Studies on Chronic Cor Pulmonale with Special Reference to Coronary Circulation

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ACCORDING to the report of an Expert Committee of World Health Organization in 1961,¹⁾ chronic cor pulmonale is defined as hypertrophy of the right ventricle resulting from diseases affecting the function and/or the structure of the lung, except when these pulmonary alternations are the result of diseases that primarily affect the left side of the heart or of congenital heart disease. Therefore, increase in pulmonary vascular resistance and pulmonary arterial hypertension arising from the structural change or dysfunction of the lung are naturally considered to play the most important role in the development of cor pulmonale. However, little is known about the status of the left ventricle in cor pulmonale.

The author performed the following experiments in order to study the coronary circulation and the left ventricular function in chronic cor pulmonale.

MATERIAL AND METHOD

The patients with chronic pulmonary diseases were employed in this study, including the cases of cor pulmonale. Coronary and pulmonary circulation were examined simultaneously by performing coronary sinus and right cardiac catheterization. Coronary blood flow was measured by N₂O method.²⁾ Calculation of left ventricular residual volume was made as follows. Dye concentration curve was obtained by injecting T-1824 (Evans blue) dye or Coomassie blue dye into pulmonary artery or left auricle (when transseptal catheterization was performed) and sampling it from brachial artery. Left ventricular residual blood volume was calculated from the dye concentration curve according to the following formula (Table I).

RESULTS

(1) Data on pulmonary and coronary circulation

The patients were divided into 2 groups. Group I consisted of the cases with the mean pulmonary arterial pressure 15 mm.Hg or less. Group II consisted of the cases with the mean pulmonary arterial pressure 16 mm.Hg or more, including the cases of cor pulmonale. One case in Group II was in congestive heart failure at the time of examination.

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Table I

$$V_D = V_R + V_E$$

$$n = Rt$$

$$C_2 = C_1 \left(\frac{V_R}{V_D} \right)^n$$

$$C_2 = C_1 \left(\frac{V_R}{V_R + V_E} \right)^{Rt}$$

$$\ln C_2 - \ln C_1 = Rt \ln \left(\frac{V_R}{V_R + V_E} \right)$$

$$\lambda = \frac{\ln C_2 - \ln C_1}{t}$$

$$\lambda = Rt \ln \left(\frac{V_R}{V_R + V_E} \right)$$

where

V_D : end-diastolic volume of left ventricle

V_R : end-systolic volume (residual blood volume) of left ventricle

V_E : stroke volume of left ventricle

n : heart rates during $t_1 \sim t_2$

R : heart rate per min.

t : time from t_1 to t_2

C_1 : dye concentration at the time t_1

C_2 : dye concentration at the time t_2

λ : downslope of dye dilution curve

Data on pulmonary circulation are shown in Fig. 1.

Mean pulmonary arterial pressure was markedly elevated in the cases of cor pulmonale. The elevation of right ventricular end-diastolic pressure or pulmonary capillary pressure was found in some cases of Group II. These two pressures were markedly elevated in the cases with congestive heart failure (shown with arrow in the Fig.). The decrease in arterial O_2 saturation and the

Fig. 1. Pulmonary circulation.

Fig. 2. Arterial blood gases.

increase in arterial CO_2 tension were seen only in Group II, especially in the cases of cor pulmonale, as shown in Fig. 2.

(2) Data on coronary circulation

Any significant difference was not found between 2 groups in coronary blood flow, ratio of coronary blood flow to cardiac output, myocardial O_2 consumption and coronary arterio-venous O_2 difference (ΔO_2). Myocardial O_2 extraction coefficient increased in many cases of Group II, especially in most cases of cor pulmonale.

Coronary venous O_2 tension decreased also in many cases of Group II, especially in most cases of cor pulmonale (Fig. 3 and Fig. 4).

Fig. 5 represents the relation between coronary arterio-venous O_2 difference and coronary arterial O_2 content.

Many cases of Group II, especially the most cases with cor pulmonale, belonged to the cases with relatively increased coronary arterio-venous O_2 difference in relation to coronary arterial O_2 content, namely the cases plotted

Fig. 3. Coronary circulation.

Fig. 4. Coronary circulation.

Fig. 5. Arterial O_2 content and coronary arterio-venous O_2 difference.

above the oblique line in Fig. 5. In other words, coronary arterio-venous O_2 difference as against the same level of the arterial O_2 content was greater in Group II, especially in cases of cor pulmonale, than in Group I.

The responses to the exercise test in normal subject and a patient in congestive heart failure with cor pulmonale are shown in Fig. 6. In normal subject, mean pulmonary arterial pressure and arterial O_2 saturation did not change on exercise.

Coronary blood flow and myocardial O_2 consumption increased, and coronary venous O_2 tension was almost unchanged. "Excess lactate" and "redox potential" of myocardium were also unchanged. However, in the patient with cor pulmonale, mean pulmonary arterial pressure, already high at rest, rose further and arterial O_2 saturation decreased on exercise. Cardiac output increased, but coronary blood flow and myocardial O_2 consumption decreased. Coronary venous O_2 tension also decreased markedly.

Fig. 6. Exercise test.

Fig. 7. Left ventricular residual blood volume.

Fig. 8. Left ventricular residual ratio (RV/EDV).

“Excess lactate” changed from negative to positive and “redox potential” from positive to negative.

(3) Data on left ventricular residual blood volume

The left ventricular residual blood volume tended to increase in the patients with chronic pulmonary disease, cor pulmonale and coronary sclerosis as compared with that in normal subject.

Left ventricular residual ratio, the ratio of left ventricular residual blood volume to end-diastolic volume, also increased in these patients as compared with that in normal subject (Fig. 7 and Fig. 8).

DISCUSSION

Coronary venous O_2 tension and myocardial O_2 extraction coefficient are generally considered to reflect the O_2 level of the left ventricular myocardium as a whole. And decrease in the coronary venous O_2 tension and increase in myocardial O_2 extraction coefficient are considered to indicate myocardial hypoxia in the left ventricle. “Excess lactate” and “redox potential” are also considered to be dependent on the O_2 level of the myocardium. Positive “excess lactate” and negative “redox potential” are considered to reflect localized myocardial hypoxia.

On pulmonary circulation, hypoxemia and hypercapnia are found in the cases of pulmonary hypertension, especially markedly in the cases of cor pulmonale.

On coronary circulation, decrease in coronary venous O_2 tension and increase in myocardial O_2 extraction coefficient, which would indicate O_2 lack in left ventricular myocardium, are found in the most cases of cor pulmonale. However, arterial O_2 saturation also decreased in the cases of cor pulmonale. It is possible that decrease in coronary venous O_2 tension in the cases of cor pulmonale is only due to decrease in coronary arterial O_2 content and does not necessarily indicate myocardial hypoxia in the left ventricle.

Therefore, the relation between coronary arterial O_2 content and coronary arterio-venous O_2 difference was examined. As shown in Fig. 5, coronary arterio-venous O_2 difference as against the same level of the coronary arterial O_2 content tended to be greater in the cases with pulmonary hypertension, especially in the most cases of cor pulmonale, than in the cases without pulmonary hypertension. Consequently, decrease in coronary venous O_2 tension in the cases of cor pulmonale cannot be attributed only to decrease in coronary arterial O_2 content, but it indicates the existence of myocardial hypoxia in the left ventricle.

In the patient with cor pulmonale and congestive heart failure, coronary

blood flow did not increase and coronary venous O_2 tension decreased markedly on exercise. "Excess lactate" and "redox potential" became positive and negative, respectively. These results strongly suggest that myocardial hypoxia in the left ventricle was developed because of the disturbance of coronary circulation during exercise. Left ventricular residual blood volume and left ventricular residual ratio were generally greater in the cases with chronic pulmonary disease than in normal subjects, which was marked in the cases of cor pulmonale. From the foregoing results, it seems justified to say that the cases of cor pulmonale are in the latent phase of left heart failure.

SUMMARY

(1) Myocardial hypoxia in the left ventricle exists at rest in the most cases of cor pulmonale, which is not due to decrease in arterial O_2 saturation.

(2) In some cases of cor pulmonale, myocardial hypoxia in the left ventricle develop because of the disturbance of coronary circulation during exercise.

(3) Residual blood volume and residual ratio of left ventricle tended to increase in cases of cor pulmonale.

(4) From the foregoing facts, it can be said that the case of cor pulmonale is in the latent phase of left heart failure.

REFERENCES

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