EDITORIAL

On the Interpretation of the Exercise Test

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SUMMARY The widespread popularization of stress testing and the extensive application of its results in a variety of clinical settings make it imperative that a better method than the presently used simplistic "positive" or "negative" interpretation be devised. As a step toward a comprehensive diagnostic and prognostic index based on stress tests, a simple grading system of electrocardiographic changes, together with recognition of clinical modifiers, is suggested.

ONE OF THE Earliest OBSERVATIONS in clinical electrocardiography revealed that the tracings recorded during attacks of anginal pain demonstrated the concomitant appearance of reversible ST segment depression. On the basis of this finding, the "two-step test" was designed, in which a patient performed a brief bout of exercise, and an electrocardiogram was obtained immediately after. Based on follow-up studies of patients showing normal or abnormal ST segment responses, the two-step test was generally accepted as a test for myocardial ischemia with criteria defined for a positive and negative response.

In the past decade, advances in technology and the development of the motor-driven treadmill and bicycle ergometer have permitted electrocardiographic recordings not only after, but also during exercise. Thus, the amount of exercise could be quantified, with the workload gradually increased to the point of being physiologically taxing, and the end point of the test (for example, symptom-limited or heart rate-limited) preselected. Concomitantly, widespread use of the selective coronary angiogram provided the independent yardstick with which to measure the presence and severity of coronary disease in patients having exercise testing. Correlation of exercise-induced electrocardiographic changes with coronary angiographic findings permitted delineation of sensitivity, specificity and predictive accuracy of the exercise test. Thus, compared with the two-step test, treadmill or ergometric stress testing provided opportunity for refinements in interpretation. In this regard, the precise configuration of the ST segments, depth of ST segment depression, time of appearance and duration of ST segment abnormalities, and the appearance of ventricular arrhythmias have all been used fruitfully to refine the accuracy of the test. Yet, despite the considerable degree of sophistication in interpretation of stress testing, it remains customary to report the results as either positive or negative.

Some diagnostic methods in cardiology lend themselves to presentation of results that are purely qualitative. Such methods involve problems to which there is a "yes or no," or "present or absent," answer; for example, whether or not atrial fibrillation is present. Test results of purely quantitative nature are found in only limited areas of cardiology, such as the reporting of levels of blood pressure, heart rate or hemodynamic data obtained from cardiac catheterization procedures. Results of the great majority of diagnostic tests are given in semiquantitative terms using subjective estimates and arbitrary classifications. Examples of these arbitrary classifications might be the grading of the intensity of cardiac murmurs and the classification of the functional capabilities of a patient. When appropriate, designations such as +, ++, +++ and ++++ are used. The custom of describing degrees of obstruction of coronary arteries, as determined by coronary angiography in percent of luminal stenosis, suggests quantification, although in reality this description is only a crude estimate, and thus constitutes still another example of semiquantitative reporting.

The purpose of this essay is to emphasize the merit of abandoning the customary qualitative reporting of exercise testing results and to advocate the adoption of a semiquantitative reporting system. In so doing, the interpretation of the more comprehensive stress test will find easy clinical application in a wide range of settings, in addition to confirming the presence or absence of myocardial ischemia. The test can identify...
patients with precarious degrees of coronary artery stenosis; it can aid in the selection of patients in whom coronary arteriography may be indicated; it may be used to collect follow-up data in patients after myocardial infarction or aortocoronary bypass surgery; and it can be used as an adjunct in recommending and planning an exercise rehabilitation program. In all of these settings there is great need for discrimination between patients who become barely ischemic at high levels of exercise and patients who develop early and severe ischemia. Currently available data permit a reasonable separation of various ischemic responses, and a semiquantitative interpretation of stress test results is therefore both desirable and attainable.

Interpretation of stress tests includes two components: 1) the electrocardiographer's assessment of electrocardiographic abnormalities that develop during exercise and their relationship to myocardial ischemia, and 2) the clinician's evaluation of observations made during the test, and appreciation of variables pertaining to the patient which could influence the final interpretation. The eventual aim is to collate information about the patient and the exercise-induced electrocardiographic response, extrapolating from these to a clinically relevant conclusion. While frequently performed jointly with a cardiologist, the two equally important components of exercise test interpretation may be handled separately by two clinicians. There is an advantage to limiting the semiquantitative grading of stress tests to only the electrocardiographic changes and using additional information as clinical modification.

The concept of grading involves, by definition, some degree of subjective judgment. The classification suggested herein is meant as an illustration and guideline, and is not intended to be a set of inviolate criteria; modification of these criteria may become necessary as additional data become available.

We propose that five categories of exercise test results be recognized by the electrocardiographic reader: normal tests, uninterpretable tests and mildly, moderately and strongly positive tests. The underlying clinical application of these categories lies in the fact that the greater the degree of positivity, the greater the accuracy of the test and the more likely is a patient to have severe or critical coronary narrowing. Conversely, the greater the degree of negativity, the less likely is the patient to have coronary disease, especially a critical lesion.

Comments regarding ventricular ectopic activity are made with the knowledge that ventricular ectopy is not diagnostic of coronary disease per se, and may occur frequently in other conditions. Nonetheless, serious degrees of ventricular ectopic activity, when associated with other evidence of myocardial ischemia, may be added to the interpretative severity of the ischemic response to exercise. Although inadequate increment in heart rate (chronotropic incompetence) is considered by some investigators to correlate with severity of disease and prognosis, we have not included this variable in the current grading system, since 1) our own studies have found the heart rate response to be of little use in test interpretation and 2) a lower achieved heart rate due either to coronary or myocardial disease cannot always be readily distinguished from that due to fatigue and/or poor motivation. On the other hand, rapid heart rate at a very high level of exercise in association with a negative test enhances the probability of the test being a true negative one.

The Grading System

I. Normal electrocardiographic response (negative test):
   A. Absence of any change in the ST segment at maximal or near maximal heart rate.
   B. Junctional depression with rapidly rising ST segment slope.
   C. Development of isolated T wave inversion without ST segment displacement.
   D. Ventricular ectopic beats occurring infrequently, especially those occurring at heart rates exceeding 130/min.
   E. Appearance of atrial arrhythmia.
   F. Development of right bundle-branch block.

II. Uninterpretable exercise test responses:
   A. Failure to attain at least 85% of the age-predicted maximum heart rate, with absence of ischemic changes, in a well-motivated patient.
   B. Presence of baseline electrocardiographic abnormality, known either to predispose to false positive results should ST abnormalities occur during exercise, or to mask possible ST changes. These include electrocardiographic evidence of left ventricular hypertrophy, left bundle-branch block (fixed or rate-dependent), accessory atrioventricular conduction of the Wolff-Parkinson-White type, mitral valve prolapse with resting or hyperventilation-induced ST-T changes, ST segment and/or T wave abnormalities that occur with standing or develop in the pre-exercise hyperventilatory period and presence of digitalis.

III. Mildly positive electrocardiographic response (+):
   A. Horizontal ST segment depression between 1–1.5 mm (0.1–0.15 mV).
   B. Junctional depression with slowly rising ST slope that remains depressed 1.5 mm or more 80 msec after the J point.

IV. Moderately positive electrocardiographic response (++):
   A. Horizontal ST depression of between 1.5–2.5 mm (0.15–0.25 mV).
   B. Slowly upsloping ST segment depression with

*Some data suggest that in the presence of resting ST-T changes, further ischemic depression of an additional 2–3 mm may connote coronary disease. The number of cases available to substantiate this suggestion is, in our opinion, inadequate.
the ST segment being depressed in excess of 2.5 mm, 80 msec after the J point.
C. Downsloping ST depression with the J point depressed 1–2 mm.
D. Frequent ventricular ectopic activity (15–20% of QRS complexes over a period of time), especially when appearing during exercise at low heart rates (under 130/min) and when associated with ischemic ST segment abnormalities.

V. Strongly positive electrocardiographic response (++++):
A. Downsloping ST segment depression, the J point depressed 2 mm or greater.
B. Downsloping or flat ST segment depression in excess of 2.5 mm.*
C. Horizontal or downsloping ST segment depression appearing during the first stage of exercise and/or persisting beyond 8 minutes in the recovery phase.**
D. Complex ventricular ectopic activity, including multiform ventricular ectopic beats, salvos or runs of ventricular tachycardia or occurrence of ventricular fibrillation.

The clinician may then apply clinical modifiers to this semiquantitative grading system. Positive modifiers increase the probability that a positive stress test is a true positive and may place the patient in a higher diagnostic category. Negative modifiers 1) enhance the likelihood of a false positive test, or 2) suggest that a negative result represents a true negative stress test.

Positive modifiers based on clinical observations during the exercise test include (in order of decreasing importance, with A and B being considerably stronger):
A. Hypotension, or a significant drop in blood pressure during moderate levels of exercise coincident with ischemic electrocardiographic changes. This is a strong modifier, often indicating severe coronary disease.8
B. History of classic angina pectoris, thus placing the subject in a population with a high prevalence of coronary disease.
C. Development of severe, typical angina, coincident with ischemic electrocardiographic changes.
D. Development of S3 gallop and/or abnormal precordial motion.
E. Development of holosystolic murmur of mitral regurgitation.
F. Development of unusually severe shortness of breath, ataxic gait or lightheadedness.
G. Presence of coronary risk factors (hyperlipidemia, hypertension, smoking), this being a weak positive modifier.

Negative modifiers include:
A. Presence of clinical conditions known to cause false positive stress test results, such as left ventricular hypertrophy and use of digitalis. These enhance the probability of a false positive test.
B. Subject is part of a sub-population with low prevalence of coronary artery disease (young or asymptomatic subjects — especially those without known risk factors and premenopausal women). A negative test under such circumstances is more likely to be correct.

New data are becoming available which combine clinical and electrocardiographic information in an attempt to develop an overall diagnostic and prognostic index based on stress testing. On this basis, some investigators6, 6, 10 have suggested that the "positive"-"negative" interpretation be abandoned in favor of a comprehensive index. It is probably too early to come to an agreement on a comprehensive classification. However, a simple electrocardiographic semiquantitative grading system appears to be a logical first step in this direction.

References

*This criterion holds only if exercise is terminated within 1–2 minutes after ischemic ST changes appear. Marked ischemic changes will appear in many patients with coronary disease if they are exercised beyond their ischemic threshold.
On the interpretation of the exercise test.
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