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Effects of Aortocoronary Bypass Surgery on Myocardial Blood Flow

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ABSTRACT. The effects on myocardial blood flow of aortocoronary bypass surgery for twenty patients with ischemic heart disease and the influence of hand grip exercise were studied using ^{201}Tl myocardial scintigraphy.

1. The ratio of preoperative myocardial blood flow to cardiac output was 4.41% in the group of patients with angina pectoris and 4.33% in the group with a history of myocardial infarction. No significant increase was noted following the aortocoronary bypass surgery in both groups. After preoperative exercise loading, a significant increase in the ratio from 4.33% to 6.47% was noted only in the group with a history of myocardial infarction ($p<0.05$).
2. The cardiac output did not increase in either group in response to preoperative exercise, however significant increase of that was seen on exercise after the operation in both groups.
3. There was no significant increase in myocardial blood flow following the operation. After the postoperative exercise, however, a significant increase was obtained, from 253 ml to 357 ml in the group with angina pectoris and from 199 ml to 334 ml in the group with a history of myocardial infarction.

Aortocoronary bypass operations for angina pectoris have been widely performed with a marked improvement of clinical symptoms and an increasing ability. These improvements have been objectively demonstrated by improvement in exercise loading tests, improvement of cardiac function, confirmation of bypass patency by angiography and improvement of distribution of local myocardial blood flow shown by ^{201}Tl-chloride myocardial scintigraphy. The purpose of this study was to assess the effects on myocardial blood flow of the operation and changes in myocardial blood flow with exercise loading using ^{201}Tl myocardial scintigraphy.

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MATERIALS AND METHODS

Twenty patients with ischemic heart disease treated with A–C bypass operation were studied. They were divided into 3 groups ; group I, 10 patients with angina pectoris without a history of myocardial infarction, group II, 8 patients with angina pectoris with a history of myocardial infarction and group III, 2 patients with perioperative myocardial infarction and graft occlusion.

In all patients, patency of the graft was confirmed by postoperative angiography. 1.6 bypass grafts on an average were performed in group I and 2.1 bypass grafts in group II. No significant age difference was noted between the two groups.

Cardiac output was measured before and 1–2 months after surgery using an impedance cardiography. Then 2 mC of ^{201}Tl was injected as a bolus into the cubital vein. The initial process of its passage through the heart and lung followed by the whole body uptake was recorded as the frontal view in a sitting position for 3 minutes using a scintillation camera equipped with a parallel collimeter (15,000 holes) for recording in VTR. Then, using the method reported by Ishii et al.[1)], the ratio of myocardial blood flow to cardiac output (MBF/CO) was calculated by the following equation.

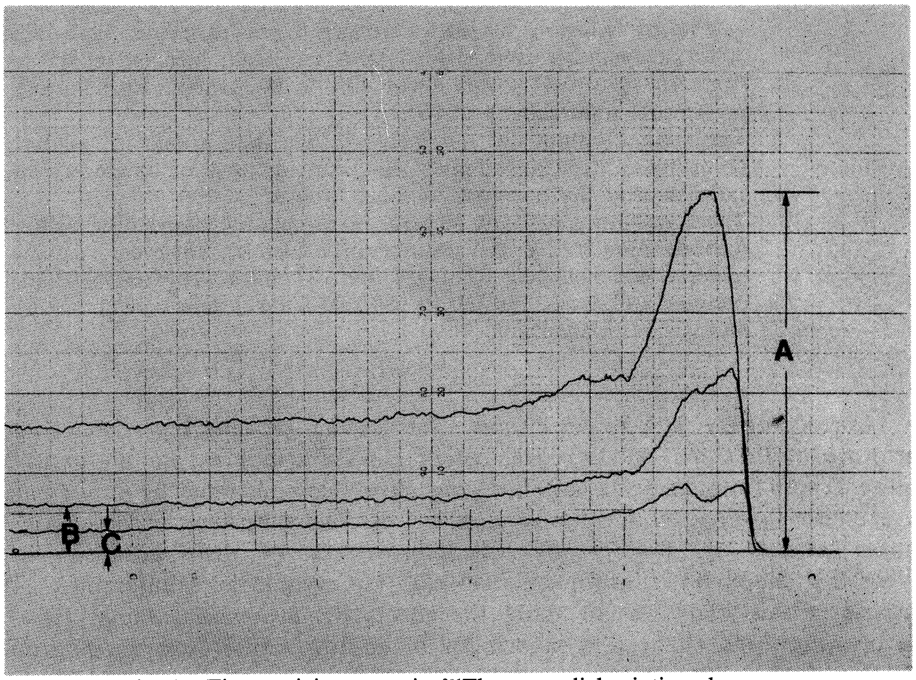

Fig. 1. Time–activity curve in ^{201}Tl myocardial scintigraphy
A : total injected dose
B : myocardial uptake
C : back ground uptake

$$MBF/CO \doteqdot \frac{B-C}{A} = \frac{\text{myocardial uptake} - \text{background uptake}}{\text{total injection dose}}$$

Where A is an activity measured on passage through the heart and lung immediately after injection, B represents a myocardial ^{201}Tl uptake obtained by setting a region of interest and C represents a background to be subtracted. Myocardial blood flow was calculated by multiplying the cardiac output with MBF/CO. The time-activity curve (Fig. 1) was then represented and the process of ^{201}Tl bolus injection was confirmed as adequate.

One week later, ^{201}Tl was injected after 3 minutes of hand grip exercise at 40% of maximum hand grip force. The MBF/CO, CO and MBF during exercise were calculated similarly as above mentioned.

RESULTS

1. Changes of MBF/CO, CO and MBF following the operation. (Fig. 2,3,4)

MBF/CO in group I averaged 4.41% preoperatively and increased to 4.93% postoperatively. CO increased from 4.43 l/min to 5.16 l/min, MBF from 200 ml/min to 250 ml/min. In group II, MBF/CO rose from 4.33% preoperatively to 5.13% postoperatively, CO from 3.75 l/min to 3.89 l/min and MBF from 164 ml/min to 199 ml/min. However there was no significant difference in the changes of these value following the operation.

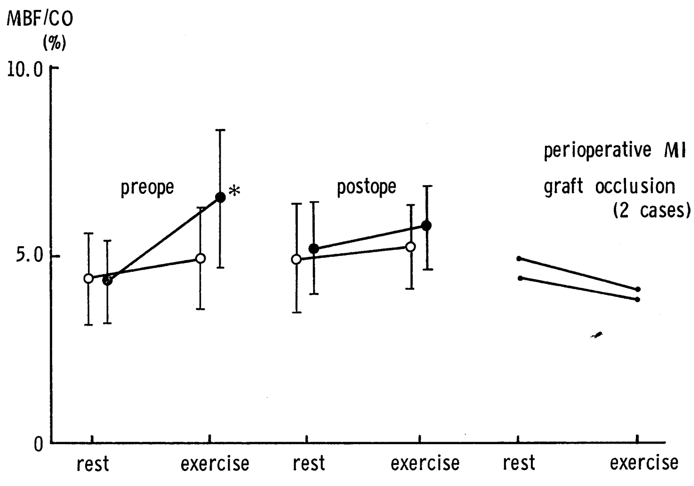

Fig. 2. Myocardial blood flow/cardiac output at rest and exercise before and after the operation
○—○ : group without MI ●—● : group with MI * : $P<0.05$

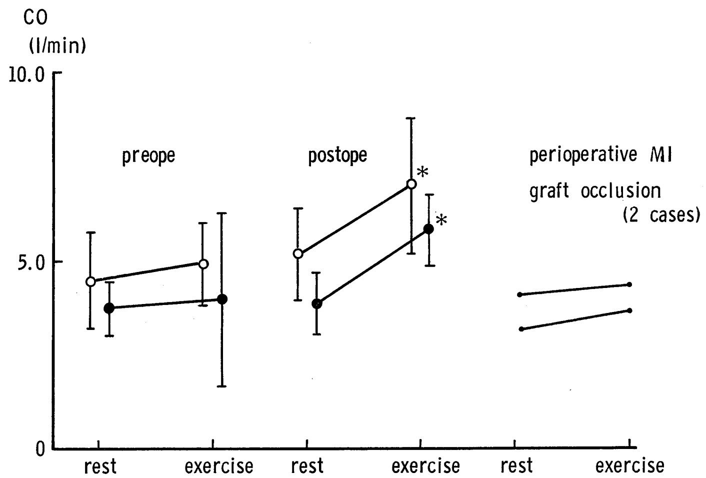

Fig. 3. Cardiac output at rest and exercise before and after the operation
○—○ : group without MI ●—● : group with MI * : $P<0.05$

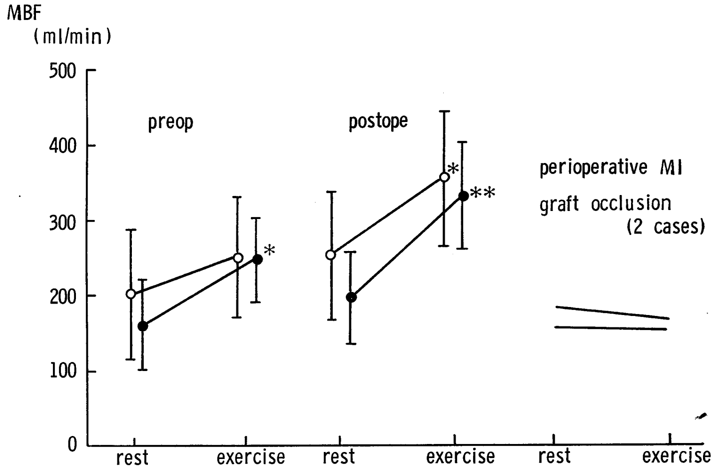

Fig. 4. Myocardial blood flow at rest and exercise before and after the operation
○—○ : group without MI ●—● : group with MI * : $P<0.05$ ** : $P<0.01$

2. Comparison between the group with angina pectoris and that with a history of myocardial infarction.

MBF/CO showed no difference between these two groups pre- or post-operatively. CO was low in group II preoperatively without a significant postoperative increase, but in gorup I, it increased postoperatively, so that a significant difference was found in the postoperative CO between these two

groups ($p<0.05$). MBF showed a difference between these two groups of 36 ml preoperatively and 54 ml postoperatively, without a significant difference.
3. Changes in response to hand grip exercise.

In response to hand grip exercise at 40% of maximum hand grip force, blood pressure rose from 140 ± 16 mmHg to 185 ± 24 mmHg, and the pulse rate from 58 ± 8 to 76 ± 16 before the operation. After the operation, blood pressure rose from 131 ± 18 to 174 ± 21 mmHg and pulse rate from 68 ± 14 to 86 ± 13.

MBF/CO rose in response to exercise loading both pre- and postoperatively, but no significant difference was found except in group II before the operation. The increase of MBF/CO during exercise was greater in group II than that in group I. Especially before the operation, it rose from 4.33% to 6.47%, a 49% increase during exercise ($p<0.05$).

CO showed no significant increase after exercise in either group, preoperatively. After the operation, however, marked increase in CO was noted in response to exercise, 36% in group I ($p<0.05$) and 51% in group II ($p<0.01$).

MBF was increased in response to exercise in both groups, before and after the operation. In group I, it increased from 200 ml/min to 250 ml/min preoperatively (without a significant difference) and from 253 ml/min to 357 ml/min postoperatively following exercise (41%) ($p<0.05$). In group II, MBF increased from 164 to 247 ml/min, 51% preoperatively ($p<0.05$), and from 199 to 334 ml/min, 68% postoperatively following exercise ($p<0.01$).
4. Cases with graft occlusion and development of myocardial infarction.

In 2 patients with occlusion of the graft and new myocardial infarction, the findings were unlike those in patients with a history of myocardial infarction. Postoperatively, MBF/CO was decreased and CO did not increase in response to exercise. Consequently MBF was decreased after the operation and did not increased following exercise.

DISCUSSION

A-C bypass surgery has been performed widely for ischemic heart disease, and in many cases, a marked clinical improvement was obtained. However, postoperative clinical improvement was also seen in a considerable number of patients with graft occlusion. Apparent effects based on the development of perioperative infarction or the placebo effect of surgery, often do not adequately reflect the clinical findings[2,3].

The effects of A-C bypass surgery have been evaluated functionally as an increase of exercise ability and improvement of cardiac function and morphologically through the confirmation of graft patency and improved local myocardial blood flow[4,5,6,7,8]. The blood flow through the graft measured during the operation does not indicate an increase of myocardial blood flow after the operation. The amount of increase of myocardial blood flow following A-C bypass surgery and the influence of postoperative exercise loading on myocardial blood flow have scarcely been studied, despite their vital importance.

Bing et al.[9] measured coronary blood flow using nitrous oxide gas inhalation in normal subjects. This method has been used clinically as the most reliable method. This method, however, has a disadvantage to sample coronary venous blood over a long period of time, and to be invasive for the patient. Knobel et al.[10] noninvasively measured coronary blood flow using ^{84}Rb clearance method as an extracorporeal measurement. Ishii et al.[1] used a method expressing myocardial blood flow as a proportion of cardiac output employing ^{201}Tl myocardial scintigraphy. The value in normal subjects was reported to be 4.0±0.5% and that in the patients with ischemic heart disease 4.0±0.8%. Knobel et al.[10] reported satisfactory agreement with the value simultaneously obtained by Fick method, 269±61 ml in normal subjects, with a cardiac output ratio of 5.2±1.6%. According to many reports, normal coronary blood flow is 200–350 ml/min, and the ratio to cardiac output is approximately 5%.

In this study, hand grip exercise was performed to determine the effect on myocardial blood flow of A–C bypass surgery during exercise.

Both before and after the operation, the ratio of myocardial blood flow to cardiac output was found to be similar in the group with angina pectoris and that with a history of myocardial infarction. The increase of the ratio during exercise was greater in the group with myocardial infarction, especially before the operation than that after the operation. Preoperative cardiac output, on the other hand, showed low value in the group with myocardial infarction, and failed to increase in response to loading. This finding would indicate that an increase in myocardial blood flow in this group during exercise is dependent on an increase of the ratio of myocardial blood flow to cardiac output before the operation, and an increase of cardiac output due to the improvement of left ventricular function would play a major role in the increased myocardial blood flow during exercise after the operation.

The effect of A–C bypass surgery on myocardial blood flow was slight at rest, but a marked effect was demonstrated on exercise loading.

In normal subjects, the coronary blood flow increases markedly during exercise. Gregg[11] et al. showed experimentally a marked increase of coronary blood flow during exercise with treadmill in a non-anesthetized dog. Following mild or moderate exercise loading, the coronary blood flow increased in proportion to the cardiac rate, and the ratio to the cardiac output remained unchanged. With extreme exercise, on the other hand, the coronary blood flow per heart beat markedly increased and psychological excitation causes also similar changes in coronary circulation to those during extreme exercise. Various types of complex factors are considered to be concerned in the mechanism of coronary circulation during exercise.

According to Rowe et al.[12], coronary blood flow, in normals and in patients with ischemic heart disease, was similar at rest, therefore not reliable as an indicator of severity in ischemic heart disease. In our subjects, no relationship was found between the number of diseased coronary vessels or the number of bypass grafts and myocardial blood flow at rest.

CONCLUSION

In the patients with A–C bypass surgery for ischemic heart disease, the ratio of myocardial blood flow to cardiac output and myocardial blood flow were calculated using ^{201}Tl myocardial scintigraphy, to evaluate the effect of A–C bypass surgery both pre- and postoperatively and with exercise loading.

Pre- and postoperative myocardial blood flow showed no difference between the group with angina pectoris and that with prior myocardial infarction. No significant increase was noted in both groups postoperatively. With postoperative exercise loading, however, a marked increase in myocardial blood flow was noted in both groups. The efficacy of A–C bypass surgery on myocardial blood flow was demonstrated only on exercise.

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