoked. Excluded were 419 subjects who had not fasted or from whom insufficient blood was taken, and 351 women who were pregnant or taking oral contraceptives.

Differences between groups in blood pressure, heart rate, plasma lipid and lipoprotein levels, and the prevalence of plasma lipid abnormalities were tested using t tests, analysis of covariance, and chi-

### Table 1. Age, Blood Pressure, and Heart Rate

<table>
<thead>
<tr>
<th></th>
<th>Normal blood pressure</th>
<th>High blood pressure</th>
<th>On antihypertensive drugs</th>
<th>Normal blood pressure</th>
<th>High blood pressure</th>
<th>On antihypertensive drugs</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>1776</td>
<td>568</td>
<td>214</td>
<td>1678</td>
<td>322</td>
<td>295</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>41.5 ± 10.9</td>
<td>47.9 ± 10.8</td>
<td>53.2 ± 8.7</td>
<td>43.1 ± 10.5</td>
<td>53.1 ± 8.4</td>
<td>53.6 ± 7.8</td>
</tr>
<tr>
<td>SBP (mm Hg)</td>
<td>125.7 ± 11.4</td>
<td>153.8 ± 15.4</td>
<td>147.1 ± 20.1</td>
<td>119.9 ± 13.0</td>
<td>158.1 ± 15.0</td>
<td>146.4 ± 19.1</td>
</tr>
<tr>
<td>DBP (mm Hg)</td>
<td>80.7 ± 9.2</td>
<td>97.2 ± 8.2</td>
<td>94.9 ± 11.5</td>
<td>75.4 ± 13.7</td>
<td>95.8 ± 9.2</td>
<td>90.8 ± 10.0</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>72.8 ± 10.1</td>
<td>79.1 ± 12.7</td>
<td>72.7 ± 11.7</td>
<td>76.1 ± 10.1</td>
<td>80.2 ± 11.0</td>
<td>75.4 ± 11.1</td>
</tr>
</tbody>
</table>

Values represent means ± sd. SBP = systolic blood pressure; DBP = diastolic blood pressure; HR = heart rate.
PLASMA LIPOPROTEINS AND HYPERTENSION

MacMahon et al.

Table 2. Plasma Lipid and Lipoprotein Concentrations and Ratios

<table>
<thead>
<tr>
<th></th>
<th>Normal blood pressure</th>
<th>High blood pressure</th>
<th>Difference between normal &amp; high BP</th>
<th>On antihypertensive drugs</th>
<th>Difference between high BP &amp; on drugs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-C</td>
<td>219</td>
<td>227</td>
<td>p&lt;0.001</td>
<td>226</td>
<td>NS</td>
</tr>
<tr>
<td>LDL-C</td>
<td>146</td>
<td>148</td>
<td>NS</td>
<td>147</td>
<td>NS</td>
</tr>
<tr>
<td>HDL-C</td>
<td>48</td>
<td>48</td>
<td>NS</td>
<td>45</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>T-C/HDL-C</td>
<td>4.79</td>
<td>5.01</td>
<td>p&lt;0.01</td>
<td>5.96</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Tg</td>
<td>125</td>
<td>138</td>
<td>p&lt;0.001</td>
<td>165</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-C</td>
<td>219</td>
<td>230</td>
<td>p&lt;0.001</td>
<td>227</td>
<td>NS</td>
</tr>
<tr>
<td>LDL-C</td>
<td>143</td>
<td>152</td>
<td>p&lt;0.001</td>
<td>149</td>
<td>NS</td>
</tr>
<tr>
<td>HDL-C</td>
<td>59</td>
<td>58</td>
<td>NS</td>
<td>56</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>T-C/HDL-C</td>
<td>3.95</td>
<td>4.21</td>
<td>p&lt;0.001</td>
<td>4.26</td>
<td>NS</td>
</tr>
<tr>
<td>Tg</td>
<td>87</td>
<td>102</td>
<td>p&lt;0.001</td>
<td>110</td>
<td>NS</td>
</tr>
</tbody>
</table>

Abbreviations: T-C = total cholesterol; LDL-C = low density lipoprotein cholesterol; HDL-C = high density lipoprotein cholesterol; T-C/HDL-C = ratio of total cholesterol to high density lipoprotein cholesterol; Tg = total triglycerides; NS = not statistically significant (p > 0.05).

Results

In this study population, 8% of the men and 13% of the women were receiving antihypertensive treatment; a further 22% of the men and 14% of the women had a diastolic blood pressure of 95 mm Hg or more or a systolic blood pressure of 150 mm Hg or more (Table 1). Men and women receiving antihypertensive treatment had lower systolic and diastolic blood pressures than those with high blood pressure not on treatment (p < 0.001), but higher blood pressures than normal (p < 0.001). Heart rates were greater in the group with high blood pressure compared to the group with normal blood pressure (p < 0.001); heart rates were lower in the group on antihypertensive treatment compared with the high blood pressure group not being treated (p < 0.001).

Age, body mass index, alcohol consumption, and smoking are associated with plasma lipid and lipoprotein levels.27-30 Table 2 presents mean plasma lipid and lipoprotein levels with the linear adjustment by analysis of covariance for age, body mass index, alcohol consumption, and smoking. To take account of the sharp increase in TC, LDL cholesterol and TG in women over age 50, these levels were adjusted for age.2 In both sexes, TC/HDL cholesterol ratio and TG were higher in subjects with treated or untreated high blood pressure than in subjects with normal blood pressure. In women, LDL cholesterol was also greater in subjects with untreated high blood pressure than in subjects with normal blood pressure. In both sexes, HDL cholesterol was similar in normal and untreated high blood pressure groups; in subjects receiving treatment for high blood pressure, HDL cholesterol was lower than in subjects with untreated high blood pressure. In men, TC/HDL cholesterol ratios and TG were higher in those receiving antihypertensive treatment than in those with untreated high blood pressure. The differences in HDL cholesterol, TC/HDL cholesterol ratios and TG between the three groups persisted when considered separately for systolic (>150 mm Hg) and diastolic (>95 mm Hg) blood pressure elevations.

Table 3 shows the unadjusted prevalence of elevated TC (>252 mg/dl) and elevated TC/HDL cholesterol ratios (>6.0) in normotensive and hypertensive groups in the study population. In men, the

Table 3. Prevalence of Hypercholesterolemia and Elevated Ratio of Total to HDL-Cholesterol

<table>
<thead>
<tr>
<th></th>
<th>Normal blood pressure</th>
<th>High blood pressure</th>
<th>Antihypertensive drugs</th>
<th>Normal blood pressure</th>
<th>High blood pressure</th>
<th>Antihypertensive drugs</th>
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</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>No.</td>
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<td>568</td>
<td>214</td>
<td>1678</td>
<td>322</td>
<td>295</td>
</tr>
<tr>
<td>High chol (%)</td>
<td>18.1</td>
<td>28.5</td>
<td>34.6</td>
<td>19.1</td>
<td>37.0</td>
<td>36.3</td>
</tr>
<tr>
<td>High ratio (%)</td>
<td>15.4</td>
<td>20.6</td>
<td>29.9</td>
<td>5.3</td>
<td>12.5</td>
<td>13.2</td>
</tr>
</tbody>
</table>

**Women**

<table>
<thead>
<tr>
<th></th>
<th>Normal blood pressure</th>
<th>High blood pressure</th>
<th>Antihypertensive drugs</th>
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</tbody>
</table>
prevalence of hypercholesterolemia was 57% greater in subjects with untreated high blood pressure than in subjects with normal blood pressure ($p < 0.001$); in women the prevalence of hypercholesterolemia was 94% greater in subjects with untreated high blood pressure ($p < 0.001$). In men with untreated high blood pressure, the prevalence of elevated TC/HDL cholesterol ratios was approximately 34% greater than in those with normal blood pressure ($p < 0.01$); in women, the prevalence of elevated TC/HDL cholesterol ratios was more than twice as great in those with untreated high blood pressure ($p < 0.001$). The greater difference in the prevalence of elevated TC and TC/HDL cholesterol ratios between hypertensive and normotensive women in comparison with men, was primarily the result of the greater age difference between normotensive and hypertensive groups in women. In men, but not women, there was a significantly greater prevalence of elevated TC/HDL cholesterol ratios in subjects receiving antihypertensive treatment in comparison with subjects with untreated high blood pressure ($p < 0.01$). However, this difference probably represents age differences between groups as well as the effects of antihypertensive treatment.

Discussion

Comparison of plasma lipid and lipoprotein levels in subjects with normal blood pressure and in subjects with untreated high blood pressure indicated significantly higher levels of TC, TC/HDL cholesterol ratios and TG in the hypertensive group. In women, but not men, LDL cholesterol was also higher in those with untreated high blood pressure than in those with normal blood pressure. In both men and women there was no difference in HDL cholesterol between these groups. Comparison of plasma lipid and lipoprotein levels in subjects being treated for hypertension and in subjects with untreated high blood pressure indicated that in both men and women, HDL cholesterol was lower in the treated group. In men, TC/HDL cholesterol ratios and TG were also higher in treated than in untreated hypertensive subjects. The differences between treated and untreated hypertensive groups were independent of age, body mass index, alcohol consumption, and smoking. The lower HDL cholesterol in subjects receiving antihypertensive treatment is consistent with reports of the effects on plasma lipoproteins of beta-blockers and methyldopa, both of which were widely used in Australia to treat hypertension at the time of the study. The reduced heart rate in men and women receiving antihypertensive treatment in comparison with those with untreated high blood pressure is strongly suggestive of the widespread use of beta-blockers in this study population. The greater TG levels in men receiving antihypertensive treatment is consistent with reports of the effects of beta-blockers and diuretics.

The differences between treated and untreated hypertensive groups suggest that the effects on HDL cholesterol and TG of antihypertensive therapy, as practiced in Australia, are of sufficient magnitude and duration to affect the mean plasma lipid and lipoprotein levels of treated hypertensive groups in the community. These results are consistent with the Lipid Research Clinics’ observation of a lower HDL cholesterol level and a higher TG level in the small group of subjects receiving propranolol in comparison with matched controls from the same study population.11 Our finding of similar levels of TC and LDL cholesterol in treated and untreated hypertensive subjects suggests that: 1) diuretics were most often prescribed in conjunction with beta-blockers, which prevent the increase in TC and LDL cholesterol normally associated with diuretic therapy;16 or 2) the effects of diuretic monotherapy on TC and LDL cholesterol are not of sufficient magnitude or duration to significantly affect population lipid or lipoprotein levels.

It is possible to estimate the overall effects that antihypertensive treatment may have had on the risk of CAD in these subjects by using data from the Framingham Study about the risk of developing CAD at different blood pressure and plasma lipoprotein cholesterol levels. In the Framingham Study, the risk of coronary artery disease in men with “borderline hypertension” (a systolic blood pressure of 140–159 mm Hg and/or a diastolic blood pressure of 90–95 mm Hg), was 18% less in men with “established hypertension” (systolic blood pressure of 160 mm Hg or more and/or a diastolic blood pressure greater than 95 mm Hg); in women, the risk was 29% less in the borderline hypertension group.25 In the present study, the blood pressures of subjects treated for high blood pressure closely approximated those of the Framingham borderline hypertension group; pretreatment blood pressures in this group were probably similar to those of the established hypertension group. If lowering blood pressure from established hypertension levels to borderline hypertension levels reduces the risk of CAD to the level associated with the lower blood pressure, then antihypertensive treatment in our subjects may have reduced the risk of CAD by 18% in men and 29% in women. (This assumes that all other risk factor levels remain constant.)

Using similar data from the Framingham Study about CAD risk associated with different levels of HDL cholesterol, we estimated that for both sexes, the 5% lower HDL cholesterol level in subjects being treated for high blood pressure increased the CAD risk associated with this lipoprotein by 12%.30 Therefore in men, who have most of the coronary events, approximately two-thirds of the estimated reduction in risk associated with lowering blood pressure could be offset by a 5% decrease in HDL cholesterol. In women, at least 40% of the reduction in risk associated with lowering blood pressure could be offset by such a decrease in HDL cholesterol. While these
effects on the calculated risk of CAD warrant concern, work is still required to determine the true significance of drug-induced changes in plasma lipids and lipoproteins.

The importance of considering plasma lipid and lipoprotein changes during antihypertensive therapy is accentuated by our finding that, even before treatment, more than 40% of all hypertensive subjects had a TC higher than 252 mg/dl or a TC/HDL cholesterol ratio higher than 6.0. The tendency for persons with high blood pressure to have high plasma lipid levels has also been observed in studies from the United States and Norway. However, it is not widely recognized that almost one in two patients with high blood pressure will probably have a significant plasma cholesterol abnormality. In men in our study who received antihypertensive treatment, abnormalities of plasma lipid and lipoprotein cholesterol occurred with even greater frequency than in men with untreated high blood pressure. In men on treatment, more than 50% had elevated TC levels or TC/HDL cholesterol ratios.

The results of the present study indicate that a large proportion of persons with untreated high blood pressure probably have a plasma lipid or lipoprotein cholesterol abnormality, and that such abnormalities may be aggravated by antihypertensive therapy. This suggests that there is a strong case for the routine investigation of plasma lipid and lipoprotein levels in high blood pressure patients before and during antihypertensive treatment. In patients with pre-existing plasma lipid or lipoprotein abnormalities or in patients whose plasma lipid levels react adversely to conventional antihypertensive therapy, it seems reasonable to consider therapeutic agents without known adverse effects on plasma lipids or lipoproteins. In addition, lipoprotein abnormalities may be aggravated by antihypertensive therapy. The criteria for successful treatment of high blood pressure should include the absence of adverse effects on plasma lipid and lipoprotein levels.

Acknowledgments

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Index Terms: hypertension • cholesterol • triglycerides • high density lipoprotein cholesterol • propanolamines
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S W MacMahon, G J Macdonald and R B Blacket

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