Relationship between Arterial Pressure and Exertional Angina Pectoris in Hypertensive Patients

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ELEVATION of arterial pressure has been found in patients during attacks of angina pectoris and relief of exertional angina has been reported in hypertensive patients following satisfactory control of hypertension. Further, anginal pain has been found to occur in hypertensive patients during lowering of arterial pressure.

Although these observations suggest an etiologic correlation between angina pectoris and level of arterial pressure, this has not been adequately established. The present study was undertaken to determine the possible relationship between arterial pressure and exertional angina pectoris in hypertensive patients with and without coronary arterial disease.

Methods

Seven hypertensive patients (four women and three men) in the Research Ward of the Cleveland Clinic Hospital with unequivocal history of exertional angina pectoris of the functional class II were studied. Coronary arteriography by Sones' technic; revealed segmental disease of the left coronary artery in four and of both coronary arteries in one (fig. 1); the remaining two were found to have normal coronary arteries (fig. 2). Radiographic, as well as electrocardiographic, evidence of left ventricular hypertrophy was present in all. None had a history or electrocardiographic evidence of recent or remote myocardial infarction.

The five patients with coronary arterial disease had not taken any antihypertensive treatment prior to the study and during the study had moderate to severe hypertension; the two patients with normal coronary arteries had received guanethidine and had normal supine arterial pressure and significant postural hypotension.

Exercise was performed in sitting position on a stationary bicycle and in supine position by successive elevation of the legs with attached three-pound sand bags on each lower leg. The duration of exercise lasted 3 minutes, unless angina pectoris occurred earlier. The five patients with coronary arterial disease were subjected, in addition, to exercise in supine position during intravenous administration of sodium nitroprusside, as recommended by Page et al.; in two of these, exercise was repeated 2 months after satisfactory control of hypertension was achieved with oral guanethidine.

Twelve-lead electrocardiograms (six standard limb leads and precordial leads V₁, through V₅) were taken prior to each exercise, and every 3 minutes thereafter three standard limb leads (I, II, III) and one precordial lead (V₄ or V₅) were taken for the following 15 to 20 minutes. The arterial pressure was measured sphygmomanometrically before exercise and every half minute during and following exercise.

In the two patients with normal coronary arteries, the effects of intravenous sodium nitroprusside (100 µg. per minute) and norepinephrine (5 µg.) given in the supine position were studied separately.

Results

Effects of Exercise on Five Patients with Angina Pectoris and Coronary Arterial Disease

During exercise, all five patients developed marked pressor response; the average increasing from 184/109 to 243/142 mm. Hg with exercise in supine position and from 179/110 to 216/120 mm. Hg with exercise in sitting position. Following exercise, arterial pressure returned to pre-exercise level within 3 minutes. Angina pectoris occurred in all, immediately after the peak of pressor effect was reached, within 1½ to 3 minutes from the beginning of the exercise and lasted from ½ to 1 minute. Because of anginal pain, exercise was discontinued earlier than had been planned in four.
Abnormal electrocardiographic responses were obtained in all, following exercise in both positions; these consisted of depressed S-T segments ranging from 1 to 2 mm, and inverted or diphasic T waves in one or more leads (figs. 3A and 4A); the changes lasted from 6 to 12 minutes and subsided gradually. In one, negative U waves appeared in lead from that in top figure. In top and middle figures the tip of the catheter is placed in the orifice of the main left coronary artery. Bottom. Normal right coronary artery. Arrow points to a collateral branch leading toward the distribution of the left circumflex coronary artery. Patient is rotated in left anterior oblique position about 60 degrees. Tip of catheter is placed in the orifice of the right coronary artery.

Figure 1
Coronary arteriograms on a 51-year-old man with hypertension and angina pectoris. Top. Arrow points to a segmental lesion in a branch of the left anterior descending coronary artery. Patient is rotated in left anterior oblique position about 45 degrees. Middle. Another segmental lesion at the proximal third of the left circumflex coronary artery. Rotation of patient only slightly different from that in top figure. In top and middle figures the tip of the catheter is placed in the orifice of the main left coronary artery. Bottom. Normal right coronary artery. Arrow points to a collateral branch leading toward the distribution of the left circumflex coronary artery. Patient is rotated in left anterior oblique position about 60 degrees. Tip of catheter is placed in the orifice of the right coronary artery.

Figure 2
Normal left (top) and right (bottom) coronary arteries. Catheter tip lies in the orifice of each artery. Patient is rotated in left anterior oblique position.
SUPINE EXERCISE

Blood pressure

225 -
200 -
175 -
150 -
125 -
100 -
75 -

LEAD

Control

II

III

AFTER EXERCISE

Immediately

3 minutes

6 minutes

Figure 3A

SUPINE EXERCISE

Blood pressure

225 -
200 -
175 -
150 -
125 -
100 -
75 -

I.V. No NITROPRUSSIDE

(No AP)

LEAD

Control

II

III

AFTER EXERCISE

Immediately

3 minutes

6 minutes

Figure 3B
V5 immediately after exercise and became upright within 3 minutes, when the arterial pressure returned to control levels. Average increase in pulse rate when the angina pectoris occurred was 20 per minute. The pressor effect produced by exercise in the supine position was more pronounced than that in the sitting position; similarly, electrocardiographic changes, severity of angina pectoris, and the duration of both were greater with exercise in the supine position.

**Effects of Exercise during Intravenous Administration of Sodium Nitroprusside on the Five Patients with Coronary Arterial Disease**

With simultaneous intravenous infusion of sodium nitroprusside (400 to 600 µg. per minute) during the 3-minute exercise in supine position, pressor response to exercise was abolished in all; none experienced angina pectoris during or following exercise. Electrocardiographic changes did not occur (figs. 3B and 4B). Average pulse rate increased by 23 per minute over the pre-exercise control.

The results were reproduced in all patients in similar fashion on two occasions.

**Effects of Exercise on Two Patients with Angina Pectoris and Normal Coronary Arteries**

Both patients had orthostatic hypotension, secondary to antihypertensive treatment, which was exaggerated by exertion. A marked depressor effect occurred during exercise in the sitting position in both; average pressure fell from 122/86 to 80/55 mm. Hg. Angina pectoris developed immediately after the maximum depressor effect, about 2 minutes from the beginning of exercise, and lasted from 1/2 to 1 minute. Electrocardiographic changes (depressed S-T segments and diphasic T waves) appeared in both; these lasted from 6 to 9 minutes and gradually disappeared. In one, the depression of S-T segments was very pronounced (fig. 5A).

During exercise in supine position only minimal pressure changes occurred in both; angina pectoris and electrocardiographic changes did not occur (fig. 5B).

**Additional Studies**

Two of the five patients with coronary arterial disease, in addition, were subjected to 3-minute exercise in both positions, 2 months after control of hypertension with oral guanethidine. Exercise elicited no pressor response, no angina, nor electrocardiographic changes (fig. 4C).

In the two patients with normal coronary arteries, the effects of intravenous sodium nitroprusside (100 µg. per minute) and norepinephrine (5 µg.) in the resting supine position were studied separately. With sodium nitroprusside, arterial pressure was lowered to the same levels as with exercise in the sitting position during which angina pectoris had occurred before; with the norepinephrine the arterial pressure rose from 140/90 to 200/110 mm. Hg in one, and from 130/80 to 210/100 mm. Hg in the other. Neither the depressor nor the pressor effects produced angina pectoris or electrocardiographic changes.

**Discussion**

Rise in arterial pressure occurs in both normotensive and hypertensive patients during attacks of angina pectoris. We found that this elevation of arterial pressure in hypertensive patients with coronary arterial disease is an important precipitating factor in production of exertional angina pectoris. When the pressor response to exercise is eliminated by administration of an infusion of sodium nitroprusside or following antihypertensive treatment with guanethidine, angina pectoris, S-T depression and T-wave inversion can be prevented.

The mechanism by which elimination of the

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**Figure 3**

*A 39-year-old woman with hypertension, angina pectoris, and coronary arterial disease.*

A. Marked pressor response to exercise occurred; this was followed by angina pectoris and electrocardiographic changes. Numbers below arterial pressure graph indicate time in minutes. B. Marked pressure changes were not produced by a 3-minute exercise in supine position during intravenous sodium nitroprusside administration. Angina pectoris and electrocardiographic changes did not occur.
Figure 4A

Figure 4B
Figure 4

A 59-year-old man with severe hypertension, angina pectoris, and segmental disease of both coronary arteries. A. Exercise prior to treatment with guanethidine. Marked pressor response occurred, followed by angina pectoris and electrocardiographic changes. B. Similar exercise as in A (the same day). Intravenous sodium nitroprusside during exercise eliminated the pressor response and prevented angina pectoris and electrocardiographic changes. C. Supine exercise after 2 months' treatment with oral guanethidine. Marked arterial pressure changes, angina pectoris, and electrocardiographic abnormalities did not occur.

Arterial pressure is one of the most important constituents of the work of the heart, and angina pectoris may be relieved by decreasing cardiac work. It is therefore probable that in hypertensive patients reduction of cardiac work by eliminating the pressor effect of exercise is a significant factor in preventing attacks of exertional angina pectoris.

Tachycardia occurring during exercise has been suggested as a possible cause of exertional angina pectoris. In our study, increase in heart rate was not an important factor because it also occurred when the angina pectoris was prevented with administration of sodium nitroprusside.

The possibility of a direct action of sodium nitroprusside on the coronary arterial circulation has not been completely eliminated. In two patients in whom we had the opportunity to perform coronary arteriography before and after intravenous administration of sodium nitroprusside, we did not observe dilatation of coronary arteries similar to that seen in patients following administration of nitro-
Figure 5A

Blood pressure
200 -
175 -
150 -
125 -
100 -
75 -
50 -

SITTING EXERCISE

LEAD  Control  immediately  3 minutes  6 minutes
II
V5

AFTER EXERCISE

Figure 5B

Blood pressure
200 -
175 -
150 -
125 -
100 -
75 -
50 -

SUPINE EXERCISE

LEAD  Control  immediately  3 minutes  6 minutes
II
V5

AFTER EXERCISE

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glycerin. Since angina pectoris also did not occur with exercise in the two patients treated with guanethidine, we assume that sodium nitroprusside relieved angina pectoris, not by a direct vasodilating effect on the coronary arteries, but by eliminating the pressor response to exercise.

The occurrence of angina pectoris in the absence of obstructive lesions in the coronary arterial tree has been reported in severe anemia, aortic valve lesions, and patients with hypertension. We found that marked temporary fall in arterial pressure is a factor of importance in precipitating exertional angina pectoris in hypertensive patients. The two patients in whom this occurred had left ventricular hypertrophy and normal coronary arteries. Since it is known from the work of Roberts and Wearne that the capillary bed of the hypertrophied myocardium is decreased in proportion to the increase in heart weight, we assume that the fall in arterial pressure results in a further reduction in the myocardial blood supply, leading to exertional angina pectoris. Because angina was not produced in these two patients by exercise in the supine position, during which fall in arterial pressure was avoided, we conclude that hypotension was the main factor in the production of exertional angina pectoris.

The possibility exists that hypertensive patients with coronary arterial disease may also experience angina as a result of lowered arterial pressure during exercise. Similarly, in hypertensive patients with normal coronary arteries and angina, elevation of arterial pressure during exercise may be an important factor in precipitating angina pectoris. Both these two possibilities, not studied here, would need further investigation.

Summary

Seven hypertensive patients, five with coronary arterial disease and two with normal coronary arteries, with exertional angina pectoris and left ventricular hypertrophy were subjected to exercise in the sitting and supine position.

The five patients with coronary arterial disease developed, during exercise in both positions, striking arterial pressure elevation followed by angina pectoris and electrocardiographic changes. When the pressor response to exercise was eliminated by intravenous sodium nitroprusside, these were prevented.

In the two patients with normal coronary arteries who had orthostatic and exertional hypotension secondary to antihypertensive treatment, exercise in the sitting position caused intense hypotension followed by angina pectoris and electrocardiographic changes. In contrast, exercise in the supine position, which caused only minimal pressure changes, was not followed by angina pectoris.

It is concluded that in hypertensive patients with coronary arterial disease, further elevation of arterial pressure during exercise is an important factor in precipitating angina pectoris by increasing cardiac work. In hypertensive patients with normal coronary arteries and exertional hypotension secondary to antihypertensive treatment, marked lowering of arterial pressure during exercise is a factor of importance in producing angina pectoris, probably by reduction of perfusion pressure and coronary flow relative to the hypertrophied left ventricle.

References


Figure 5

A 35-year-old hypertensive woman with exertional hypotension, angina pectoris, and normal coronary arteries. A. Sitting exercise produced marked depressor response, angina pectoris, and pronounced depression of the S-T segments in lead V5 of the electrocardiogram. B. Three-minute exercise in supine position did not produce pressure changes, angina pectoris, or electrocardiographic abnormalities.

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The great and fruitful ideas which Darwin brought to the attention of the whole world have long since been incorporated into human thought. Not the least important among them is the new scientific concept of fitness, as it emerges from the discussion of natural selection. Before Darwin, this concept possessed all the vagueness of an idea which, though in part founded on observation, was not to be explained with the help of existing scientific theories. But although Darwin’s fitness involves that which fits and that which is fitted, or more correctly a reciprocal relationship, it has been the habit of biologists since Darwin to consider only the adaptations of the living organism to the environment. For them, in fact, the environment, in its past, present, and future, has been an independent variable. Yet fitness there must be, in environment as well as in the organism. How, for example, could man adapt his civilization to water power if no water power existed within his reach?—LAWRENCE J. HENDERSON. The Fitness of the Environment. New York, The MacMillan Co., 1924 p. 5.
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