Collateral Circulation of the Lung

a. Fundamental and morphological studies

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I. Introduction

The circulatory system in the lung consists of the pulmonary and bronchial, which participates in gas exchange and in nourishment of the tissue, respectively. The pulmonary artery has been considered to be “Endarterie”, which has no collateral vessels. In pathologic conditions of the lung, however, there exists anastomosis between the pulmonary and bronchial circulatory systems. It is an important problem to study the development of this collateral vessels in diseases of the heart and lung, to elucidate the pathologic physiology in those patients.¹

The present author reports on the relationship between these two circulatory systems, with special reference to the morphological observations.

II. Broncho-pulmonary Circulatory Pathway in Normal Lung

Broncho-pulmonary circulatory pathway in normal human lung is summarized schematically in Fig. 1. It has already been known that the pulmonary veins collect blood from branches of the intrapulmonary bronchial veins, and the azygos and semi-azygos vein collect blood from branches of the extrapulmonary veins only in the region close to the hila, and that there is a venous communication between the extrapulmonary bronchial veins and the pulmonary veins. The presence of anastomoses between the bronchial and the pulmonary arteries through the channel of “Sperrarterie” described by Hayek² has been questioned. To our knowledge, the “Sperrarterie” is a branch of the bronchial artery, while according
to Hayek it is a branch of the pulmonary artery. The term "Bronchialsperrarterie", therefore, would be more appropriate. The "Bronchialsperrarterie" connects the bronchial arteries with the pulmonary arteries exclusively in the small bronchial walls and in the parts close to the pleura. Fig. 2 shows an autopsied normal lung having an anastomosis between the bronchial and the pulmonary artery, visualized by contrast medium injected into the pulmonary artery. The anastomosis of the "Bronchialsperrarterie" with the pulmonary artery was also traced by means of serial

Fig. 2. In adult normal lung (31 years old woman), arterial anastomosis between the bronchial and the pulmonary artery was visualized by contrast medium filled into pulmonary artery.

P. A.—pulmonary artery
B. A.—bronchial artery
A. —anastomosis
sections. The morphological study revealed the presence of this type of anastomosis even in the normal lung. It has not been clarified, however, whether the anastomotic vessels have the same functional character as glomus in the peripheral parts of the extremities.

III. Broncho-pulmonary Collateral Circulation in Various Cardiopulmonary Diseases

The close relationship between the bronchial and pulmonary circulation is observed in the following cases with various cardiopulmonary diseases:

1) in the cases with stenosis or obstruction of the pulmonary artery,
2) in the cases with elevation of the left atrial pressure, and 3) in the cases with abnormal circulatory disturbances due to inflammatory irritants.

1) Cases with stenosis or obstruction of the pulmonary artery—arterial collateral circulation.

Fallot's tetralogy and pulmonary embolism etc. belong to this group. In a autopsied case of Fallot's tetralogy, 20 years old man, remarkable enlargement of the bronchial arteries was found and their diameter was several times as large as the normal one. Histologically, transition of the branches of the bronchial arteries into the pulmonary capillary beds was observed and the arterial anastomoses between the bronchial and pulmonary arteries were revealed. Following ligation of the pulmonary artery, similar change can be experimentally observed in the lung of dogs. The bronchial arteries extremely develop with the lapse of time after unilateral ligation of the pulmonary artery, and an abundant arterial network is formed in both the intra- and extra-pulmonary courses. Three months after the ligation, development of the pre-capillary anastomoses between the bronchial and pulmonary arteries was already demonstrated by the cast. Additionally, the abundant anastomoses extending from the bronchial, intercostal and pulmonary arteries are formed in the pleural adhesions due to operation. In experimental pulmonary embolism in dogs, likewise, development of the bronchial arteries became remarkable with the lapse of time. Although in 3 days subsequent to the embolism the alteration of
the bronchial artery was negligible, in one week a slight proliferation was observed. In 3 weeks its dilatation became evident and in 3 months the strikingly dilated and tortuous bronchial arteries were demonstrated.

The influence of the aging factor on the development of the bronchial collateral pathway following the obstruction of the pulmonary artery was great. One month after the ligation of one lobar-artery in experimental dogs of 2-3 months and 5-10 years old, the development of collateral pathway in younger dog was greater than that in the other. However, the size of the obstructed artery may be regarded as the most important factor in development of the bronchial collateral circulation in the cases with obstruction of pulmonary artery. Bronchial collateral circulation hardly develops, when only small pulmonary artery is obstructed, e.g., in the cases with disseminated simple silicosis, miliary carcinoma, and so on. This must be emphasized because this may offer an important key to resolve the mechanism of development of the bronchial collateral circulation. The author would like to discuss on this problem in the chapter IV.

2) Cases with elevated left atrial pressure—venous collateral circulation.

The anastomoses between the extrapulmonary bronchial veins and the pulmonary veins develop in mitral stenosis with the elevation of the left atrial pressure. Prevented from returning to the left auricle owing to high left atrial pressure, the blood of the pulmonary veins takes a route to the direction of the extrapulmonary bronchial veins. Histologically, extensive developments and dilatations of the bronchial veins in the wall of the hilar bronchi were observed. A similar change was experimentally demonstrated by ligation of the pulmonary vein in dogs. With the lapse of time after ligation of one or two lobes of the lung, the bronchial veins in the hilar portion, becoming extensively dilated and tortuous, pour into the azygos vein, while they form numerous anastomoses with the pulmonary veins. The mediastinal veins such as the pericardiacophrenic veins etc. which greatly developed, furthermore, form a communication with the network of the bronchial veins in the hilar portion, and also frequently anastomose with the lobar and
segmental pulmonary veins. In the pleural adhesion due to operation a large number of the proliferated blood vessels are present as a collateral pathway. Accordingly, it is easily recognized that the pulmonary venous blood, being prevented from flowing into the left side of the heart, pours into the systemic vein through the collateral vessels as described above. It is, accordingly, likely that such a mechanism plays an important rôle as a pressure-lowering factor against an elevation in the pulmonary venous pressure or in the left atrial pressure. On the other hand, this collateral circulation is to be appreciated as arterial admixture to systemic circulation.

3) Cases with the circulatory disturbances due to inflammatory irritants.

Strictly speaking, vascular change in the inflammatory lesion could not be discussed in the relation with collateral circulation. This change may be very interesting to study from the view-point of broncho-pulmonary circulation. In the case of pulmonary tuberculosis, the bronchial arteries are enlarged and tortuous in the hilum. Especially in the affected lungs these developments are most remarkable, though the pulmonary artery shows a decrease in blood supply with its displacement and obliteration in these lesions. The anastomoses between the bronchial and pulmonary arteries develop near the affected lungs. In the case of bronchiectasis, the proliferation and development of the bronchial arteries and the anastomoses between the bronchial and the pulmonary arteries, as Liebow et al. indicated, are the most conspicuous among various chronic pulmonary diseases. The recurrence of chronic bronchial infection and the younger age may be the main factors to develop bronchial circulation. In the silicotic lesions showing massive formation, the developments of the bronchial arteries take place in company with the development of inflammatory process in the massive formation and the drainage bronchi to the mass.

In chronic pulmonary diseases we frequently find pleural adhesions, in which the systemic arterial blood through the intercostal and mediastinal arteries and so on runs into the lungs.

In order to study the bronchial vascular changes in the inflammatory lesion, experimental inflammation in the air way was pre-
pared in the dog. In the hemorrhagic stage, the stoppage of the blood flow is rather observed than the development of the bronchial artery. In the purulent stage, the tendency of development of the bronchial artery was noted and then in the proliferative stage, the enlargement of the bronchial artery was found together with the development of granulation tissue.

It seems important that the well-oxygenated bronchial artery blood is supplied to the inflammatory lesions, where arrest of pulmonary blood flow and resultant local anoxia may be induced. Thus, the bronchial artery blood possibly serves not only for arresting the development of intermediate metabolic products of the inflammatory lesions, but also for supplying energy for the tissue reaction in the lesions.

Other pulmonary diseases:
The cases with primary lung cancer and those with chronic pulmonary emphysema were also studied. In primary lung cancer, the destruction of the pulmonary artery and the development of bronchial artery in tumour mass were observed. In chronic pulmonary emphysema, the bronchial artery in the small bronchi was on the process to occlusion, and enormous muscular hypertrophy appeared. Cudkowicz⁴) thinks that this occlusion of the bronchial artery may be an etiological factor of pulmonary emphysema, while the author regards this occlusion as the secondary finding of emphysematous change.

IV. Observations Concerning Mechanism of Development of Bronchial Collateral Circulation

In general, development of collateral circulation is affected by several factors such as anoxia, pressure difference, general condition and so on. However, the author would like to discuss on the mechanism of development of the bronchial collateral circulation from the standpoint of the speciality of vascular system.

That is to say, the most important factor to affect the mechanism of the development of the bronchial collateral circulation in the case of occlusion of the pulmonary artery is the capacity of the compensation of pulmonary circulation.
As described above, pulmonary artery is "Endarterie" and the pulmonary capillary bed around the alveolar wall are closely connected each other and compensated some or less for the pathological condition of pulmonary circulation. Cast of the pulmonary capillary bed in human being is shown in Fig. 3, which shows that the pulmonary capillary bed belonging to the two arterioles are connected each other (plastic cast).

Fig. 3. Pulmonary capillary bed belonging to the two arterioles are connected each other (plastic cast).

Therefore, the bronchial collateral circulation may not be developed as long as the compensatory capacity is enough to compensate this condition. Limit of area to compensate this condition is considered to be the lobule. Although the border of the lobule is not clearly lined frequently in adult, it is clearly bordered from the standpoint of the vascular system of the pulmonary circulation. That is, the serial angiography of the pulmonary arteriole revealed that medium was filled in the pulmonary capillary bed in lobule through the pulmonary arteriole and then transferred to the venule around the lobular margin and returned to the pulmonary vein as shown in Fig. 4. The simultaneous angiography of the two pulmonary arterioles revealed the interlobular vein in each lobule and clearly divided two lobules. Consequently, the obstruction of the arteries which is larger than the lobular artery is considered to be necessary in order to develop the bronchial collateral circulation because the pulmonary circulation is not compensated in the case of obstruc-
Fig. 4. Contrast medium are filled in the pulmonary capillary bed in lobule through the pulmonary arteriole and then transferred to the venule around the lobular margin.

C.—catheter
V.—pulmonary vein
Vv.—venule

V. Summary

Broncho-pulmonary circulation was studied on the cast, angiographically and histologically from the morphological point of view, and summarized as follows. It was shown that the bronchial and pulmonary arterial anastomosis by “Bronchialsperrarterie” was
found on the small bronchial wall and pleura in the normal lung. The conditions of the broncho-pulmonary circulation in the patients with various cardio-pulmonary diseases were discussed in the following three cases: 1) cases with stenosis or occlusion of the pulmonary artery, 2) cases with elevation of left atrial pressure, and 3) cases with inflammation. It was shown that a close relation was found between development of the bronchial collateral circulation and capacity of compensation in pulmonary circulation, particularly in the cases with obstruction of the pulmonary artery and it was stressed that the obstruction of the artery at least larger than lobular artery is necessary for the development of the bronchial collateral circulation. It was also discussed on the change of bronchial circulation following the inflammatory process in the experimental study of pulmonary infection.

References