The Independent Value of Exercise Thallium Scintigraphy to Physicians

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SUMMARY To determine the effect of exercise myocardial scintigraphy with thallium-201 on diagnostic accuracy and the need for coronary angiography, consecutive patients with a variety of clinical presentations were identified. Clinical summaries, including a detailed history, physical examination, and complete data from a standard treadmill exercise test, were presented to 91 cardiologists. The cardiologists assessed the probability of coronary disease and the need for coronary angiography. They were then presented the results of thallium scintigraphy and revised their assessments if warranted.

Scintigraphy significantly increased the cardiologists’ diagnostic accuracy beyond that attained with other clinical information (p < 0.0001). The change in accuracy varied from +4% to +20% in different patient groups, and was greatest in patients with atypical angina and a positive exercise ECG. Ratings of the need for coronary angiography changed from −13% to +21% in different patient groups. We conclude that exercise thallium scintigraphy can provide independent diagnostic information and influence the need for coronary angiography.

STRESS perfusion scintigraphy with thallium-201 is a new diagnostic test for coronary artery disease.1,4 As initial myocardial uptake of thallium is proportional to coronary blood flow, scintigraphic images can reveal inhomogeneous myocardial perfusion due to coronary disease. Scintigraphy documents a different manifestation of myocardial ischemia than the exercise ECG and may improve diagnostic accuracy.

The use of exercise testing for the diagnosis of coronary disease is controversial.5,6 There is considerable disagreement as to whether exercise testing adds new and significant information to that already available from clinical examination. Documentation of the independent value of thallium scintigraphy is therefore particularly important, as this procedure supplements, rather than replaces, the exercise ECG. Moreover, scintigraphy exposes the patient to a small amount of radiation, requires 1–5 hours to perform, and costs several hundred dollars.

The present study was designed to measure how much information thallium perfusion scintigraphy adds to that already available from the history, physical examination and standard exercise testing. The study also examines the effect of perfusion scintigraphy on the need for coronary angiography, an important aspect of clinical management.
Methods

We assessed the independent value of stress perfusion scintigraphy in a controlled fashion by having cardiologists evaluate clinical summaries of randomly selected patients. The following sections explain the cardiologists’ evaluation procedures, the method of patient selection and testing and the method of data analysis.

Evaluation by Cardiologists

One hundred fifty-one cardiologists in the San Francisco Standard Metropolitan Statistical Area listed by the Subspeciality Board on Cardiovascular Disease of the American Board of Internal Medicine or by the American College of Cardiology were identified and contacted. Ninety-one physicians, a broad sample of cardiologists in a wide variety of practices, participated in the study.

Each cardiologist evaluated the case histories of eight patients chosen at random. (Methods of patient selection and testing are described in detail later.) Each brief summary was written in a uniform format and described (1) the chest pain, including its location, quality, duration, precipitating and relieving factors, and radiation (Interpretation of this discomfort as typical or atypical angina was left to the judgment of the evaluating cardiologist.); (2) other cardiac symptoms; (3) coronary risk factors; (4) hospitalizations for chest pain; (5) current medications; (6) problems in other organ systems; (7) physical examination; (8) chest x-ray; (9) resting ECG; and (10) treadmill exercise test data, including the duration and stage of exercise attained, actual heart rate and percentage of predicted maximal heart rate achieved, blood pressure response, symptoms, reasons for terminating exercise, arrhythmias precipitated, and the slope and maximum depth of the ST-segment response.

After reviewing the clinical summary, the cardiologists performed an initial baseline assessment of the patient. They estimated the probability of finding significant fixed coronary obstructions at coronary angiography; estimates were expressed on a scale of 0–100%. They also rated the need for coronary angiography on a five-point scale: 4 = definitely indicated; 3 = probably indicated; 2 = undecided; 1 = probably not indicated; and 0 = definitely not indicated. Ratings on this scale measured the overall need for angiography, including studies to evaluate the extent of disease, as well as studies for strictly diagnostic purposes.

After completing this baseline evaluation, the physician then received the results of stress perfusion scintigraphy, which detailed the presence, location, and reversibility of defects, as well as the final interpretation. The cardiologist then reevaluated the probability of coronary disease on the 0–100% scale and re-evaluated the need for coronary angiography on the 0–4 scale.

Thus, for each patient summary reviewed, the cardiologist made paired judgments before and after scintigraphy of both the likelihood of coronary disease and the need for coronary angiography. These paired judgments were analyzed to measure the independent clinical impact of the scintgram. Ninety-one participating cardiologists each evaluated eight patients, for a total of 728 paired evaluations of the likelihood of coronary disease and 728 paired evaluations of the need for angiography.

Patient Selection and Testing

One hundred fifty-four consecutive patients who had both exercise thallium scintigraphy and coronary angiography at the University of California, San Francisco, Medical Center in 1978 and 1979 were identified through record review. Ninety-nine patients were excluded because they had a definite myocardial infarction, coronary angiography, or coronary artery bypass surgery before the exercise thallium study; in these patients, the diagnosis of coronary disease was considered established. Four additional patients with valvular heart disease, bundle branch block or left ventricular hypertrophy were also excluded, because in these patients the exercise ECG was unreliable for diagnosis. The final sample consisted of the remaining 51 patients, all of whom had satisfactory records available for review.

For each physician, two patients were randomly selected from each of four clinical groups: typical angina with a positive exercise ECG, typical angina with a negative exercise ECG, atypical angina with a positive exercise ECG, and atypical angina with a negative exercise ECG. For this selection process, chest pain was classified according to the criteria established by the Coronary Artery Surgery Study. Chest pain was considered typical angina if it was substernal, with or without radiation, precipitated principally by exertion, and relieved by rest or nitroglycerin within 10 minutes. Discomfort that did not meet all three criteria was classified as atypical. In the presence of an isoelectric ST segment on the resting ECG, the exercise ECG was classified as positive if 0.1 mV or greater flat or downsloping ST-segment depression was present 0.08 second past the J point. If the resting ECG displayed ST-segment abnormalities, 0.2 mV of additional flat or downsloping ST-segment depression over the baseline was required to be classified as a positive test. Using these criteria, 13 patients had typical angina and a positive exercise ECG, eight had typical angina and a negative exercise ECG, 17 had atypical angina and a positive exercise ECG, and 13 had atypical angina and a negative exercise ECG. Nine of the patients with negative exercise ECGs did not achieve their target heart rate.

Exercise thallium scintigrams were obtained after injection of 1.5 mCi of thallium-201 at peak exercise, using a high-sensitivity collimator with an Ohio Nuclear portable scintillation camera. Images were obtained in five projections. When stress-related abnormalities were noted, redistribution views were obtained after 4 hours. Images were interpreted by consensus among three experienced observers, using a computer-enhancement method previously described, without
knowledge of the coronary angiographic results. In these patients, the predictive value of thallium scintigraphy was 80%, and that of the exercise ECG was 55%.

A lesion on coronary angiography was considered significant if the luminal diameter was narrowed by 70% or more in any projection. By this criterion, 22 of the 51 study patients had insignificant or no coronary disease, six had one-vessel disease, seven had two-vessel disease, 15 had three-vessel disease, and one patient had three-vessel and a left main coronary disease.

The exercise ECG, exercise thallium scintigram, and coronary angiogram were performed and interpreted as part of routine clinical care; the original interpretations, as reported in the medical record, were accepted in all cases.

Measurement of Diagnostic Accuracy

The cardiologists' diagnostic judgments were expressed as the probability of coronary disease. This method allows the level of diagnostic certainty to be expressed, and also allows changes in the level of diagnostic certainty to be expressed. The accuracy of these diagnostic judgments cannot be measured as the percentage of "right" diagnoses, for a probability estimate is neither right nor wrong; rather, a probability estimate is either more or less accurate. A general method for measuring the accuracy of probability estimates by assigning accuracy scores has been developed and applied to medical predictions.

All probability estimates made by cardiologists in this study were converted to accuracy scores, using the coronary angiogram as the diagnostic standard. The accuracy score used was:

$$S_i = \frac{(1 + X_i) \log (1 + p_i) + (2 - X_i) \log (2 - p_i)}{\log (2/\log (2))} \times 100$$

where $p_i$ = the estimated probability of coronary disease in patient "i," $S_i$ = the accuracy of this estimate, $X_i = 1$ if patient "i" has coronary disease, and $X_i = 0$ if patient "i" does not have coronary disease. This accuracy score ranges from 0 to 100, and is highest when the actual outcome is predicted with certainty. (If coronary disease had simply been judged as present or absent, rather than by using probabilities, the accuracy score would equal the percentage of correct diagnoses.) The score is also related to the amount of information contained in the probability estimate.

Several examples will illustrate the properties of this accuracy score. If the physician had assigned a 100% probability of coronary disease to patient A, who is proved to have coronary disease, the accuracy score would be 100. However, if he had estimated a 0% chance of coronary disease in patient A, the accuracy score would be 0. Conversely, if the physician had estimated the probability of coronary disease as 0% in patient B, who is shown not to have coronary disease, the accuracy score would be 100; if the physician had estimated the probability of coronary disease in patient B as 100%, the accuracy score would be 0.

Data Analysis

To determine the change in diagnostic accuracy specifically due to thallium scintigraphy, diagnostic accuracy was measured twice: first for the probability estimate based on the history, physical examination, and exercise ECG; and second for the probability estimate based on the scintigram as well. The change in diagnostic accuracy due to thallium scintigraphy was then measured by subtracting the first accuracy score from the second.

The change in the cardiologists' need for coronary angiography due to scintigraphy was also assessed by comparing the paired pre- and postscintigraphy judgments. The difference between the first and second rating measured the specific impact of scintigraphy on the cardiologists' need for angiography.

Each physician was presented two patients from each of four clinical groups: typical angina with a positive exercise ECG, typical angina with a negative exercise ECG, atypical angina with a positive exercise ECG, and atypical angina with a negative exercise ECG. For each physician, data from both patients in each of these four groups were averaged. This averaging process was repeated for all of the 91 participating physicians. The statistical significance of the resulting averages was tested by the Wilcoxon signed-rank method, using two-tailed tests and the physician as the unit of statistical analysis.

Results

The baseline diagnostic accuracy of cardiologists using the clinical history, physical examination, chest x-ray, resting ECG, and physiologic and electrocardiographic data from the exercise test is summarized in Table 1. As expected, the cardiologists' baseline diagnostic accuracy differed among groups of patients, ranging from 87.3 in patients with typical angina and a positive exercise ECG to 70.6 in patients with atypical angina and a positive exercise ECG. Thus, a perfect diagnostic accuracy score of 100 was not achieved in any group using clinical information.

<table>
<thead>
<tr>
<th>Clinical class</th>
<th>Before scintigraphy</th>
<th>After scintigraphy</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical angina, positive ECG</td>
<td>87.3</td>
<td>92.0</td>
<td>+5.4%†</td>
</tr>
<tr>
<td>Typical angina, negative ECG</td>
<td>83.2</td>
<td>91.1</td>
<td>+9.5%†</td>
</tr>
<tr>
<td>Atypical angina, positive ECG</td>
<td>70.6</td>
<td>84.8</td>
<td>+20.1%†</td>
</tr>
<tr>
<td>Atypical angina, negative ECG</td>
<td>79.8</td>
<td>82.6</td>
<td>+3.5%</td>
</tr>
</tbody>
</table>

*Diagnostic accuracy expressed on a 0–100 scale as defined in the text. Change in diagnostic accuracy is expressed as a percentage, with the difference in accuracy (after scintigraphy minus before scintigraphy) divided by the accuracy before scintigraphy. †p < 0.0001.
After the results of stress perfusion scintigraphy were presented, the cardiologists improved their diagnostic accuracy from this baseline. In figure 1, points to the right of zero indicate an improvement in diagnostic accuracy. The effect of scintigraphy in changing diagnostic accuracy was different in each of the four clinical groups. In patients with typical angina and a positive exercise ECG, where baseline diagnostic accuracy was the highest, presentation of the thallium scintigram increased the average diagnostic accuracy only slightly, from 87.3 to 92.0 (table 1). In contrast, for patients with atypical angina and a positive exercise ECG, baseline diagnostic accuracy was the lowest, and average diagnostic accuracy was sharply improved from 70.6 to 84.8 after scintigraphy. Overall, the improvement in diagnostic accuracy after scintigraphy was statistically significant in all patient groups except the group with atypical angina and a negative exercise ECG (table 1).

The average increment in diagnostic accuracy after presentation of the results of thallium scintigraphy was similar in patients who achieved their target heart rate (+ 7.8 on the 0–100 accuracy scale) and in patients who did not achieve their target heart rate (+ 8.2). The change in average diagnostic accuracy was significantly greater than zero in each (p < 0.0001).

The cardiologists’ baseline need for coronary angiography, judged after presentation of the clinical history and standard exercise test, also differed among clinical groups (table 2). Need for coronary angiography was judged the highest in patients with typical angina and a positive exercise ECG: 2.74 on the 0–4 scale. In contrast, the need for coronary angiography was judged the lowest in patients with atypical pain and a negative exercise ECG: 1.40 on the 0–4 scale.

After the scintigraphic results were presented, the cardiologists revised their initial assessments of the need for coronary angiography in most cases. In figure 2, points to the right of zero indicate an increase in the need for angiography and points to the left of zero indicate a decrease in the need for angiography. Scintigraphy decreased the average need for angiography in patients with a positive exercise ECG and either typical or atypical angina, but this decrease was not statistically significant. Scintigraphy significantly increased the average need for angiography in patients with a negative exercise ECG and either typical or atypical angina (table 2).

Changes in the need for coronary angiography after scintigraphy were also correlated with the final diagnosis (table 2). Initially, the need for coronary angiography was rated higher in patients ultimately proved to have coronary disease (2.12 on the 0–4 scale) than in patients ultimately proved to have no coronary disease (1.67). The scintigraphic findings reduced the need for angiography in patients without coronary disease by 12.6% (p < 0.0001), and increased this need

**Figure 1.** The effect of scintigraphy on cardiologists’ diagnostic accuracy. The average change in diagnostic accuracy after presentation of the scintigraphic findings is plotted against the number of cardiologists who changed diagnostic accuracy by a given amount. Each panel shows the results for a different group of patients. The number of cardiologists whose average change in diagnostic accuracy was zero is off the scale in the top panel; the actual number of cardiologists was 36. S-ECG = stress electrocardiogram; + = positive, ischemic response; – = negative, no ischemic response.

**Table 2. Change in Need for Coronary Angiography Due to Thallium Scintigraphy**

<table>
<thead>
<tr>
<th>Clinical class</th>
<th>Need for angiography*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before angiography</td>
</tr>
<tr>
<td>Typical angina, positive ECG</td>
<td>2.74</td>
</tr>
<tr>
<td>Typical angina, negative ECG</td>
<td>1.68</td>
</tr>
<tr>
<td>Atypical angina, positive ECG</td>
<td>1.98</td>
</tr>
<tr>
<td>Atypical angina, negative ECG</td>
<td>1.40</td>
</tr>
<tr>
<td>Anatomic class</td>
<td></td>
</tr>
<tr>
<td>Coronary disease</td>
<td>2.12</td>
</tr>
<tr>
<td>No coronary disease</td>
<td>1.67</td>
</tr>
</tbody>
</table>

*Indicates cardiologists’ ratings of the need for coronary angiography on a 0–4 scale as defined in the text. Change in the need for angiography is expressed as a percentage, with the difference in the ratings (after scintigraphy minus before scintigraphy) divided by the rating before scintigraphy.
†p < 0.0001.
‡p < 0.01.
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FIGURE 2. Effect of scintigraphy on cardiologists’ ratings of the need for coronary angiography. The average change in the cardiologists’ ratings of the need for coronary angiography on a 0–4 scale (defined in the text) is plotted against the number of cardiologists who changed the rating of the need for angiography by a given amount. Each panel displays the results in a different group of patients. The number of cardiologists whose average change in rating the need for coronary angiography was zero is off the scale in each panel. The actual number of cardiologists was: typical angina and a positive stress-ECG, 47; typical angina and a negative stress-ECG, 35; atypical angina and a positive stress-ECG, 43; and atypical angina and a negative stress-ECG, 38. Abbreviations are as in figure 1.

Discussion

Exercise perfusion scintigraphy with thallium-201 has been widely accepted since its introduction in 1975. Many laboratories have correlated the results of scintigraphy with coronary angiography; the scintigram is abnormal in an average of 82% of patients who have coronary disease (sensitivity), and the scintigram is normal in an average of 91% of patients with normal coronary arteries (specificity).\(^1\)\(^-\)\(^4\) Compared with the stress ECG, thallium scintigraphy has greater sensitivity and specificity.\(^1\)\(^-\)\(^4\) While studies of the sensitivity and specificity of a new diagnostic procedure are the essential first step in its evaluation, a full assessment of its role in clinical practice requires further information. Thallium perfusion scintigraphy is usually performed after a substantial amount of information about the patient is already known. A realistic appraisal of the clinical value of scintigraphy must determine whether it significantly changes physician opinions about the patient’s diagnosis and management.

Perfusion scintigraphy significantly improved cardiologists’ diagnostic accuracy beyond that achieved with a detailed history, physical examination, and complete data from the standard exercise test. The extent of improvement depended on the patient’s clinical presentation, and was greatest in the patients with atypical angina and a positive exercise ECG. These findings demonstrate that exercise perfusion scintigraphy can provide additional new information. They also confirm the predictions of Hamilton et al.\(^16\) that scintigraphy would be most valuable when diagnostic uncertainty is the greatest.

These findings are of particular interest for several reasons. First, earlier studies of exercise testing have been criticized for simply correlating exercise test results with coronary angiographic results without considering the clinical context in which the exercise test was performed. The application of Bayes’ rule, a mathematical tool for integrating the results of a diagnostic test with previously available clinical information,\(^5\)\(^,\)\(^17\) to exercise electrocardiography has raised doubts about the utility of stress testing.\(^5\) However, these analyses may have oversimplified the interpretation of the exercise test.\(^6\)\(^,\)\(^8\)

Our study addressed the concerns of both sides in the debate over exercise testing. The improvement in diagnostic accuracy specifically due to scintigraphy was documented directly by first measuring the diagnostic accuracy possible with pre-existing clinical information alone, and then measuring the diagnostic accuracy possible when the results of perfusion scintigraphy were added. Oversimplification of the interpretation of symptoms, signs, and test results was avoided by using cardiologists’ assessment of all available clinical information, including complete data from exercise testing.

Second, the reported value of a diagnostic procedure depends on the patients in whom it is applied.\(^18\) Entry criteria for this study selected only patients without prior myocardial infarction in whom exercise electrocardiography was feasible. Previous studies of thallium scintigraphy have included 26 to 43% of patients with previous myocardial infarction and Q waves on the resting ECG.\(^5\) The independent contribution of perfusion scintigraphy to establishing a diagnosis of coronary disease must be very small in these patients, even though scintigraphy may be appropriate for assessing residual ischemia.\(^19\) For this reason, patients with previous infarction were excluded. Exercise perfusion scintigraphy is particularly useful when the exercise ECG is unreliable because of coexisting heart disease or an abnormal resting ECG.\(^20\) Including this group of patients would have increased the measured value of
perfusion scintigraphy and biased the study results; these patients were therefore excluded. Perfusion scintigraphy has also been shown to be particularly useful if the level of exercise is low. Patients in this study were not selected on the basis of the level of exercise achieved, but the increment in diagnostic accuracy after thallium scintigraphy was similar in patients who did achieve their target heart rate compared with those who did not (+ 7.8 and + 8.2, respectively).

Certain aspects of the design of this study may be important in its interpretation. First, the physicians could neither interview and examine the patient, nor review and discuss the primary laboratory data personally, which may have influenced their responses. However, written case summaries are the traditional method of medical communication about patients, both in the clinical and research setting. Furthermore, use of patient summaries permits the contribution of each step in the diagnostic process to be isolated. Second, patients were selected by several criteria, including a requirement for both exercise thallium scintigraphy and coronary angiography at a particular university hospital, and may not be a representative sample of all patients with chest pain. Third, the value of perfusion scintigraphy was assessed through its effects on physicians’ clinical judgment, which has advantages and disadvantages. The measured value of scintigraphy might be affected if physicians do not properly weigh the information provided. However, all physicians in this study were board-certified cardiologists and well qualified to assess clinical and laboratory findings in patients with chest pain. Moreover, since determining the practical clinical value of scintigraphy was the goal of this study, measurement of the actual value of scintigraphy to physicians is of fundamental importance. Finally, biased physicians might have manipulated their responses. This seems unlikely, for results of the coronary angiography were not provided to the evaluating physicians, the sample of physicians was very large and diverse, the methods of data analysis were not known to study participants, and the findings differed among patient subgroups in a manner consistent with previous predictions.

This study was designed to determine the effect of thallium scintigraphy upon the diagnostic accuracy of cardiologists. One would expect cardiologists, compared with other physicians, to have better diagnostic accuracy in the evaluation of patients with chest pain, as well as a better appreciation of the value of thallium scintigraphy. We did not examine the effect of thallium scintigraphy on the diagnostic accuracy of other physicians, such as internists or family practitioners, and it is not certain whether scintigraphy would have more or less value to these physicians. It is clear, however, that the clinical value of any diagnostic test is not a fixed quantity, but depends on the patient population in which the test is used, other available information about the patient, the methods used in performing and interpreting the test, as well as the diagnostic acumen of the physician in synthesizing these data.

Effect on Patient Management

This study documents a statistically significant effect of exercise thallium scintigraphy upon cardiologists’ diagnostic accuracy, but one might question whether statistical significance implies clinical importance. Improved diagnostic accuracy is an important quality in its own right, but unless a new diagnostic test influences the management of patients, its results will only be of academic interest. One important aspect of clinical management, the need for coronary angiography, was assessed in the present study. Other potential effects of thallium scintigraphy, such as assisting therapeutic decision-making or estimation of prognosis, were not assessed here, but have been by others.

We found that cardiologists’ judgments of the need for coronary angiography were usually altered by the results of thallium scintigraphy (fig. 2). This finding suggests that scintigraphy can have a clinically important effect on patient management. While these changes might not lead to an improved outcome for patients, an indication can be determined by considering the changes in need for angiography tabulated by the final diagnosis (table 2). The decreased need for coronary angiography in the patients without coronary disease should decrease the low, but not negligible, morbidity and mortality due to performing an invasive procedure. The effect of increased angiography in patients with coronary disease is conjectural, and would depend on how the scintigraphic findings were used in changing therapy and the effect of any changes upon outcome.

Another question of particular interest is whether thallium scintigraphy can reduce the overall need for coronary angiography. If scintigraphy reduced the need for angiography in some clinical settings, its value and cost effectiveness would be increased. However, the scintigraphic findings might also lead to more angiography because of unexpected findings or suggestions of substantial ischemia.

Thallium scintigraphy decreased cardiologists’ ratings of the need for angiography in patients with a positive exercise ECG and either typical or atypical angina (table 2). However, the decrease was not statistically significant. In contrast, scintigraphy significantly increased cardiologists’ ratings of the need for angiography in patients with a negative exercise ECG and either typical or atypical angina. The failure to document a significant decrease in the need for angiography in any of these four clinical presentations suggests that perfusion scintigraphy may not replace angiography in these settings.

Our findings in regard to the need for coronary angiography should be interpreted cautiously. To measure diagnostic accuracy, all patients in this study had both scintigraphy and coronary angiography. The participating cardiologists were unaware that angiography had been performed in these patients, so their evaluations were not directly affected. However, patients in whom the scintigraphy findings averted coronary angiography could not be included in the study, and inclusion of these patients might have altered the find-
ings. In contrast to our results, Goldman et al. prospectively studied unselected patients undergoing stress perfusion scintigraphy and found a decrease in angiography and in health care costs. The effect of perfusion scintigraphy upon the use of coronary angiography needs further study.

We offer the following guidelines, based on the findings of this study and previous work by us and others. Exercise thallium scintigraphy should be ordered selectively, not routinely, to provide information for diagnosis or specific management decisions. A reliable history of typical angina or myocardial infarction usually leaves little doubt about the diagnosis, but an unreliable history may prompt an effort to obtain objective confirmation. If the diagnosis is in doubt after a thorough history and physical examination, a standard exercise ECG is the appropriate next step, unless baseline ECG changes or coexisting heart disease would make the exercise ECG difficult to interpret reliably. Perfusion scintigraphy is most useful in clarifying the diagnosis when the patient has atypical symptoms and a positive exercise ECG, and may also be helpful in patients with otherwise typical symptoms and a negative exercise ECG. If a patient’s symptoms and exercise ECG findings are concordant, i.e., typical angina with a positive test or atypical symptoms with a negative test, further testing with perfusion scintigraphy adds little to diagnostic accuracy.

This study addressed the clinical value of a particular diagnostic procedure, but our method is of general interest, for it could readily be applied to the assessment of other diagnostic techniques. The method’s advantages are that it uses a representative cross section of physician opinion about individual patients, identifies the contribution of each step in the diagnostic process, and simplifies data collection. The method can be used to document the effectiveness of a laboratory test in improving diagnosis, in improving prognostic estimates, or in affecting management decisions. Modifications of this method would allow a controlled comparison of the efficacy of alternative diagnostic methods by selective presentation of the results of each to different physicians. We believe that this method is a rigorous, cost effective, and adaptable technique of evaluating medical technology.

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