The Arm-Ankle Pressure Gradient in Relation to Cardiovascular Risk Factors in Intermittent Claudication

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SUMMARY  The arm-ankle systolic pressure gradient was measured in 165 male patients with intermittent claudication and was correlated with different combinations of known cardiovascular risk factors. The pressure gradient increased with increasing number of risk factors. We conclude that intermittent claudication may be used as a simple model for studies of arteriosclerosis, the arm-ankle systolic pressure gradient being a measure of the degree of arteriosclerosis between heart and ankle.

NO noninvasive techniques allow quantification of the resistance to blood flow caused by arteriosclerosis in the coronary arteries. However, simple, noninvasive quantitative methods are available to detect even early effects of arteriosclerosis in leg vessels. 

Arterial disease of the legs is almost always caused by arteriosclerosis. The systolic pressure gradient between the upper arm level and the ankle level can be considered an indirect measure of the amount of arteriosclerosis from heart level to ankle level. We previously reported on a significantly greater pressure gradient between upper arm level and toe level in middle-aged smokers without signs or symptoms of peripheral arterial disease compared with nonsmokers of the same age and sex.

Our aim in the present study was to evaluate intermittent claudication as a model for studies of arteriosclerosis by analyzing the relationship of known cardiovascular risk factors and the pressure gradient between upper arm and ankle level in patients with intermittent claudication.

Material and Methods

We studied 208 consecutive male patients, 30–75 years old, who between 1975 and 1978 were referred for the first time to the Department of Surgery in Malmö because of intermittent claudication. Patients with rest pain or gangrene were excluded.

A standardized evaluation included arm blood pressure measurements after 10 minutes of rest, determination of plasma cholesterol and plasma triglycerides, and assessment of smoking habits with a questionnaire.

Segmental Measurements of Systolic Blood Pressures

The recording system has been extensively described by Gundersen, and consists of pulse sensors (mercury-in-Silastic strain gauges); two Wheatstone bridges with amplifier to record changes in the resistance of the strain gauges; blood pressure cuffs (18 × 60 cm to measure ankle pressure and a 12 × 35 cm to measure the upper arm pressure); a pressure transducer (Siemens-Elema EMT 746 with amplifier EMT 311) to record cuff pressures; and a four-channel ink-jet recorder (Siemens-Elema, Mingograph).

The pulse sensors are placed on the big toes and thumbs. When the cuff pressure is raised to supra-systolic levels, the pulsations in the thumb and in the big toes disappear. Then, by immediate, slow deflation of the cuffs and simultaneous recording of the cuff pressures and the volume of the big toes and thumb, the time of transmission of the first pulse past the cuff is noted. The corresponding pressure in the cuff is taken as the systolic blood pressure at the upper arm and at ankle level, respectively. In our 10 years of experience with this method, the short inflation of the ankle cuff has been found to be without risk of vascular damage. The patient is in a recumbent position with his feet at heart level. The room temperature is kept constant between 21–23°C. If the pressure difference between the arms is less than 15 mm Hg, the right arm is used as a reference for calculating the pressure gradient to the right and the left ankle. Otherwise, the highest recorded pressure is used as a reference. This procedure is used to avoid an erroneous underestimation of the systemic blood pressure because of stenosis of one of the subclavian arteries. In none of the patients in this study did the pressure difference between the right and left upper arm exceed 15 mm Hg.

Definitions of Risk Factors

Hypertension was defined as a systolic blood pressure ≥ 160 mm Hg, a diastolic blood pressure of ≥ 105 mm Hg, or known treatment for hypertension.

Hyperlipidemia was defined as plasma cholesterol ≥ 7.5 mmol/l and/or plasma triglycerides of ≥ 2.8 mmol/l. The defined end points represent the ninetieth percentiles in the population of middle-aged men in Malmö.

Smoking was defined as regular smoking of at least 1 g of tobacco per day for at least 1 year.
The results are based on findings in 165 out of 208 patients, in whom data were complete.

**Statistical Methods**

The pressure gradient from right arm to right ankle and left ankle was calculated for each patient and related to his number of cardiovascular risk factors. Besides, separate analyses were made for each leg. The association between the number of cardiovascular risk factors and the systolic upper arm-ankle pressure gradient was expressed as the correlation coefficient: $H_{e}^{2} f = 0.8$.

**Results**

The distribution and combinations of risk factors are given in Table 1. All patients were or had been regular smokers. In 38% smoking was the only risk factor found. Twenty-seven percent were smokers with hypertension, 16% smokers with hyperlipidemia and 17% smokers with both hypertension and hyperlipidemia.

Table 2 shows the arm-ankle pressure gradient in the worse leg (greater pressure gradient) and the better leg (smaller pressure gradient) in relation to the number of cardiovascular risk factors. In the separate analyses for each leg, 12 subjects were excluded because they had equal pressure gradients in both legs. The mean pressure gradient in those with smoking as the only risk factor was 32 mm Hg (one leg 51 mm Hg, the other leg 13 mm Hg). In smokers with hypertension or hyperlipidemia the pressure gradient was 41 mm Hg (one leg 52 mm Hg, the other leg 20 mm Hg). In smokers with both hypertension and hyperlipidemia, the pressure gradient was 50 mm Hg (one leg 70 mm Hg, the other leg 31 mm Hg). A significant correlation between the number of cardiovascular risk factors and arm-ankle pressure gradient was found for the better leg ($r = 0.33, p < 0.01$) as well as for the worse leg ($r = 0.24, p < 0.01$).

**Discussion**

To study whether the degree of arteriosclerosis between heart and ankle increases with an increasing number of risk factors, subjects with arteriosclerotic lesions of different severity must be included. Patients with rest pain or gangrene would not be suitable for such studies because of advanced age and state of the disease. On the other hand, among patients with intermittent claudication one will find early as well as mild and moderately severe cases of arteriosclerosis.

The fact that the arm-ankle pressure gradient increased to both legs with increasing number of risk factors supports the view that arteriosclerosis is a generalized disease. The difference in pressure gradient between the two legs when exposed to the same set of risk factors emphasizes that there are factors besides smoking, hypertension and hyperlipidemia that are important in the development of arteriosclerosis. The influence of different hemodynamic factors on the atherosclerotic process was studied by Texon et al.

The systolic blood pressure in the brachial artery and in the arteries of the lower legs is considered to be mainly independent of tone in the resistance vessels and viscosity of the circulating blood. In normal subjects there is no fall in systolic blood pressure between upper arm and ankle level. Therefore, any fall in systolic pressure between arm and ankle level may be considered to reflect structural changes in the wall of the arteries from heart to ankle level. We observed an increased pressure gradient from arm to ankle in all our patients with intermittent claudication. The pressure gradient increased with an increasing number of known risk factors for arteriosclerosis. All patients were examined with the same technique and patients from the different risk factor groups were evenly distributed during the period of the study. There were no statistically significant differences in terms of age at diagnosis or duration of disease between our groups with different combinations of known risk factors. In none of the patients did the difference between the right and left upper arm differ more than 15 mm Hg, and we have little reason to believe that the right upper arm

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**Table 1. Distribution of Cardiovascular Risk Factors in Patients with Intermittent Claudication**

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>Median age (years)</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking only</td>
<td>61</td>
<td>64</td>
<td>39</td>
</tr>
<tr>
<td>Smoking + hyperlipidemia</td>
<td>61</td>
<td>27</td>
<td>16</td>
</tr>
<tr>
<td>Smoking + hypertension</td>
<td>57</td>
<td>45</td>
<td>27</td>
</tr>
<tr>
<td>Smoking + hyperlipidemia + hypertension</td>
<td>61</td>
<td>29</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>165</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Missing cases</td>
<td>43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Arm-ankle Pressure Gradient (mm Hg) in Relation to Number of Cardiovascular Risk Factors**

<table>
<thead>
<tr>
<th>Cardiovascular risk factors</th>
<th>Worse leg ($n = 153$)</th>
<th>Better leg ($n = 153$)</th>
<th>Both legs ($n = 165$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking only</td>
<td>51 ± 2.0</td>
<td>13 ± 2.4</td>
<td>32 ± 2.4</td>
</tr>
<tr>
<td>Smoking + hypertension or hyperlipidemia</td>
<td>62 ± 2.5</td>
<td>20 ± 3.2</td>
<td>41 ± 2.7</td>
</tr>
<tr>
<td>Smoking + hypertension + hyperlipidemia</td>
<td>70 ± 4.6</td>
<td>31 ± 5.9</td>
<td>50 ± 3.9</td>
</tr>
<tr>
<td>$r$</td>
<td>0.33</td>
<td>0.24</td>
<td>0.37</td>
</tr>
<tr>
<td>$p$</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

Values are mean ± sem.
arm pressure should not be representative for the systemic arterial pressure in these patients.

We believe that the increased pressure gradient that was observed reflects quantitatively an increasing degree of arteriosclerosis between heart and ankle with increasing number of risk factors.

The present study indicates that measurements of the pressure gradient between arm and ankle level can be used to study quantitatively arteriosclerosis between heart and ankle in patients with intermittent claudication. Whether patients with intermittent claudication can be used for studies regarding the potential for secondary prevention of arteriosclerosis cannot be evaluated on the basis of the results from this study. Of course, one cannot take the amount of arteriosclerosis in the arteries between heart and ankle as an expression of the amount of arteriosclerosis in the coronary vessels and the brain vessels. However, there is little reason to believe that the arteriosclerotic process in the arteries to the legs would be different from that in the coronary vessels and the brain vessels. For studies of progression and regression of arteriosclerosis, we believe that the arteries supplying the legs could be used as a valid, simple model where the great advantage lies in the possibility of quantitating the amount of arteriosclerosis with reliable, noninvasive methods.

References
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L Janzon, S E Bergentz, B F Ericsson and S E Lindell

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