Quantitative Difference in "Critical" Stenosis Between Right and Left Coronary Artery in Man

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SUMMARY  Coronary artery stenoses that limit blood flow below demand are considered critical. In this comparative study we investigated whether the same degree of stenosis in either the proximal third of the right coronary artery (RCA) or the proximal third of the left anterior descending artery (LAD) causes critical flow reduction. Lesions were quantified from 35-mm cinefilms in multiple projections using a vernier caliper. These morphometric measurements were correlated with various manifestations of critical flow reduction, such as angina pectoris, development of collateral vessels and segmental wall motion abnormalities. In 13 patients with anginal pain and isolated RCA stenosis, the mean degree of obstruction was 63% area stenosis, which was significantly lower ($p < 0.05$) than that measured in 17 symptomatic patients who had isolated obstructions of the LAD (77% area stenosis). In patients with an identical degree of obstruction (78%) in either the LAD or RCA, collateral vessels were angiographically demonstrable in 53% of the RCA stenoses but in only 29% of the LAD stenoses. Furthermore, when the stenoses were less than 63% in the RCA and LAD, regional wall motion abnormalities were more frequently ($p < 0.05$) associated with RCA than with LAD stenoses. These observations indicate that a significantly smaller percent area of stenosis is critical in the RCA than in the LAD.

THE DEGREE of coronary artery stenosis at which the resistance to flow becomes sufficient to impair myocardial oxygenation is generally considered critical. Several experimental studies indicate that when the cross-sectional luminal area is reduced by 80%, there is a functionally significant reduction in blood flow. A similar degree of critical stenosis has been defined retrospectively in postmortem human coronary arteries and was demonstrated recently in a selected group of patients. Accurate evaluation of critical stenoses in patients with coronary artery disease requires a precise quantification of the degree of coronary obstruction from high-quality coronary angiograms. Qualitative estimation of the degree of stenosis too often is fraught with both intra- and interobserver variability. For the optimal assessment of coronary disease, accurate quantitative measurements must be correlated with clinical symptoms and with the hemodynamic and hydraulic consequences of critical flow reduction.

The purpose of the present study was to determine the cross-sectional area of stenosis in selected branches of the coronary arteries in human subjects and to correlate these quantitative measurements of coronary obstructions with three functional consequences: symptoms of anginal pain in a group of patients with one-vessel disease, development of coronary collateral vessels, and occurrence of regional ventricular wall motion abnormalities.

Methods

Patients in this study represent consecutive cases who met the criteria for selection described in the following three sections.

Morphometric Measurements of Critical Stenoses

The quantitative evaluation of the degree of coronary obstruction was performed in a group of symptomatic patients with an isolated obstruction either in the proximal third of the left anterior descending artery (17 patients) or in the proximal third of the right coronary artery (13 patients). All patients had recent onset of typical angina pectoris. In 20 patients (11 with an isolated stenosis of the left anterior descending artery and nine with an isolated stenosis of the right coronary artery), transient ischemic ST-segment depression of 1 mm or more had been demonstrated during ischemic attacks when they entered the emergency room. In the remaining 10 patients ischemic ECG changes were observed in the exercise stress test. No patient had ST-segment elevation during the episodes of chest pain. Patients with angiographically visible collateral vessels bypassing the isolated obstructions were excluded from this portion of the study. Severe arterial hypertension was ruled out in all cases by history, retinal changes, ECG changes and pressure measurements during catheterization. Furthermore, there was no significant difference in mean aortic pressure at catheterization between patients with isolated left anterior descending artery stenosis and patients with isolated right coronary artery stenosis. Vasodilator therapy was interrupted at least 24 hours before angiography and no patient was given nitroglycerin as premedication immediately before or during angiography.

The extent of obstruction was measured with a vernier caliper as previously described. The 35-mm films of coronary angiography were projected on the screen of a Tagarno projector. The enlargement factor

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caused by the image magnifier and the projection was approximately threefold, but it was determined more precisely by measuring the catheter tip placed in the coronary ostium. To minimize errors from pincushion distortion, the measurements were consistently performed near the center of the x-ray beam. Although changes in lumen diameter were not detectable during the cardiac cycle, measurements were performed only at end-diastole. This precaution virtually eliminates the blurring effect from rapid heart movements and the reading errors caused by axial or spatial rotations.

Taking into account the eccentric lumen of many obstructions, atherosclerotic lesions were measured in as many projections as possible (four to seven, average five projections). Sites of measurements in vessels with obstructions included the prestenotic segment 5–10 mm proximal to the narrowest part of the obstruction, the narrowest diameter of the obstruction itself and the immediate poststenotic segment 5–10 mm distal to the obstruction. The degree of stenosis is calculated by the formula:

\[
\% \text{ area stenosis} = \left(1 - \frac{D_{\text{sten}}^2}{D_{\text{norm}}^2}\right) \times 100.
\]

In this formula, \(D_{\text{norm}}\) is the diameter of the undiseased prestenotic vessel and \(D_{\text{sten}}\) the average stenotic diameter, both calculated as the arithmetic mean of as many measurable diameters as possible. Both diameters were used to calculate the respective cross-sectional area by the formula of a circle area (\(A = \pi r^2\)). In addition, the length of the narrowest section in each obstruction was measured in the same projections as the diameters.

Validity of this method was demonstrated in comparing intravital angiograms with postmortem histologic measurements of the same coronary lesions.\(^{11,12}\) All coronary artery measurements were performed by the same observer. To determine the intraobserver variability, 14 angiograms were analyzed at two times in a pilot study. The differences in calculating the degree of 25 obstructions ranged from 0–11% stenosis (average 6.2 ± 3% stenosis).

**Evaluation of Collateral Circulation**

To determine whether there is any difference in the development of collateral vasculature in response to a left anterior descending or right coronary artery stenosis, another group of patients with a comparable degree of stenosis in either artery was studied. In patients with a proximal obstruction in two of the three major coronary branches — left anterior descending artery, right coronary artery and left circumflex artery — the degree of the obstruction must have been measurable in at least three different projections. Patients with a complete occlusion in one or both arteries were not included. In the 24 patients selected for this study, a similar degree of obstruction in either artery could be measured: 16 patients had a nearly identical degree of stenosis in the left anterior descending artery and the right coronary artery, five in

the left anterior descending artery and the left circumflex artery and three in the right coronary artery and the left circumflex artery. Thus, collateralization could be compared in 21 stenoses of the left anterior descending artery and in 19 stenoses of the right coronary artery with a similar degree of obstruction. In each case the presence of angiographically visible intercoronary collaterals (usually two to four vessels) was evaluated. We considered as carefully as possible some of the pitfalls that make comparison of angiographically visible collaterals between different patients difficult.\(^{47}\) Physiologic factors, such as changes in aortic pressure or changes in neural regulation as estimated by heart rate variation, and technical variables, such as the amount and velocity of the contrast media injected, were similar in all patients.

**Segmental Wall Motion Analysis**

To correlate the severity of a coronary obstruction with the residual mobility of the myocardium that it supplied, two other groups of patients were examined. Group 1 was composed of 33 patients with anterior wall motion abnormality and group 2 included 23 patients who had an inferior wall motion abnormality only. Impaired segmental contraction was then compared with the degree of obstruction in the respective nutrient artery.

Segmental wall motion was analyzed from the left ventricular angiogram in 30° right anterior oblique projection at rest. Following the method described by Herman et al.,\(^{19}\) the axis from the intersection of the aortic and the mitral valve to the apex of the heart was drawn in both the end-diastolic and the end-systolic left ventricular silhouette. The longitudinal axis was divided at 25%, 50% and 75% of its length by three perpendicular axes. The shortening of the obtained six hemiaxes during systole was calculated as percentage of the end-diastolic length. Shortening of more than 25% was defined as normokinesis, a shortening of 10–25% was considered hypokinesis and a shortening less than 10% was considered akinesis. The reason for this choice is based on a pilot study conducted in 25 patients with normal coronary arteries and left ventricular angiograms in whom the systolic shortening of the six hemiaxes was 35–50% of end-diastolic length. In the selected projection (30° right anterior oblique), wall motion abnormalities of the entire anterior wall are caused by left anterior descending artery disease, whereas only the posterior segments of the inferobasal wall will show segmental abnormalities in case of right coronary artery disease in a right dominant coronary artery system.\(^{14}\) Two of the three anterior wall hemiaxes and the two posterior hemiaxes of the inferior wall had to show wall motion abnormality to be included into this study. Patients with prior myocardial infarction or with a complete obstruction in one or more vessels were excluded from the study.

The results are expressed as the arithmetic mean ± SEM. The significance of differences was assessed by \(t\) test, and \(p\) values < 0.05 were considered significant.
Results
Morphometric Measurements of Critical Stenosis

Table 1 and figure 1 illustrate the results of the morphometric analysis of the severity of proximal third coronary artery obstructions in 30 patients with isolated obstructions either in the left anterior descending artery or the right coronary artery. In both vessels the degree of flow-limiting stenoses showed a marked degree of scatter, and the overlap between the two groups was considerable. However, the average percent area of stenosis in the 17 isolated left anterior descending artery lesions was 77.1 ± 3.2%, whereas the 13 isolated right coronary artery obstructions showed a mean degree of 63.6 ± 4.4% (p < 0.05). The length of the narrowest portion in the stenosis ranged

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Mean ± SEM

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Mean ± SEM

RCA stenoses (n = 13)
77.1 ± 3.2%

63.6 ± 4.4%

Note that the prestenotic proximal diameters of the left anterior descending artery and the right coronary artery are not significantly different from diameters of normal proximal left anterior descending arteries and right coronary arteries.

Abbreviations: LAD = left anterior descending coronary artery; RCA = right coronary artery.
from 0.8–2.9 mm (average 2.0 mm) in the obstructions of the left anterior descending artery and from 1.1–3.3 mm (average 2.4 mm) in the right coronary artery obstructions (NS).

Evaluation of Collateral Circulation

Table 2 is a comparison of the difference in collateralization in a group of 24 patients with a similar degree of stenosis in two of the major coronary branches. In 16 patients comparable obstructions were measured in the proximal third of the left anterior descending artery and in the proximal third of the right coronary artery. In addition, five patients had a comparable stenosis in the left anterior descending artery and in the left circumflex artery and three patients in the right coronary artery and in the left circumflex artery. In every vessel the measured stenosis was the only significant obstruction; the distal segment had either no disease or had only few minor irregularities that did not exceed 30% stenosis. The 21 stenoses of the left anterior descending artery had a mean degree of obstruction of 78 ± 4.1%, and in six of these 21 (29%), there were angiographically visible collaterals. In contrast, in 19 nearly identical obstructions of the right coronary artery wherein the mean degree of stenosis was 78 ± 4.9%, 10 of the 19 (53%) showed clearly visible collateral circulation. In most cases the collaterals originated from the undiseased vessel. Although the difference is not statistically significant, these results illustrate that angiographical-

ly visible collaterals can be demonstrated more frequently in severe stenoses of the right coronary artery than in comparable stenoses of the left anterior descending artery.

Segmental Wall Motion Analysis

We found no correlation between the degree of wall motion deterioration (hypokinesis and akinesis) and the severity of obstruction (table 3), which is again comparable in either the left anterior descending or in the dominant right coronary artery. For example, comparing wall motion abnormalities of the anterior wall and the posterior wall with the degree of obstruction in the left anterior descending and right coronary artery yielded a correlation coefficient of \( r = 0.06 \) and \( r = 0.13 \), respectively. Based on the assumption that the degree of stenosis that is critical in the dominant right coronary artery is significantly less than the one in the left anterior descending artery, we then analyzed our results considering 63% of stenosis as the reference standard. Table 4 is a summary of this analysis, showing that when the degree of stenosis is 63% or less, 11 of 23 patients with right coronary artery disease show inferior wall segmental wall motion abnormalities, whereas only five of 33 patients with left anterior descending artery disease show anterior wall motion abnormalities (\( p < 0.01 \)).

Taken collectively, these observations indicate that more obstruction is required to produce a critical decrease in flow in the left anterior descending artery than in the right coronary artery.

Discussion

The general belief that not all stenoses in the coronary arterial system need be hemodynamically significant has led to the concept of the critical stenosis. This is usually defined as the percentage by which the cross-sectional area of a vessel must be reduced to produce a functionally significant decrease in blood flow. In an intact heart with critical stenosis, the resistance offered by the obstruction has increased to the point that it can no longer be compensated by autoregulatory decreases in resistance.\(^2\) However, the degree of stenosis that will impede flow is also critically dependent upon changes in flow rates.\(^3\) Changing flow rates in physical models,\(^4\) in iliac\(^5\) or coronary\(^6\) arteries of the dog or in postmortem human coronary arteries\(^6\) have demonstrated that critical flow reduction requires less anatomic obstruction at high flow rates than under low flow conditions.\(^1\)

Although several investigators have measured coronary artery diameters in a variety of animal models\(^21-22\) or from coronary angiograms in man,\(^21,24-29\) including some studies that were particularly concerned with measurements performed in patients with coronary artery obstructions,\(^7,21-23\) we could not find any study comparing quantitative measurements of isolated right coronary artery and isolated left anterior descending artery obstructions in two matching groups of symptomatic patients. Although
Table 2. Degree of Stenosis, Origin and Incidence of Angiographically Visible Collaterals in 24 Patients with a Comparable Obstruction in Two of the Three Major Coronary Arteries

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Mean ± SEM 78 ± 4 78 ± 5 82 ± 3

Incidence of collaterals 6 10 3

Abbreviations: LAD = proximal third of the left anterior descending artery; RCA = proximal third of the right coronary artery; LCX = main stem of the left circumflex artery to the origin of obtuse marginal artery.

this question was not specifically addressed, the present study raises the possibility that a critical degree of stenosis may be different in the same vessel, depending on momentary myocardial flow demands. Furthermore, the critical degree of stenosis appears to be different in two major branches of the coronary artery system, suggesting that a lesser degree of stenosis is critical in the right coronary artery than in the left anterior descending artery. Because blood flow through a stenotic lesion is also influenced by the length of the obstruction, we measured the length of the vessel segment with the smallest diameter. Although the entire stenotic segment contributes to the resistance offered by a stenosis, the minimal cross-sectional area is the most important factor in limiting flow. In our patients with isolated proximal obstructions of the left anterior descending artery and the right coronary artery, the lengths at which minimal vessel diameter was measured were not significantly different. This observation suggests that length of the stenotic lesions cannot account for the difference in critical degree of stenosis that we observed in the right and left anterior descending coronary arteries.

To assess with confidence whether a stenosis is critical, precise measurements of an obstruction should be considered in conjunction with other indirect evidence of functionally important myocardial blood flow reduction. The two additional criteria included in this study were the presence of anginal pain and a measurement of regional myocardial contractile performance. Special consideration was also given to the angiographic visualization of collateral vessels.

The underlying mechanism of anginal pain in some of our patients with a single stenosis of either the right coronary artery or the left anterior descending cor-
TABLE 3. Severity of Obstructions in the Left Anterior Descending Artery of 23 Patients with Anterior Wall Motion Abnormalities Compared with Stenoses in the Right Coronary Artery of 23 Patients with Posterior Wall Motion Abnormalities

<table>
<thead>
<tr>
<th>Coronary artery</th>
<th>Degree of stenosis (%)</th>
<th>Degree of stenosis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
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</table>

Mean ± SEM 77 ± 2.0% 70 ± 2.9%

Abbreviations: LAD = left anterior descending coronary artery; RCA = right coronary artery.

TABLE 4. Number and Location of Hypo- or Akinetic Ventricular Wall Segments and Their Distribution with Regard to the Degree of Obstruction in the Nutrient Artery

<table>
<thead>
<tr>
<th>Coronary artery</th>
<th>Number and location of hypo- or akinetic wall segments</th>
<th>Degree of stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>33 anterior wall</td>
<td>≤ 63%</td>
</tr>
<tr>
<td></td>
<td>23 posterior wall</td>
<td>≥ 63%</td>
</tr>
</tbody>
</table>

χ² = 7.09.

p < 0.01.

Abbreviations: LAD = left anterior descending coronary artery; RCA = right coronary artery.

In some patients, our measurements yielded unusually low degrees of coronary obstructions, suggesting that anginal pain or regional wall motion abnormalities could be elicited by coronary narrowings of less than 50% diameter stenosis. The ratio of cross-sectional areas between the unobstructed and the obstructed segments determines the value of a critical stenosis more accurately than the diameter relationship alone.1, 7, 10 There is no general agreement about the degree of a critical stenosis. On the contrary, depending on the experimental design, a wide variety of flow-limiting stenoses have been proposed.8, 7, 17-19 Furthermore, the reported flow or pressure reduction for a given degree of obstruction varies considerably.60 In several experiments significant pressure and/or flow changes occurred at area stenoses of 70%, which correspond to diameter stenoses of only 45%. Taken collectively, results from the experimental laboratory are still difficult to compare with the in vivo measurements made in man, for at least two reasons. First, there are only few reported intravital measurements of critical stenosis in man. Despite sophisticated scoring systems the degree of a stenosis is almost never exactly measured, but is only estimated. In our recent quantitative study in patients with unstable angina,12 we found an average percent area of stenosis of 78%, which corresponds to a 53% diameter stenosis. Second, we believe that already moderate stenoses can compromise subendocardial blood flow, thus producing ischemic pain and varying degrees of ST-segment depression, as in our patients.

Several reports from studies in animals and in patients with coronary artery disease support the conclusions of our present investigation. For example, in dog experiments, comparative regional myocardial blood flow in the right coronary artery and the left anterior descending artery was assessed with various techniques, including rotameters,36 hydrogen clearance,36 and radioactive microspheres.37-39 All these investigations reported that there is normally a significantly greater flow in the left coronary artery than in the right coronary artery.

Despite the well-known differences between coronary anatomy of humans and dogs,44 blood flow in the left anterior descending artery of man was also significantly higher than in the right coronary artery in several studies using the 133-xenon clearance technique.40-42 Of particular interest are the angiographic data reported by Cosby et al.,43 who showed that stenosis of the right coronary artery was the most frequent finding in patients with coronary artery disease, particularly if angina pectoris was present. In a study of the natural history of coronary artery stenosis, Rösch et al.44 demonstrated that the disease progressed more rapidly in the right coronary artery than in any other coronary vessel, which might explain why Proudfit et al.45 found that the highest percentage of complete obstructions of a symptomatic population was in the right coronary artery.

After severe coronary obstructions, the blood supply must be provided by collateral vessels. The size of most normal anastomoses is below the resolution of most modern cineangiographic equipment, and they...
become angiographically visible only after enlargement. Although the underlying physiologic causes of enlargement of collateral vessels are unclear, both myocardial hypoxia and transanastomotic pressure gradients are considered the most likely causes. In advanced coronary artery disease, collateral vessels are readily visualized and should be considered as an "inherent indicator" of significant flow and pressure reduction caused by severe obstructions. In our group of patients, when comparing similar severity of stenosis in the left anterior descending artery and the right coronary artery, the right coronary artery stenoses were significantly more often bypassed by angiographically visible collaterals than the left anterior descending artery stenoses. This difference confirms the results of Harris et al., who found that the right coronary artery receives intercoronary collaterals more frequently than the left anterior descending coronary artery. In a group of patients with similar symptoms and a similar degree of coronary obstructions, Fischl et al. found more collaterals in the right coronary artery (67% of stenoses) than the left anterior descending artery (21% of stenoses). Similar differences in collateral blood supply were found to prevent ischemic ST changes during treadmill stress test more frequently in the posterior wall than in the anterior wall. Taken collectively, these observations support our conclusion that critical stenosis is less in the right coronary artery than in the left anterior descending artery, and that collateralization occurs at a lesser degree of stenosis in the right coronary artery than in the left anterior descending artery.

Coronary stenoses in the critical range will induce wall motion abnormalities of different severity. We were not surprised to find a poor correlation between the degree of stenosis and the extent of wall motion abnormalities, although patients with complete obstructions or prior myocardial infarction and those with distinct collateral vessels had been excluded from our analysis. Nevertheless, our study indicates that the majority of patients with anterior wall motion abnormalities will show more than 65% stenosis in the left anterior descending artery, whereas nearly half of the patients with posterior wall motion abnormalities had no more than 63% obstruction in the right coronary artery. This difference again supports our suggestion that a lesser degree of stenosis will reduce coronary blood flow critically in the right coronary artery than in the left anterior descending coronary artery.

We do not know why critical stenosis should occur at a lesser degree of obstruction in the right than in the left anterior descending coronary artery, particularly because flow rates are normally higher in the left anterior descending than in the right coronary artery. Several experimental studies documented that a decrease in flow rate in a severely obstructed artery tends to increase the degree of obstruction that is necessary to impede flow. Whether this consideration is a major determinant of the findings presented in this study must be proved. Most experimental studies considered the effects of changes in flow rates in a single vessel. Thus, the design of these experiments make it difficult to use the results obtained and/or the deduced formulas to calculate the relative flow resistance in an in vivo situation of two obviously different myocardial tissue beds with different oxygen requirements.

Our finding of a lesser degree of critical stenosis in the right coronary artery than in the left anterior descending coronary artery may be determined by other physiologic factors, such as anatomic differences between these arteries. In general, the left anterior descending artery immediately gives origin to several side branches, reducing its own diameter continuously over its length. In contrast, the right coronary artery represents a conduit vessel of relatively unchanged diameter as far as to the crux cordis, where it subdivides into its major branches. These anatomic characteristics might, at least in part, be responsible for the different extravascular systolic compression factors exerted on the two respective arteries and might play an important role in determining when a stenosis becomes critical. In the dog, at rest, the systolic-diastolic flow ratio is significantly greater in the right than in the left coronary artery, and it is experimentally well documented that severe stenoses of the left coronary artery increase systolic flow and decrease diastolic flow, with little change in mean flow. The fact that in those experiments with severe obstructions the stenosis pressure gradient is less during systole than diastole might perhaps represent a typical, though unique, adaptive mechanism of the coronary circulation to high degrees of stenosis. The systolic-diastolic flow ratio is already greater at rest in the right than in the left coronary artery, so one could speculate that there will be less reserve capacity for systolic-diastolic flow ratio increments in the right than in the left coronary artery. Although these observations in dogs might not apply to humans because of the well-known differences in the coronary anatomy, the concept that less reserve capacity might be available in the right than in the left coronary artery should be tested further with or without taking into consideration that there might also be noticeable differences in the autonomic neural control or even differences in vasomotor responses between the right and the left coronary arteries.

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Predictive Accuracy of Coronary Artery Calcification and Abnormal Exercise Test for Coronary Artery Disease in Asymptomatic Men

Rene A. Langou, M.D., Edwin K. Huang, M.D., Michael J. Kelley, M.D., and Lawrence S. Cohen, M.D.

SUMMARY To determine the predictive accuracy of fluoroscopically detected coronary artery calcification (CAC) and a positive submaximal exercise test, 129 asymptomatic men were screened; 13 had both coronary artery calcification and positive exercise test (≥1.0 mm ST-segment depression). These 13 men were studied at coronary arteriography. They had a mean age of 44 years (range 41–56 years); none had history or symptoms of heart disease and all had normal resting ECGs at entry.

CAC was detected in one artery in 10 men, in two arteries in two men, and in three arteries in one man. Coronary artery disease (CAD) was considered clinically significant if any major coronary branch was narrowed >50%. Coronary arteriography revealed 12 men with clinically significant CAD (one-vessel CAD in four, two-vessel CAD in five and three-vessel CAD in three men) and one man with minor one-vessel CAD. The predictive accuracy was 100% for minor CAD and 92% for clinically significant CAD. The location of CAC and CAD correlated, but the absence of CAC did not rule out the presence of CAD at coronary arteriography. Furthermore, CAC did not indicate the location of the highest stenotic (most occlusive) lesions seen at arteriography. Follow-up for the 13 patients was 36 months; three patients developed typical angina and one patient developed a transmural myocardial infarction.

This study suggests that the predictive accuracy of CAC and a positive exercise test in the middle-aged non-hyperlipidemic asymptomatic male is very high (100% for CAD and 92% for clinically significant CAD) and that CAC and a positive exercise test predict an early appearance of angina or myocardial infarction in previously asymptomatic men.

THE EMPHASIS on early diagnosis and prevention of ischemic heart disease has stimulated a search for reliable noninvasive methods of detection. Risk factor screening and resting ECGs are useful in epidemiologic and mass screening programs but are not diagnostically helpful in the asymptomatic subject.

Although exercise electrocardiography is widely used as a noninvasive procedure to diagnose coronary artery disease, the large proportion of false-positive and false-negative results precludes its use as a standard screening device in the asymptomatic person. Clinical or laboratory markers that might identify those with asymptomatic coronary artery disease would be useful. Previous reports have established the positive relationship between the presence of coronary calcification on fluoroscopy and angiographically demonstrated coronary artery disease in symptomatic patients.

In this study we used exercise electrocardiography and cardiac fluoroscopy to screen asymptomatic subjects as part of a prospective clinical research protocol. This report presents the value of combining the electrocardiographic response to exercise and fluoroscopically detected coronary artery calcification in asymptomatic subjects and the clinical course of asymptomatic subjects that have both an abnormal electrocardiographic response to exercise and coronary artery calcification on fluoroscopy.

Materials and Methods

The study group of 129 middle-aged males volunteered for two-part examinations consisting of (1) cardiac fluoroscopy and a submaximal exercise stress test; and (2) cardiac catheterization in subjects who had coronary artery calcification on fluoroscopy and an abnormal electrocardiographic response to sub-
Quantitative difference in "critical" stenosis between right and left coronary artery in man.

W Rafflenbeul, F Urthaler, P Lichtlen and T N James

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