Early exercise testing following percutaneous transluminal coronary angioplasty

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■ The value of early symptom-limited stress electrocardiography following percutaneous transluminal coronary angioplasty in assessing late outcome was evaluated in 218 patients. All subjects were tested using the Bruce or Sheffield Protocols, 2.5 ± 1.3 days after percutaneous transluminal coronary angioplasty. Repeat coronary angiography was performed after percutaneous transluminal coronary angioplasty because of symptoms (58%) or as routine follow-up (42%). Stress electrocardiography results were compared to coronary angiography. The sensitivity and specificity were 35.3% and 52.6%, respectively. The positive and negative predictive values were 39.6% and 48.0%. Two acute myocardial infarctions and one coronary angiographic-proven restenosis occurred within hours of the stress electrocardiogram in three patients (1.4%). It is concluded that symptom-limited stress testing immediately following percutaneous transluminal coronary angioplasty has no prognostic value and may carry increased risk for immediate negative coronary events.
□ INDEX TERMS: ANGIOPLASTY; EXERCISE TEST □ CLEVE CLIN J MED 1990; 57:53–56

GRADED exercise testing is performed soon after percutaneous transluminal coronary angioplasty for a variety of reasons. These include confirmation of resolution of symptoms, establishment of a new functional baseline, and reassurance of the patient or spouse.[1-10] While numerous exercise studies have demonstrated the positive effects of percutaneous transluminal coronary angioplasty on work capacity, few have looked at the diagnostic accuracy of early stress-electrocardiography for assessing late success or failure. Failure of investigators to define such terms as "soon after" or "early," or to include follow-up catheterization data, have made interpretation of early results and selection of an optimal testing protocol difficult. In addition, reports of complications[11-14] accompanying early stress testing after percutaneous transluminal coronary angioplasty raise questions about the safety of such a procedure during this time period. The purpose of this investigation was to assess the diagnostic value of early symptom-limited stress electrocardiography following percutaneous transluminal coronary angioplasty and to document any associated negative events.

MATERIALS AND METHODS

Patient population

Follow-up data were available in 437 patients who underwent symptom-limited stress testing at The Cleveland Clinic Foundation following percutaneous transluminal coronary angioplasty between January 1984 and January 1985. Of these, 219 patients were eliminated

from the analysis because of one of the following reasons: lack of follow-up catheterization data (51%), submaximal heart rate response (26%), or an abnormal resting electrocardiogram (23%) making stress response impossible to assess. The study population represented 100% of the eligible patients who underwent early symptom-limited stress electrocardiography following percutaneous transluminal coronary angioplasty at our institution during the analysis period. All stress tests were performed prior to hospital discharge.

Stress testing protocol

All patients were tested utilizing Bruce or Sheffield protocols.[15] The exercise test was terminated because of fatigue, hypotension, severe ST depression (≥3 mm), chest pain (grade 3+), claudication, dyspnea, or arrhythmia. Modified 12-lead electrocardiograms were recorded in all subjects at rest, every three minutes during exercise, during peak exercise, and every two minutes during recovery using a Mason Likar lead system. An abnormal stress-electrocardiographic result was defined as ≥1 mm of horizontal ST depression 0.08 seconds after the J point. The stress test was considered to be "early" if performed within one week of percutaneous transluminal coronary angioplasty. All tests were interpreted by the same trained observer to avoid interobserver variance.

Follow-up catheterization

Follow-up catheterization data were available for all patients included in the study population. For the purposes of this investigation, recurrence was defined as a ≥50% luminal diameter stenosis in an artery of previously successful percutaneous transluminal coronary angioplasty. A successful result was defined as a ≤50% diameter stenosis.

RESULTS

The study sample consisted of 172 men and 46 women. The mean age of the patients was 55.2 ± 8.6 years (range, 36–76 years). Prior to percutaneous transluminal coronary angioplasty, 101 patients were classified as having single-vessel coronary artery disease, with the remaining 117 patients possessing two or more stenotic vessels. A total of 315 vessels were successfully dilated: 58% because of left anterior descending disease, 26% because of disease in the right coronary artery, and 16% because of circumflex disease. Following percutaneous transluminal coronary angioplasty, stenoses were reduced to a mean value of 17.8% ± 14.3%.

The exercise test was performed 2.5 ± 1.3 days after percutaneous transluminal coronary angioplasty (range, 1–6 days). The Bruce protocol was selected for 213 patients and the Sheffield protocol was chosen for the remaining five patients. All patients exercised to at least 80% of their maximum-predicted heart rate, with a mean value of 92.9% ± 11.0%. Ninety-one tests were considered positive and 127 were considered normal.

Within hours of the symptom-limited stress tests, acute myocardial infarction occurred in two patients and catheterization-proven restenosis in another. These patients had been considered stable and had not undergone percutaneous transluminal coronary angioplasty for acute myocardial infarction intervention prior to the early stress test. Acute occlusion had occurred in one of the patients early in the percutaneous transluminal coronary angioplasty procedure while still in the catheterization laboratory.

Repeat catheterization was performed in all 218 patients one week to 12 months after PTCA. Reasons for follow-up angiography included symptoms (n=127) and routine follow-up (n=91). Recurrence was documented in 46% of the patients as defined by previously mentioned criteria.

Comparing follow-up angiography with stress-electrocardiographic data, a false-negative result was observed in 66 patients, a false-positive result in 55 patients, a true-negative result in 61 patients, and a true-positive result in 36 patients. Sensitivity and specificity were 35.3% and 52.6%, respectively, with a positive and negative predictive accuracy of 39.6% and 48.0%, respectively. The degree of coronary artery disease (single v multi-vessel) did not affect the outcome nor did the time interval between initial PTCA and follow-up catheterization.

DISCUSSION

In the presence of established coronary artery disease, graded exercise testing has been identified as a valuable noninvasive tool for assessing prognosis and stratifying risk.[16–19] Early after myocardial infarction, the presence of ≥1 mm exercise-induced ST depression has been associated with a three-to-20-fold increase in risk for subsequent cardiac events in comparison to those without ST abnormality.[19–21]

Our data show that an abnormal stress electrocardiogram within one week of percutaneous transluminal coronary angioplasty was not useful in predicting future re-stenosis. Of the total number of negative exercise tests, 52% were considered false-negative when compared to follow-up angiography. Moreover, a false-posi-

tive result occurred in 60% of the stress tests interpreted as normal.

In their initial report on percutaneous transluminal coronary angioplasty, Gruntzig et al[22] recommended the use of *submaximal* bicycle ergometric evaluation two days after dilation to evaluate the immediate success of the angioplasty. Some, however, have adopted the use of *symptom-limited* exercise testing during this period.[6,8] It is clear from the literature (*Table 1*) that testing protocols vary considerably and lack standardization. The time frame for "early" testing ranges from two days to eight months, with no clear consensus definition. A recent American College of Cardiology/American Heart Association task force[16] concluded that exercise testing following percutaneous transluminal coronary angioplasty may be performed safely prior to hospital discharge but did not specify a maximal or submaximal protocol.

There have been four reports of complications accompanying early symptom-limited exercise testing following percutaneous transluminal coronary angioplasty: exercise-induced vasospasm,[13] acute thrombus formation,[12] and two reocclusions.[11,14] In our series, acute myocardial infarction was documented in two patients and one acute occlusion in another patient. The overall incidence of acute occlusion following successful percutaneous transluminal coronary angioplasty at our institution has been reported at 2%.[23] Of these, 84% occurred within six hours of the percutaneous transluminal coronary angioplasty. The only late occlusion (>24 hours) occurred following a symptom-limited stress test. The complication rate of 1.4% (three events per 218 patients) exceeds the generally accepted risk in stress testing of three cardiac events per 10,000 patients.[15]

While the mechanism of re-stenosis remains to be established,[24] it is clear that the process generally occurs during the first six months following angioplasty.[25] If exercise testing is to be used effectively as a predictor of future cardiac events, the timing of the exercise test is crucial. Wijns et al[3] reported that myocardial thallium perfusion scintigraphy four weeks after angioplasty was highly predictive of re-stenosis, with a positive predictive value of 82% and no reported complications. However, because the stress electrocardiogram and thallium scintigraphic responses may revert from positive to negative in a delayed fashion during the recovery period, Scholl et al[1] have suggested that follow-up exercise testing be conducted at three months postangioplasty. In support of this, Manyari and colleagues[26] compared thallium stress scintigraphy at nine days and at three, six, and nine months postangioplasty in patients without evidence of recurrence on follow-up catheterization. Al-

TABLE 1
EXERCISE TESTING PROTOCOLS FOLLOWING PERCUTANEOUS TRANSLUMINAL CORONARY ANGIOPLASTY

Principal investigators	No. of patients	Protocol	Time to early graded exercise testing	Follow-up angiography
Scholl et al[1]	54	85% maximal predicted heart rate	1 mo	20 mo
Rosing et al[2]	45	Symptom-limited. Treadmill	8 mo	–
Wijns et al[3]	89	Symptom-limited. Bicycle	4.7 mo	12 mo
Miri et al[8]	71	Symptom-limited. Bicycle	2 d	28 mo
Rod et al[5]	14	Symptom-limited. Bicycle	7.8 d	–
Meier et al[6]	160	Symptom-limited. Bicycle	2 d	–
Ernst et al[7]	25	Symptom-limited. Bicycle	14 d	–

though thallium scans improved significantly immediately after angioplasty, evidence of "ischemia" was still present in over one-third of their patients. By three months, the perfusion scans normalized in all patients, with no further changes at six or nine months.

CONCLUSIONS

The results of this study suggest that early symptom-limited stress electrocardiography following percutaneous transluminal coronary angioplasty is of no diagnostic value for the prediction of future coronary events. In addition, maximal exercise testing may carry some added risk for acute complications.

The optimal timing of the test requires further investigation and will ultimately depend on the individual clinical circumstances of each patient. Delaying stress testing for four weeks or limiting the test to a moderate workload are alternative solutions. The use of testing at three or six months may also maximize early detection of recurrence. If predischarge testing is to be used routinely, test endpoints and timing need to be standardized and the potential for complications related to the exercise test in this population needs to be considered.

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