THE EXERCISE TEST IN PATENT DUCTUS ARTERIOSUS

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The clinical diagnosis of patent ductus arteriosus rests primarily upon the presence of the characteristic continuous murmur first described by Gibson (1906), but information gained by a study of the blood pressure may strengthen the diagnosis in some cases.

Gordon (1926) appears to have been the first to draw attention to abnormalities of blood pressure in patent ductus arteriosus. He predicted that low arterial tension, which was a prominent finding in his patient, would prove to be a common observation. Although this early impression has been confirmed by numerous observers, the interpretation of much of the information relating to blood-pressure studies in patent ductus remains uncertain because of the lack of controlled observations. This uncertainty in interpretation applies particularly to the changes in diastolic blood pressure after exercise. Following the introduction of the exercise test by Bohn (1938), a fall in diastolic pressure after effort has been widely sought as an ancillary sign of patent ductus arteriosus—particularly in recent years since the value of this test has been emphasized by Lewicki (1940), Gilchrist (1945, 1946), and others.

The purpose of this communication is to present the results of controlled observation on the effect of exercise upon the blood pressure in patent ductus arteriosus before and after surgical closure of the ductus, and to define more clearly the limitations and value of the exercise test in the diagnosis of this condition.

CLINICAL MATERIAL AND METHODS

Twenty-six consecutive patients with uncomplicated patency of the ductus arteriosus were studied before operation and at the end of the second week after successful ligation. All but three of the patients were girls or women and the average age was 13 years (6 to 26 years). The diagnosis, confirmed at operation, was made on the basis of a Gibson murmur, absence of cyanosis and clubbing, a palpable femoral pulse, and an electrocardiogram that was either physiological or showed only left ventricular preponderance.

Three groups of controls were studied: 26 healthy subjects of an age and sex corresponding to that of the patients, 100 healthy subjects of widely differing ages, and 24 patients recovering from various major surgical operations other than for closure of a patent ductus arteriosus or an arterio-venous fistula elsewhere.

Measurement of Blood Pressure. The right brachial blood pressure was recorded by the cuff method using a standard mercury sphygmomanometer. The joint recommendations of the British Cardiac Society and the American Heart Association (1939) for the standardization of blood pressure measurement were adopted, and the British Committee's recommendation for recording diastolic blood pressure was followed. Blood pressure readings were invariably taken with the subject recumbent and by the same observer.

Resting blood pressure records were obtained in the following manner: subjects lay comfortably on a couch in a quiet room; the cuff was applied to the right arm and a blood pressure record was taken. A period of rest of at least 20 minutes was allowed, and blood pressure records were then taken at three-minute intervals until systolic and diastolic levels remained constant. These figures were accepted as the resting blood pressure.

A standard exercise test, calculated to induce tachycardia and mild or moderate distress as recommended by Gilchrist (1945), was employed. With the sphygmomanometer cuff in position, the subject stepped briskly 24 times on to a stool 15 to 18 inches high, alternating the stepping foot after each six ascents. Immediately after the exercise the subject lay on the couch; the blood pressure was taken within 30 seconds of the end of the exercise and at minute intervals for five minutes.

Since changes in the blood pressure, and particularly the diastolic pressure, are most evident immediately after exercise, this study is concerned with the readings taken within 30 seconds.

OBSERVATIONS BEFORE OPERATION

The mean resting systolic pressure in patent ductus is greater than in controls (Table I), and the difference between the means is regarded as significant. As might be expected in ductus cases, resting diastolic readings are significantly lower and pulse pressures significantly higher than in controls.

TABLE I
MEAN BLOOD PRESSURE AT REST AND AFTER EXERCISE

Blood pressure	Patients with Patent Ductus Arteriosus (mm. Hg)	Controls (mm. Hg)	<i>t</i>	<i>P</i>
<i>Systolic</i>				
Rest	114 ± 11	107 ± 5	3.12	<0.01
Exercise	149 ± 23	143 ± 17	1.68	>0.05
<i>Diastolic</i>				
Rest	57 ± 11	68 ± 6	4.63	<0.001
Exercise	58 ± 14	67 ± 17	2.57	<0.02
<i>Pulse</i>				
Rest	57 ± 16	39 ± 7	5.84	<0.001
Exercise	91 ± 28	76 ± 17	2.93	<0.01

± Followed by a number represents the standard deviation of the observations.

After exercise, the mean systolic readings are set at a higher level, but the difference between the means is not significant in contrast with the resting figures. The difference between the mean diastolic pressures is less than at rest. The mean pulse pressure is significantly higher in the cases than in the controls, but the difference is less obvious than that of the resting figures. There is no indication that exercise lowers the mean resting diastolic pressure in patent ductus; in fact, the figures suggest a rise rather than a fall.

A fall in diastolic pressure after exercise was twice as frequent in healthy subjects as in patients with patent ductus; the incidence of a stationary diastolic pressure was comparable in the two groups, but a rise in diastolic pressure was twice as common among patients as compared with controls (Table II). Of six cases of patent ductus showing a fall in diastolic pressure, in only two did this exceed the maximum fall noted in controls, namely, 10 mm. Hg, and in these two cases it was profound (Fig. 1).

In order to study further the behaviour of the diastolic pressure following exercise in health, 100 normal subjects of widely differing ages were examined (Table II). Of the 37 subjects who showed a fall in diastolic pressure, the majority gave values of 5 or 10 mm. In three instances,

FIG. 1.—Change in diastolic blood pressure after exercise. (A) In 26 cases of P.D.A. and 26 controls. (B) In 100 healthy subjects.

however, the fall in diastolic pressure exceeded 10 mm.; and in one of these it was profound (Fig. 1). In each of these three the exercise test was repeated and the same respective fall was recorded. When the change in diastolic pressure after exercise in cases of patent ductus (Fig. 1) is compared with that in 100 normal subjects, a fall in the diastolic pressure exceeding 10 mm. might appear to be relatively more common in cases of patent ductus. Statistically, however, there is no real difference between the behaviour of the two groups ($t=1.48$).

In this preoperative investigation, the exercise test offered little information of value in diagnosis, over and above that which was apparent from a study of the resting blood pressure readings in cases of patent ductus arteriosus, and statistical evidence that the test is of any real value is lacking.

OBSERVATIONS AFTER OPERATION

Touroff and Vessell (1940) state that a Bohn exercise test was carried out 26 days after surgical division of an infected ductus arteriosus in a patient with a continuous murmur that persisted after the operation. Failure of the diastolic pressure to fall after exercise by more than 2 mm. Hg indicated, in the authors' opinion, absence of an arterio-venous shunt. This report prompted an enquiry into the effect of exercise upon the diastolic pressure in the present series during convalescence from operation. It was possible to study 15 of the 26 cases in this way two weeks after surgical ligation of the ductus when the patients had been ambulant for at least a week. In no case were there murmurs suggesting recanalization of the ductus and subsequent follow-up has shown the operation to have been successful in every case. A standard exercise test, performed two weeks after the operation, caused the diastolic pressure to fall in 7 of the 15 cases studied, despite lack of supporting evidence of ductal recanalization (Table II).

In order to allow for any influence that the trauma of operation and post-operative immobilization might have had upon the blood pressure in the cases studied, a control group of 24 patients were examined at the end of the second week of convalescence from various major surgical operations. The resting blood pressure and the effect of exercise upon it were determined by methods already described. Among surgical controls a fall in diastolic pressure was unusual and in three-quarters of them the diastolic pressure was raised by exercise. Of the seven ductus cases in which the diastolic pressure was lowered by exercise, the fall exceeded 10 mm. in four (Fig. 2); in the other three a fall of 10 mm. or less lay within the range observed in surgical control cases and in 97 per cent of normal subjects (Fig. 1).

TABLE II
INFLUENCE OF EXERCISE UPON THE RESTING DIASTOLIC PRESSURE

Age group (years) Healthy subjects	No. of cases	Change in diastolic B.P.		
		Fall	Rise	No change
5-10	17	2	10	5
11-20	41	14	17	10
21-30	12	7	2	3
31-40	10	5	3	2
41-50	7	4	1	2
Over 50	13	5	3	5
Totals	100	37	36	27
26 cases of P.D.A. (before operation)		6	14	6
26 controls		12	7	7
15 cases of P.D.A. (after operation)		7	4	4
24 surgical controls		3	18	3

The difference between the means of the change in diastolic pressure after exercise in ductus cases after operation and in surgical controls is clearly significant. Furthermore, a fall in diastolic pressure exceeding 10 mm. occurred more frequently *after* ductal ligation in these 15 cases than it did in the 26 cases *before* operation when the ductus was patent. The difference in the behaviour of these two groups is regarded as real and unlikely to have been due to chance (Fig. 2). The remarkable fall in diastolic pressure after exercise that followed successful closure of the ductus appeared to be a phenomenon associated with the early post-operative period; for in eight patients in whom the exercise test was repeated many months after the operation, this tendency for the diastolic pressure to fall steeply in early convalescence had either disappeared completely, or else the fall was within the range common to health (Fig. 3).

FIG. 2.—Change in diastolic blood pressure after exercise in 15 cases of ductus arteriosus and in 24 controls, two weeks after operation.

FIG. 3.—The change in resting diastolic blood pressure following exercise in 8 cases of patent ductus—(a) before operation, (b) two weeks after ligation of the ductus, (c) two months or more after operation.

Characteristic changes in the blood pressure, before, during, and after the operation, with special reference to the effect of exercise upon the diastolic pressure before ligation and during convalescence, are shown in Fig. 4. In the case illustrated, the preoperative fall in diastolic pressure after exercise lay within the range observed in health; in early convalescence the fall was profound (25 mm.), and in late convalescence it was minimal. Although the fall in diastolic pressure in early convalescence was great, the diastolic reading immediately after exercise did not fall below the resting diastolic pressure before operation: exercise, in fact, appeared to have momentarily abolished the steep but temporary rise in diastolic pressure that invariably followed closure of the ductus in all our 26 patients. The other cases that showed a marked fall in diastolic pressure after exercise in early convalescence behaved in the same way.

FIG. 4.—Composite graph showing changes in blood pressure before, during, and after operation in patent ductus arteriosus.

SUMMARY AND CONCLUSIONS

Controlled observations of the effect of a standard exercise upon the resting blood pressure were made in 26 consecutive cases of uncomplicated patent ductus arteriosus before and after surgical ligation. The mean resting systolic pressure was significantly higher, and the mean diastolic pressure significantly lower in patients with patent ductus arteriosus than in control subjects of corresponding age and sex.

Exercise caused no significant change in the mean diastolic pressure either of ductus cases or controls. A fall in diastolic pressure after exercise was twice as common among controls as in cases of patent ductus. In only two cases of patent ductus did the fall in diastolic pressure exceed 10 mm. Hg. In a group of 100 healthy subjects a fall in diastolic pressure after exercise was recorded in 37 per cent; frequently the pressure fell by 10 mm., and occasionally the fall was profound.

The exercise test, as judged by a fall in the resting diastolic pressure, was suspected of being positive in only 2 out of the 26 cases of patent ductus, that is, in one-third of those in which a fall in diastolic pressure was recorded. Since a fall in diastolic pressure after exercise is common in health, although rarely greater than 10 mm., it is suggested that an exercise test, carried out in proved or suspected cases of patent ductus arteriosus, should be regarded as giving a positive response only when the diastolic pressure falls by 15 mm. or more.

In this investigation the exercise test offered little information of value in diagnosis, over and above that which was apparent from study of the resting blood-pressure readings of patients with patent ductus arteriosus, and statistical evidence that the test is of any real value is lacking.

Two weeks after successful ligation of the ductus arteriosus a fall in the diastolic pressure after exercise was observed in almost half the cases. This unexpected finding, which appeared to be transitory and was found only in the early period after operation, differed significantly from the changes observed in a control group of cases in which the diastolic pressure was raised or remained stationary in 90 per cent. A fall in the diastolic pressure after exercise was significantly commoner and more profound when the ductus was closed, than it was before operation.

No satisfactory explanation for the behaviour of the diastolic pressure after exercise during convalescence from operation is apparent, but the phenomena observed permit the following inference, namely: that a sharp fall in the diastolic pressure after exercise, which follows closely on the operation, is no criterion that the ductus has recanalized.

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