Correlation of Electrocardiographic Studies and Arteriographic Findings with Angina Pectoris

By Gottlieb C. Friesinger, M.D., and Raphael F. Smith, M.D.

SUMMARY
The relationships among angina pectoris, stress tests, and arteriography are complex. The majority of patients with angina pectoris can be adequately diagnosed by a careful history. Considerable attention to detail and repeated questioning is often necessary before the pain syndrome can be accurately classified. The resting electrocardiogram is of limited value in the diagnosis despite the fact that there is a high positive correlation between abnormal ST-T changes on the electrogram and significant obstructive lesions on coronary arteriograms. The value of the electrocardiogram is enhanced, and its specificity and sensitivity increased, when used in combination with exercise stress. The lowest error percentage is achieved by utilizing rate-standardized exercise tests and multiple leads with loads that produce heart rate responses of 80–90% of the expected maximum. Coronary arteriography gives the most specific anatomic information in patients with ischemic cardiac pain but will not directly disclose the cause of the pain. This fact assumes considerable importance when the pain has atypical features or when the patient is in the age group that has a high prevalence of coronary atherosclerosis. Similarly, the presence of past myocardial infarction is likely to be associated with obstructive disease, regardless of the cause of the patient's current symptoms. The exact role of lipid and other metabolic abnormalities in producing coronary arteriographic changes in the absence of symptoms needs further clarification, although the available data suggest that marked elevations in lipid fractions are frequently associated with atherosclerotic change, regardless of symptoms. Finally, the data imply that the anatomic abnormalities and functional consequences of the coronary atherosclerotic process are more important predictors of the patient's course than any specific symptomatic expression such as angina pectoris.

Additional Indexing Words:
Venn diagrams

Angina Pectoris is a clinical term and denotes a symptom complex. As ordinarily used, there is lack of precision in the definition of the term “angina pectoris” which poses a fundamental difficulty in approaching the problem of correlating the electrocardiographic findings and arteriographic observations. It is useful to consider ischemic myocardial states as a spectrum, or set, with angina pectoris a subset of the spectrum as is shown in the Venn diagram (fig. 1). Ischemia from obstructive coronary disease and ischemia without coronary obstruction are disjoint sets within the spectrum. Ischemia due to obstructive coronary disease is the major subset of the ischemic myocardial spectrum. The subsets of myocardial infarction and angina pectoris are composed primarily of patients with obstructive coronary disease but may occur in many conditions aside from coronary arteriosclerosis which provoke an unfavorable balance between myocardial oxygen supply and needs. Examples of such conditions are hypertension, aortic valve
Venn diagram illustrating relationships among ischemic myocardial states, obstructive coronary atherosclerosis, and the pain syndromes of ischemic heart disease. The areas do not depict quantitative, only qualitative relationships. See text for discussion.

Figure 1

Disease, and cardiomyopathy of the hypertrophic and hyperdynamic type. Angina pectoris may coexist with previous myocardial infarction or may merge with myocardial infarction in "preinfarction syndromes" (E). In this discussion, we are primarily concerned with establishing correlations between coronary arteriosclerosis and electrocardiographic alterations in patients with angina pectoris (situations C, E, of fig. 1) although the importance of nonarteriosclerotic causes of myocardial ischemia (B, D, G) should not be overlooked in the clinical evaluation of patients.

Since the medical history, electrocardiography, and coronary arteriography are the mainstays in the physician's armamentarium for diagnosing and evaluating angina pectoris, it is germane to discuss the strengths and weakness of these methods. In angina pectoris the history is an extremely sensitive diagnostic method, as all cases will be identified by eliciting the patient's complaint. However, depending on the nature of the patient's complaint, the skill, interest, experience of the physician, and the precision of the definitions used, there will be wide variability in the specificity of history as a method to establish the diagnosis. This variability relates to the differences in the manifestations of ischemic cardiac pain among patients and differences among physicians in the manner in which they perceive the symptomatology and formulate the diagnosis of angina pectoris. This results in diagnostic errors, and the nature of the error will depend on the clinical acumen and particular bias of the physician. These factors undoubtedly contribute to the disparate observations that have been reported in the medical literature. For example, a prospective clinical investigation using sharply defined categories of chest pain may yield a different result from a retrospective study performed by chart review.

Selective coronary arteriography is the only technic available that can reliably give anatomic detail of coronary arteries. Properly performed and interpreted, it is an extremely specific examination. However, the examination does not directly disclose myocardial ischemia and does not determine if the patient's complaint is related to the arteriographic abnormalities demonstrated. Furthermore, the sensitivity of the method is not known; that is, the degree of narrowing required to be appreciated by arteriography has not been determined. High-quality radiographic equipment and adequately filled coronary arteries will resolve vessels under 1 mm. However, in major trunks, a 20–30% narrowing of the vessel may be necessary before the reduction in the lumen size can be appreciated. It is the opinion of most arteriographers that the methodology will underestimate the degree of narrowing present. Furthermore, the branching patterns of the coronary arterial tree are so variable that secondary branches can conceivably be obstructed at their origin from the parent vessel and the absence of the branch vessel not be appreciated if no collaterals to the distal segment are present.

Information relative to the important question of how much coronary atherosclerosis is
necessary to produce symptoms is not available. However, in typical angina pectoris severe narrowing and/or multiple-vessel abnormalities are likely to be present. This is certainly true in postmortem studies in patients with angina pectoris. However, postmortem studies are by necessity biased and contain a disproportionate number of patients with far-advanced and long-standing symptomatic disease. In separate studies, Enos and McNamara and their associates have observed that coronary atherosclerosis is prevalent in an asymptomatic population. Assuming that these observations can be extended to the general population, it should be possible to observe lesions early in the natural history of coronary atherosclerosis by utilizing coronary arteriography at a time when there are no symptoms referable to the lesions. A number of studies have indicated that the duration of symptoms is not well related to the severity of arteriographic lesions found. When only a single lesion is present, the patient will likely have had symptoms of short duration. However, most patients with symptoms for a short time will have multiple lesions. It is impossible to predict with any certainty the arteriographic changes on the basis of duration of symptoms, location of symptoms, and severity of symptoms.

Electrocardiography may be considered to occupy an intermediate position between history and arteriography in the assessment of patients with angina pectoris. Resting electrocardiographic tracings are quite insensitive and nonspecific for diagnosing angina pectoris. Both the sensitivity and specificity of electrocardiography are enhanced by studying S-T-segment shifts during and after exercise. However, controversy exists relative to the technic of administering exercise and the interpretation of electrocardiographic responses.

**Correlative Studies between Clinical History and Coronary Arteriography**

Table 1 summarizes data from four studies relating clinical history and arteriographic findings. The studies are not strictly comparable since the definitions used were not identical. For example, Proudfit et al. defined angina pectoris as "pain somewhere in the upper half of the body precipitated by walking and relieved promptly (within 15 minutes) by rest." The other investigators used a definition similar to that of Ross and Friesinger: "Pain or discomfort clearly precipitated by exertion and relieved by rest. It must involve some part of the sternum and be described as visceral in character, such as, tightness, squeezing, pressure, or burning." In spite of minor differences in the classification of chest pain, the studies have been included for the purpose of correlating chest pain and arteriographic findings. Utilizing these relatively uniform definitions, the results are surprisingly similar. The studies showed a high correlation between typical angina pectoris and significant obstruction on coronary

<table>
<thead>
<tr>
<th>Reference</th>
<th>Typical AP (ischemic pain &quot;undoubtedly present&quot;)</th>
<th>Atypical AP (ischemic pain less certain)</th>
<th>Ischemic pain not present</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of pt</td>
<td>% with pos arteriography*</td>
<td>No. of pt</td>
</tr>
<tr>
<td>Ross and Friesinger</td>
<td>97</td>
<td>92</td>
<td>41†</td>
</tr>
<tr>
<td>Proudfit et al.</td>
<td>380</td>
<td>90</td>
<td>141†</td>
</tr>
<tr>
<td>Paulin</td>
<td>107</td>
<td>85</td>
<td>56</td>
</tr>
<tr>
<td>Campeau et al.</td>
<td>55</td>
<td>89</td>
<td>26</td>
</tr>
</tbody>
</table>

*Defined as 50% luminal narrowing in one or more coronary vessel.
†In this prospective study, 111 patients whose complaints were atypical for angina were divided into two groups depending on whether the investigators felt ischemia was highly probable (41) or less probable (70).
‡Friesinger GC, Ross RS: Unpublished observations.

*Circulation, Volume XLVI, December 1972*
 arteriograms (85–92%). As has been appreciated since Heberden's description, angina pectoris is an excellent, albeit not perfect, predictor of the presence of ischemic heart disease. Of clinical importance is the fact that in patients in whom the historical diagnosis of atypical angina is made, varying degrees of atherosclerosis will be found by coronary arteriography. Depending on the definition used, 23–66% of patients had obstructive coronary arteriographic changes. In those patients whose chest complaints were judged to be unrelated to ischemic heart disease, the prevalence of obstructive change was low (4–6%) in three series. The 17% prevalence of obstructive lesions reported by Paulin7 is possibly attributable to bias in case selection, since five of the six patients with obstructive lesions in his nonischemic pain group had hypertension and evidence of myocardial infarction. The weaker correlation in the complaint groups that do not manifest typical angina pectoris emphasizes need for a functional evaluation, i.e. electrocardiography, to evaluate these clinical problems.

The patient's age, presence of a lipid abnormality, and previous history of myocardial infarction are three associations which must be carefully considered in reaching a conclusion concerning the relationship between atypical symptoms and arteriographic findings. Each of these factors may be the explanation for the arteriographic abnormalities when there is, in fact, no causal relation-

ship between the patient's symptoms and those abnormalities.

No systematic studies are available to define the relationship between age and the arteriographic severity of coronary atherosclerosis. The detailed histologic studies of Edwards17–18 emphasize the location and progression of atherosclerosis with age. Despite the histologic evidence of atherosclerosis in younger males, very few patients under the age of 50 years without clinical manifestations of ischemic heart disease have arteriographic abnormalities.8,16 This observation is undoubtedly influenced by the fact that there is reluctance to carry out coronary arteriography in asymptomatic patients or in patients without electrocardiographic abnormalities. Conversely, it is unjustified to attribute atypical chest complaints categorically to myocardial ischemia on the basis of arteriographic changes in patients in older age groups.

Myocardial infarction with residual electrocardiographic changes is likely to be associated with arteriographic abnormalities (83 of 88 subjects) as shown in table 2.7,16 Hence, in these subjects the physician must exercise caution in relating atypical symptoms to the arteriographic lesions that are observed.

Metabolic abnormalities, especially hyperlipidemic states, undoubtedly will influence the arteriographic findings. The data are inadequate to reach firm conclusions, but arteriographic findings in patients with increased cholesterol have been studied in

Table 2

<table>
<thead>
<tr>
<th>Arteriographic Findings</th>
<th>With abnormal ST-T</th>
<th>With MI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of evaluated</td>
<td>No.</td>
</tr>
<tr>
<td>Typical AP7</td>
<td>93</td>
<td>30</td>
</tr>
<tr>
<td>Atypical AP7</td>
<td>47</td>
<td>9</td>
</tr>
<tr>
<td>AP not present7</td>
<td>27</td>
<td>2</td>
</tr>
<tr>
<td>Typical AP14</td>
<td>97</td>
<td>16</td>
</tr>
<tr>
<td>Atypical AP14</td>
<td>111</td>
<td>23</td>
</tr>
<tr>
<td>AP not present14</td>
<td>43</td>
<td>11</td>
</tr>
<tr>
<td>Totals</td>
<td>418</td>
<td>91</td>
</tr>
</tbody>
</table>

*Luminal obstruction greater than 50% in at least one major coronary artery.
highly selected groups, and a relationship between lipid abnormalities and arteriographic changes has been demonstrated. Proudfoot et al. found arteriographic abnormalities in five of 28 subjects with cholesterol levels less than 200 mg%, but only one of 14 subjects with levels greater than 300 mg% had no demonstrable arteriographic lesion. Nine of 33 patients with hypercholesterolemia studied by Baltaxe et al. prior to ileal bypass surgery had abnormalities without symptoms or electrocardiographic evidence of ischemic heart disease. Heine et al. studied 192 patients and also demonstrated a higher prevalence of arteriographic lesions in those patients with lipid or carbohydrate abnormalities. It should be pointed out that the primary indication for coronary arteriography in most of the patients studied was not the metabolic abnormality but was usually some form of chest pain, thus introducing a bias.

The importance of collateral vessels visualized on arteriography has been debated. Inadequate sensitivity of the technic to detect collaterals may contribute to the problem. Collaterals may be visualized with one injection or after drug intervention, such as nitroglycerin, and not be detectable at other times. Intuitively, it is reasonable to conclude that collaterals represent a desirable compensatory adjustment. However, the evidence that collaterals noted on arteriography are "protective" or specifically alter symptoms or the course of ischemic heart disease is equivocal. At our present state of knowledge, collaterals can be considered to be indicators of severe obstructive disease but other generalizations are tenuous.

Electrocardiography in Stress Tests in Ischemic Myocardial States

It is beyond the scope of this paper to discuss in detail the electrophysiologic basis of the electrocardiographic changes observed in ischemic heart disease but it is relevant to mention factors that inherently limit the usefulness and reliability of the method. Electrocardiography is a very indirect measure of myocardial ischemia. It has been estimated that more than 90% of the voltage produced by ventricular fibers is canceled by the divergency of excitation waves which results in a general reduction of the sensitivity of the electrocardiogram to detect abnormalities. Since differences between divergent electrical forces are measured, the sensitivity of the electrocardiogram for coexisting lesions may be less than for a single lesion. For example, an infarction of the posterior wall of the heart may decrease the electrocardiographic manifestations of an anterior infarction. Alterations of the repolarization process especially lack specificity. Changes in the T wave can be produced by differences in the speed of repolarization in different layers of the heart or by a change in the direction of repolarization. Thus, conduction abnormalities, abnormal excitation sequences such as the Wolff-Parkinson-White anomaly, digitalis, and electrolyte disturbances may mimic or obscure repolarization abnormalities that are characteristic of myocardial ischemia. In addition, technical considerations such as the frequency response of the electrocardiographic instrument, electrode placement and orientation of the electrocardiographic leads, and the signal-to-noise ratio of the electrocardiographic system are of great importance. The problems related to analyzing electrocardiographic stress tests are discussed elsewhere in this symposium.

In groups of patients with angina pectoris it has been shown that selected electrocardiographic items differ significantly from those found in groups of normal patients and in groups studied with coronary arteriography. ST-T abnormalities are associated with a high prevalence of significant coronary obstruction. Data from two studies are shown in table 2. The studies were selected because similar classifications of chest pain were used. Despite the high positive correlation of ST-T changes with arteriographic lesions, the predictive value for the individual patient is poor because of lack of sensitivity. Electrocardiographic sensitivity and specificity for acute and remote myocardial infarctions is greater and significant arteriographic abnormalities are usually present when definite
changes of myocardial infarction are present. However, even in this situation, the correlation is not perfect. Table 2 shows that five of 88 patients with myocardial infarction patterns on the resting electrocardiogram had no arteriographic evidence of atherosclerosis. The finding of a remote infarction pattern in the electrocardiogram of the patient undergoing evaluation of chest pain is highly indicative of ischemic heart disease and increases the probability that the pain is related to myocardial ischemia, but does not establish causation. For these reasons, the diagnostic power of the conventional resting electrocardiogram is unacceptably low for the diagnosis of angina pectoris.

The sensitivity and specificity of the electrocardiogram for myocardial ischemia is enhanced by employing stress situations that increase myocardial oxygen demand. This is especially true when the resting electrocardiogram is normal and is also true, with certain qualifications, when the resting electrocardiogram is abnormal. Sensitivity is improved because the imbalance between oxygen supply and demand is increased, which results in manifest electrocardiographic changes; specificity is improved by correlating an electrocardiographic abnormality with an intervention that is known to induce ischemia. Although many forms of cardiac stress have been utilized with electrocardiography, exercise stress is the most widely used method in clinical practice, and electrocardiographic stress tests have proven to be safe when reasonable precautions are followed. Electrocardiographic stress methods have been discussed in detail elsewhere in the symposium and have been comprehensively reviewed by Taylor et al.

Since this discussion is concerned primarily with the diagnostic accuracy of electrocardiographic stress testing, exercise test protocols have been divided into two broad groups: tests with standardized external work loads and tests which are standardized by heart rate response. The test protocol which has been proposed by Master and Rosenfeld is the most widely used standardized load method. A variety of exercise devices have been used to produce a standardized rate response and, in the United States, the treadmill has been employed most frequently. Straightening and depression of the S-T segment is the indication of ischemia that is generally accepted, although measurements of the S-T and T area by computer have been shown to have discriminating value in limited studies. The appearance of bundle-branch block or cardiac arrhythmia is considered by the authors to be a nonspecific response to exercise and not necessarily indicative of myocardial ischemia.

There is no completely satisfactory manner to assess the diagnostic accuracy of electrocardiographic exercise tests for ischemic heart disease since there is no highly sensitive and specific test for myocardial ischemia that can be used as a standard for comparison. Errors associated with coronary arteriography have been discussed above, and it has been pointed out that ischemia can occur in the absence of obstructive lesions, or myocardial ischemia not be present when there is severe obstruction. The measurement of coronary sinus-arterial lactate difference is not a sensitive test for myocardial ischemia although myocardial lactate production is a specific indication of ischemia. The clinical syndrome of angina pectoris has limitations when used as a standard upon which to judge an objective test. Although studies have been performed in which exercise stress test, coronary arteriography, and angina pectoris were compared, selection bias and differences in technic prevent rigid interstudy comparisons, or pooling of data. However, such studies provide valuable information upon which certain generalizations can be based.

Table 3 contains data extracted from seven studies in which exercise stress testing and coronary arteriography were done. Patients with arteriographic evidence of minor obstruction have been deleted from this table, and the deletions are explained in the footnotes. For the purpose of this discussion, we have compared exercise stress testing to coronary arteriography, and the false-positive
Table 3

<table>
<thead>
<tr>
<th>Reference</th>
<th>No. of pt</th>
<th>Reason for study</th>
<th>Arteriographic % narrowing</th>
<th>Exercise protocol</th>
<th>ECG criteria for ischemia (mm)</th>
<th>False-positive (%)</th>
<th>False-negative (%)</th>
<th>Error ratio* (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demany et al.12</td>
<td>75</td>
<td>Chest pain</td>
<td>50</td>
<td>Double Master</td>
<td>1.0</td>
<td>10/33(30)</td>
<td>24/42(57)</td>
<td>34/41(82)</td>
</tr>
<tr>
<td>FitzGibbon et al.42</td>
<td>150†</td>
<td>MI; chest pain; abnormal ECG</td>
<td>50</td>
<td>Double Master</td>
<td>0.5</td>
<td>6/37(16)</td>
<td>69/113(61)</td>
<td>75/75(100)</td>
</tr>
<tr>
<td>McConahay et al.14</td>
<td>100</td>
<td>Chest pain</td>
<td>50</td>
<td>Double Master</td>
<td>0.5</td>
<td>6/35(17)</td>
<td>24/65(36)</td>
<td>30/70(42)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.75</td>
<td>3/35(8)</td>
<td>38/65(58)</td>
<td>41/59(69)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
<td>0/35(0)</td>
<td>42/65(64)</td>
<td>42/58(72)</td>
</tr>
<tr>
<td>Paulin†</td>
<td>107‡</td>
<td>Chest pain; arrhythmia; diabetes</td>
<td>50</td>
<td>Heart rate 140-170</td>
<td>0.5</td>
<td>3/35(8)</td>
<td>14/72(19)</td>
<td>17/69(24)</td>
</tr>
<tr>
<td>Mason et al.59</td>
<td>75§</td>
<td>Chest pain; abnormal ECG</td>
<td>50</td>
<td>90% max heart rate</td>
<td>1.0</td>
<td>4/26(15)</td>
<td>6/49(12)</td>
<td>10/62(16)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1/26(3)</td>
<td>8/49(16)</td>
<td>9/63(14)</td>
</tr>
<tr>
<td>Kassebaum et al.40</td>
<td>62**</td>
<td>Chest pain</td>
<td>50</td>
<td>85% max heart rate</td>
<td>1.0</td>
<td>1/23(4)</td>
<td>21/39(53)</td>
<td>22/40(55)</td>
</tr>
<tr>
<td>Roitman et al.41</td>
<td>46</td>
<td>Chest pain</td>
<td>50</td>
<td>90% max heart rate</td>
<td>1.0</td>
<td>2/26(7)</td>
<td>6/20(30)</td>
<td>8/38(21)</td>
</tr>
</tbody>
</table>

*Error ratio = number of incorrect diagnoses/number of correct diagnoses.
†Ten patients with mild coronary obstruction (index 2) were excluded.
‡Patients with “irregular vessel walls” were excluded.
§Nine patients with < 50% luminal obstruction were excluded from table.
**Two patients with “minimal angiographic evidence of arteriosclerosis” were excluded.
test result is defined as ischemic S-T depression where there is no arteriographic evidence of coronary obstruction, and a false-negative test is a normal ECG response to the exercise protocol when arteriography reveals greater than 50% obstruction of the lumen of a major coronary artery. The diagnostic error percentage is a ratio of the total false diagnoses (false-positive and false-negative) to the number of correct diagnoses.\(^\text{15}\) The best discriminating value is that with the smallest error ratio.

In table 3, the error ratio for the double Master test ranges from 43 to 100%. In studies where a comparison was made between S-T-segment depression of 0.5 mm and 1.0 mm, the lowest error occurred with the 0.5-mm criterion. Comparison with arteriography indicates that the double Master test is an insensitive test for obstructive coronary disease. The rate-standardized exercise tests utilizing heavier work loads have been shown, in most studies, to have a greater sensitivity for obstructive coronary disease (and presumably myocardial ischemia) than the double Master test. It would appear that with these tests the lowest error is obtained with a 1.0-mm S-T-segment depression criterion and by utilizing electrocardiograms during exercise.

The most favorable error ratio was obtained by Mason et al.\(^\text{59}\) who used multiple-lead electrocardiograms both during and after exercise, a 1.0-mm S-T-depression criterion for an ischemic response, and exercise to 90% of the predicted maximum heart rate before discontinuing the test.

The error ratio is a reasonable standard for judging diagnostic accuracy in clinical applications. However, there are special situations where one may select a diagnostic criterion or test method where specificity is sacrificed for greater sensitivity. For example, when exercise stress testing is used as a screening test or when the test is used in the evaluation of special groups such as aviators, a more sensitive test may be desired.

In studies where electrocardiographic exercise tests were correlated with typical angina pectoris, McConahay et al.\(^\text{14}\) found that 57% had a positive double Master test and evidence of significant coronary obstruction on arteriograms. Mason et al.\(^\text{59}\) using a rate-standardized test and recording multiple leads demonstrated ischemic responses in 84% of patients with typical angina and major obstructive lesions on coronary arteriograms. These data are shown in table 4. They are consistent with other studies and show again that the use of heavier exercise loads increases the incidence of ischemic responses in patients who have angina pectoris and arteriographic evidence of coronary obstruction. The patients whose chest pain did not fit typical description of angina pectoris formed an intermediate group where the correlation of arteriographic lesions, chest pain, and abnormal electrocardiographic tests was lower.

### Angina Pectoris with Normal Coronary Arteriography

Much attention has been directed to the problem of angina pectoris in the presence of a radiographically normal coronary arteriogram.\(^\text{44-47}\) It is evident from the data contained in table 1 that this is an unusual occurrence when a relatively specific definition

<table>
<thead>
<tr>
<th>Pain</th>
<th>No. evaluated</th>
<th>Exercise protocol</th>
<th>S-T depression criterion (mm)</th>
<th>Arteriographic findings</th>
<th>Normal tests</th>
<th>Positive tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No lesion</td>
<td>Major lesion*</td>
</tr>
<tr>
<td>Typical AP(^\text{14})</td>
<td>56</td>
<td>Double Master</td>
<td>0.5</td>
<td></td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>Atypical AP(^\text{14})</td>
<td>19</td>
<td>Double Master</td>
<td>0.5</td>
<td></td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Typical AP(^\text{57})</td>
<td>69</td>
<td>90% max heart rate</td>
<td>1.0</td>
<td></td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Atypical AP(^\text{57})</td>
<td>17</td>
<td>90% max heart rate</td>
<td>1.0</td>
<td></td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

*Luminal obstruction greater than 50% in at least one major artery.

Circulation, Volume XLVI, December 1972
ELECTROCARDIOGRAPHY AND ARTERIOGRAPHY

for angina pectoris is used. Possible explanations for this apparent paradox are listed in table 5. In general, the patients with this syndrome are likely to be women, are younger, have a lower prevalence of cardiovascular risk factors, and in many instances have complaints which do not fit the description of typical angina pectoris that has been used in this discussion. Thus it must be concluded that in some of these patients myocardial ischemia is not present and the clinical data had been misinterpreted. The technical limitations of coronary arteriography have been emphasized previously and perhaps explains some cases. James suggests that this is the common explanation for the paradoxical association. Complete cardiac catheterization studies are necessary to rule out cardiomyopathy when the coronary arteries appear normal and angina pectoris is present. Abnormal oxyhemoglobin kinetics have been proposed by Eliot and Bratt but this has not been an explanation for the syndrome of angina with normal arteriography in other investigators’ experiences. Involvement of the small coronary arteries occurs in diabetes mellitus and in a variety of conditions but angina pectoris, as strictly defined, is not a frequent manifestation in these conditions. Regardless of the precise etiology of this syndrome, it is probable that the outlook is quite favorable compared to the prognosis of typical obstructive coronary atherosclerosis. Many patients improve or recover completely and the patients rarely experience myocardial infarction, sudden death, and congestive heart failure, complications that are all too common in typical obstructive coronary heart disease.

Prognostic Value of Coronary Arteriography

In view of the fact that the correlations among patterns of pain, electrocardiographic findings, and arteriography are so imperfect, it is interesting to consider the value of arteriography, per se, as an indicator of the presence and severity of the disease process. This is an intriguing question because the degree of obstructive coronary arterial disease present and the severity of the attendant left ventricular dysfunction should be a more reliable indicator of the disease process than subjective symptoms or indirect electrocardiographic manifestations. Collateral vessel formation may modify the consequences of obstructive disease, but there is no evidence that this modification affects the long-term course of obstructive coronary disease.

There is general agreement that if obstructive disease is present to the degree that marked left ventricular dysfunction results, the patient’s prognosis is extremely poor. A prospective study of a small group of patients has demonstrated that the 5-year survival of patients is markedly reduced for patients with multiple-vessel obstruction when these patients are compared with others having less severe disease. All patients had cardiac complaints, but the prognosis was not related to the type or duration of the complaint. In this study, 48% of the patients with severe arteriographic abnormalities (usually triple-vessel involvement), survived for 5 years while 95% of the patients with mild or

### Table 5

**Possible Explanations for “Angina Pectoris” and “Arteriographically Normal Coronary Arteries”**

1. Ischemic heart disease is not present, that is, the clinical data have been misinterpreted.
2. The arteriogram is technically inadequate or improperly interpreted.
3. The arteriogram is not able to demonstrate lesions which are present and responsible for angina pectoris (a "false-negative" test).
4. Other cardiac disease (especially subtle cardiomyopathies) account for the symptoms.
5. Humoral and autonomic nervous factors account for the symptoms, for example, “spasm” and abnormal oxyhemoglobin dissociation.
6. “Small-vessel” disease is responsible.

*Circulation, Volume XLVI, December 1972*
moderate disease survived for 5 years. Favaloro\textsuperscript{31} has reported similar findings in a retrospective study although the details of the study are not provided. This series of patients from the Cleveland Clinic were reviewed relative to the presence of single-, double-, or triple-vessel disease, and the mortality after 5 years increased directly with the severity of the lesions.\textsuperscript{31} Sixty-two percent of the patients with triple-vessel disease were dead at the end of 5 years, but of the patients with single-vessel disease only 15\% were dead at the end of 5 years.\textsuperscript{31} It is possible that the additional consideration of the functional consequences of the obstructive coronary disease would provide an even better prognostic indicator.

The relationships among angina pectoris, stress tests, and arteriography are summarized in the Venn diagram in figure 2. The square depicts the population with ischemic heart disease. The overlap zone (A) represents the population of patients who can be diagnosed most confidently because all three important manifestations are present. Depending on definitions, selection, and the precise conduct of the study, more than 50\% of patients with angina pectoris may have abnormal stress tests and abnormal coronary arteriograms. The precise relationship between abnormal stress tests and abnormal coronary arteriographic findings in asymptomatic patients (G) is not known. Zones F, H, and D represent patients with unusual expressions of myocardial ischemia and create special diagnostic problems for the clinician. The patients (B) with normal coronary arteriograms have a better prognosis than those with obstructive lesions even when there is other evidence of ischemia (F, H, D). Because of the many combinations of findings in ischemic heart disease, in the final analysis, clinical judgment must be exercised in utilizing test results in the management of patients with anginal symptoms.

\textbf{References}


\textbf{Figure 2}

Venn diagram depicts the relationships among the three principal examinations considered in the diagnosis of ischemic heart disease. The square represents the entire population of ischemic heart disease. The zones are only qualitative representations. For further discussion see text.


31. GARDNER M, OLSEN F: Electrocardiographic changes induced by the taking of food. Amer Heart J 17: 725, 1933


33. ROCHMIS P, BLACKBURN H: Exercise tests: A survey of procedures, safety, and litigation experience in approximately 170,000 tests. JAMA 217: 1061, 1971


Correlation of Electrocardiographic Studies and Arteriographic Findings with Angina Pectoris

GOTTLIEB C. FRIESINGER and RAPHAEL F. SMITH

Correlation. 1972;46:1173-1184
doi: 10.1161/01.CIR.46.6.1173

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX
75231
Copyright © 1972 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/46/6/1173

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at: http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at: http://circ.ahajournals.org//subscriptions/