Evidence for emotionally-induced coronary arterial spasm in patients with angina pectoris*

FREDRIC SCHIFFER, L HOWARD HARTLEY, CHARLES L SCHULMAN,
WALTER H ABELMANN

From the Department of Medicine and Thorndike Laboratory, Harvard Medical School and
Beth Israel Hospital, Boston, Mass, USA

SUMMARY Twelve executives with typical angina pectoris, given a 12-minute quiz, designed to be
psychologically stressful, responded with ST depressions of \( \geq 1.0 \) mm. Each of these patients was given
an exercise tolerance test on an upright bicycle to induce an amount of ST depression equivalent to
that observed during the quiz. A statistical analysis was made of the products of the heart rate and the
systolic blood pressure (rate-pressure product), at the onset of equivalent ST depression on both tests.
At the maximal ST depression during the quiz, the mean rate-pressure product was \( 181 \pm 64 \) (SD) \( \times 10^3 \),
and at an equivalent ST depression during exercise it was \( 225 \pm 54 \times 10^3 \); the mean difference was
\( 44 \pm 40 \times 10^3 \).

Inasmuch as the rate-pressure product is an index of myocardial oxygen consumption, the
differences in rate-pressure product suggest that myocardial ischaemia occurred at a lower myocardial
oxygen consumption during emotional stress than during exercise. If equivalent degrees of ST
depression during exercise and the quiz are indicative of equivalent ischaemia, then a relative reduction
in coronary blood flow during emotional stress, probably by coronary spasm, may be postulated as the
most reasonable explanation for these observations.

It has been observed that, in patients with angina pectoris, chest pain tends to be produced whenever
the myocardial oxygen consumption exceeds a critical value.1 Whether the angina occurred
spontaneously or in response to exercise, it seemed always to recur at about the same myocardial
oxygen consumption for each patient. These results furthered the theory that angina was produced by
a fixed atherosclerotic coronary lesion and seemed to refute a role for coronary spasm in the syndrome
of typical angina pectoris. Robinson2 reported one patient who developed angina in response to
performing mental arithmetic as well as to exercise. Using the rate-pressure product (heart rate multi-
plied by systolic blood pressure) as an index of myocardial oxygen consumption, he noted that the
rate-pressure products were similar at the onset of the angina, regardless of how it was provoked. He

* This research was supported, in part, by grants from the National
Heart and Lung Institute, and by a grant from the General Clinical
Research Centers Program of the Division of Research Resources,
National Data Organization, and analysis was performed on the
PROPHET System, a national computer resource sponsored by the
Chemical/Biological Information Handling Program, National
Institutes of Health.

Received for publication 5 November 1979

suggested that emotional stress, like exercise, provokes angina by increasing the myocardial
oxygen consumption above a critical level.

We examined the relation between angina pectoris and emotional stress using a larger patient popula-
tion and electrocardiographic criteria for myocardial ischaemia, rather than subjective patient reporting.
A comparison was made of the rate-pressure products at the time of equivalent ST responses to
exercise and to emotional stress.

Subjects and methods

Thirty-six patients with angina pectoris and not
taking digitalis were given a 12-minute tape
recorded quiz, designed to be stressful, while the
electrocardiogram and blood pressure were being
monitored. A full description of the quiz electro-
cardiogram has been reported.2 Those patients
manifesting at least 1 mm of ST segment depression
in response to the quiz were selected for exercise
tolerance testing.

Each patient, upon arrival at the cardiovascular
laboratory, was familiarised with the laboratory and
then asked for written informed consent to the study. The tests were given without cost or remuneration to the patient. After a detailed history and physical examination, a 12 lead, supine, resting electrocardiogram was recorded. A brief unstructured psychiatric interview was also conducted. No patient was accepted for study who manifested unstable angina, recent myocardial infarction (within six weeks), unstable resting electrocardiogram, or other significant illness except stable hypertension. All tests were performed in an exercise laboratory, using the same precautions as are used for tolerance testing. For both the quiz electrocardiogram and the exercise tolerance test, exercise electrocardiographic electrodes were applied as described by Mason and Likar. The electrocardiogram was calibrated to 1 mV/10 mm, and the response signal was evaluated before each test. Blood pressure measurements were obtained by auscultation using a standard sphygmomanometer. Diastolic blood pressure was determined by the disappearance of the Korotkoff sounds.

A baseline electrocardiogram was recorded with the exercise electrodes, with the patient sitting in the same position used during exercise and the quiz. Three baseline blood pressure readings were also taken.

Subjects were then instructed to answer questions asked on a 12-minute tape recording. During this quiz, the electrocardiogram was monitored continuously, and the blood pressure was measured at least every two minutes.

The 12 patients with positive responses to the quiz electrocardiogram constituted the study group. They were given an upright bicycle exercise tolerance test to induce an equivalent ST segment depression. Progressively more intense four-minute work loads, each followed by a five-minute rest period, were used. Blood pressure was measured by auscultation during the last minute of each exercise load, or at the onset of ST segment depression.

Most of the exercise tests were performed on the same day as the quiz electrocardiogram, with a 45-minute rest period between tests. When the tests were performed on different days, they were performed within 48 hours of each other. Both the quiz electrocardiogram and the exercise tolerance test used the same monitoring leads, and were conducted at a room temperature of 21°C (70°F) and at approximately the same time of day with patients in the fasting state and in the same body position.

Using the criteria of Ellestad and Wan, the ST segments were carefully measured with a magnifying glass, using the PQ junction as a reference. The ST segment depression at 0.08 second after the J point was considered as the extent of depression. Each reported ST segment value represented the average of the measurements of 10 consecutive beats.

All the patients in this study were executives, defined as those whose occupation is classified by the US Bureau of the Census as either professional, managerial, or sales. A previous study has shown that executives tend to respond significantly more to the quiz electrocardiogram than do non-executives.

The study group consisted of 11 men and one woman, aged 52 to 69 years (mean 62). All had typical angina, defined as recurrent chest pressure discomfort of brief duration, usually precipitated by physical exertion. Two had undergone coronary angiography, each revealing at least 70 per cent occlusion of a coronary artery; five had a history of a documented myocardial infarction; and two had a history of hypertension. One patient was taking propranolol at the time of the study; otherwise no medication known to affect the cardiovascular system was taken for 72 hours before the study. The 12 patients in the study group did not differ from the 24 patients who had less than 1.0 mm ST depression on the questionnaire, with regard to physical examination, history, or psychiatric interview.

Results

ST SEGMENT RESPONSES

In each of the 12 patients who developed $>$1.0 mm ST segment depression during the quiz electrocardiogram, exercise testing was able to induce an amount of ST segment depression equivalent to that on the quiz. The Figure shows the equivalent ST segment changes for four patients. No patient developed chest pain during the study.

DIFFERENCES IN THE RATE-PRESSURE PRODUCTS

The Table presents the individual heart rates, blood pressures, and rate-pressure products for both tests at the onset of ST segment depression. A statistical analysis was made of the rate-pressure products at the time of equivalent ST segment depressions on both tests. At the time of maximal ST depression during the quiz, the mean rate-pressure product was $181 \pm 64$ (SD) $\times 10^3$, and at an equivalent ST depression during exercise it was $225 \pm 54$ (SD) $\times 10^3$. The mean difference was $44 \pm 40$ (SD) $\times 10^2$. By paired $t$ test $p$ was $<0.005$.

Discussion

Roughgarden reported that patients with spon-
mental arithmetic, as well as to an exercise stress. In that patient, angina occurred when a critical rate-pressure product was exceeded, regardless of the type of provocative stress. The work of Roughgarden and Robinson thus tends to argue against a significant role for coronary spasm in ischaemic heart disease.

Using the same basic arguments as Robinson, we hypothesised that if ischaemia were the result of a fixed coronary blockage, then the myocardial oxygen consumption at the onset of ischaemia should be the same regardless of how the ischaemia was provoked. In 12 patients we were able to provoke ST segment responses suggesting ischaemia under two conditions: emotional stress and physical stress. Ischaemic ST responses occurred at significantly lower rate-pressure products during emotional stress than during exercise stress. If ST depression during exercise had occurred when a "critical" rate-pressure product was reached, then during the emotional stress the ST depression occurred at a point significantly below the alleged "critical" rate-pressure product.

The rate-pressure product is considered to be a valid index of myocardial oxygen consumption. The occurrence of ST segment depression at a lower rate-pressure product reflects less coronary blood flow only if the myocardial oxygen demands are faithfully reflected in the rate-pressure product. Increased left ventricular volume leads to increased wall tension, and thus myocardial oxygen uptake is increased for any given rate-pressure product. Hence, if ventricular volume were greater for the psychological stress than during exercise, more ST segment depression would be expected. In this

Table Individual heart rates, blood pressures, and rate-pressure products at time of equivalent ST responses to quiz and to exercise

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Quiz electrocardiogram</th>
<th>Exercise electrocardiogram</th>
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<tbody>
<tr>
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<td>Heart rate (b/min)</td>
<td>Systolic blood pressure (mmHg)</td>
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<tr>
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</table>

Mean ± SD 102 ± 25 174 ± 24 99 ± 12 181 ± 64 119 ± 17 187 ± 25 101 ± 13 225 ± 54

* p<0.02 (compared with exercise); ** p<0.01 (compared with exercise); *** p<0.005 (compared with exercise);
NS, not significant; SD, standard deviation.
The systolic pressure was equivalent during the emotional quiz compared to exercise. This lower pressure would be expected to be associated with a lower ventricular volume. Also, during exercise, the increased venous return would be expected to lead to a larger ventricular volume than during emotional stress. On the other hand, emotional stress may be associated with increased venous tone which might lead to an increase in central venous pressure and ventricular volume. Therefore, alterations in ventricular volume have not been ruled out. Myocardial contractility may also affect myocardial oxygen demands and, in view of the higher heart rate during exercise, may have been higher during exercise stress.

We compared the rate-pressure products at equivalent amounts of ST segment depression during the exercise and emotional stress. Though it cannot be considered proven that equivalent amounts of ST segment depression represent equivalent amounts of ischaemia, this assertion is supported by work in animals. ST segment depression is a more objective index of the degree of myocardial ischaemia than subjective reporting of a chest discomfort.

If the rate-pressure product adequately reflects the myocardial oxygen consumption, and if equivalent amounts of ST segment depression represent equivalent amounts of ischaemia, then the most likely explanation for our findings is that emotional stress provoked a transient, relative decrease in myocardial oxygen delivery. A hypothesis that a shift in the oxyhaemoglobin curve could produce clinical ischaemia has not been sustained. A hypothesis that platelet aggregation might cause a transient coronary obstruction has some support from work on a dog preparation, but has not yet been demonstrated to have clinical significance in angina patients. Generalised or local constriction—or even local dilatation—of coronary resistance vessels are potential but unproven pathophysiological mechanisms by which emotion might induce ischaemia. Furthermore, ST and T changes resembling myocardial ischaemia have been encountered at rest in healthy men with normal coronary arteriograms and attributed to catecholamine hypersecretion or hypersensitivity. On the other hand, it is known that the conducting coronary arteries contain smooth muscle which is sensitive to neural and chemical stimulation and which has been repeatedly shown by coronary visualisation to cause clinically significant coronary spasm.

Our observations in patients with classical angina are compatible with the hypothesis that coronary artery spasm, in addition to atherosclerosis, may play a role in the production of the ischaemic electrocardiographic responses to emotional stress.

References

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Requests for reprints to Dr Walter H Abelmann, Cardiovascular Unit, Beth Israel Hospital, 330 Brookline Avenue, Boston, Massachusetts 02215, USA.