CHANGES IN THE LUNG WITH AN ASEPTIC OR INFECTED INFLAMMATORY FOCUS FOLLOWING LIGATION OF THE PULMONARY ARTERY

N. V. Boikova

Department of Pathological Anatomy (Head, Professor M. A. Zakhar'evskaya),
Academician I. P. Pavlov First Leningrad Medical Institute
(Presented by Academician N. N. Anichkov)
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As a result of advances in thoracic surgery, operative treatment of diseases of the lungs is being adopted on an increasing scale. In cases where the lung cannot be removed, the operation is terminated by ligation of the pulmonary artery. Since they often feel much improved, such patients frequently refuse to undergo the second stage of the operation, so that ligation of the pulmonary artery itself becomes a therapeutic procedure. Many writers [2, 3, 4, 6, 8, 12-15, 20, 21] favor this operation, but others [1, 7, 10, 11] state that after ligation of the pulmonary artery the disease progresses.

Experimental investigations [9, 22, 23, 24, 26] have demonstrated the development of pneumosclerosis, the genesis of which is still obscure. In addition to pneumosclerosis, the development of bronchiectasis has been observed [16-19], and this has led to discouragement of the use of the operation in bronchiectasis.

Our experiments on rabbits [5] have shown that after ligation of the pulmonary artery diffuse or focal anemic infarcts develop, followed by organization of the necrotic masses and the development of focal or diffuse pneumosclerosis. Bronchiectasis developed in individual cases only after secondary infection of the necrotic masses.

Our object was to study the changes in the inflammatory focus in the lung after ligation of the pulmonary artery. For this purpose we chose a focus caused by an aseptic, nonbronchogenic method, and subsequently infected.

EXPERIMENTAL METHOD

Experiments were carried out on 17 rabbits of both sexes weighing from 1.5 to 2.5 kg. In the first series of experiments, in aseptic conditions a needle was introduced into the thorax of ten rabbits and through it from 0.3 to 0.5 ml of "turpentine oil" (turpentine and sunflower oil, thoroughly mixed in a proportion of 1 : 1) was injected into the lung; transpleural ligation of the pulmonary artery was carried out after 49-55 days. In the second series, in eight rabbits, on the 21st-23rd day after the injection of the "turpentine oil" a foreign body (a sterile silk thread) was introduced into the trachea, and the pulmonary artery was ligated 27-35 days after the second operation. The rabbits of the first series were sacrificed by air embolism on the 7th, 16th, 27th, 39th, 72nd, 93rd, 131st, 197th, and 256th days after ligation of the pulmonary artery, and one rabbit died on the 128th day. In the second series, five rabbits died on the 2nd, 7th, 140th, and 206th days, and three were sacrificed by air embolism on the 33rd, 129th, and 237th days after ligation of the artery.

The lungs were fixed in 10% formalin solution in situ, after preliminary ligation of the trachea (before thoracotomy). Total sections of each lobe of both lungs were made, embedded in paraffin-celloidin, and stained with hematoxylin-eosin or by van Gieson's method, with counterstaining for elastic tissue by Hart's method or the Gram–Weigert method.

EXPERIMENTAL RESULTS

First series. The right lung was free from adhesions and inflated with air, and in two rabbits a focal pneumomia was present (16th, 27th days). The pleural cavity on the side of ligation contained multiple adhesions between the left lung and the parietal pleura and between the two lobes; the lung was reduced in size, and part of the pleural cavity was occupied by a projection of the intercostal fatty areolar tissue covered with parietal pleura. Microscopic

examination in every case revealed focal changes in the lung tissue at the site of injection of the "turpentine oil." On the 7th, 16th, 17th, 93rd, and 256th days after ligation of the pulmonary artery, an encapsulated oleogranuloma was found, and on the 39th day a cavity, the connective-tissue wall of which was lined with cylindrical epithelium; within the lumen of the cavity an area of necrotic lung tissue lay freely.

When we compared the state of the focus at intervals after the day of ligation of the pulmonary artery, we found no differences caused by ligation, but such changes were found in the area surrounding the focus. For instance, in the surrounding lung tissue on the 7th day after ligation an anemic infarct was present, with slight proliferation of connective tissue around it. On the 16th day proliferation of connective tissue was found around the infarct, which in some places was anemic, and in others hemorrhagic in character (Fig. 1). On the 27th day these areas of proliferation occupied almost the entire lung, and the anemic infarct persisted in the form of small foci. Among the proliferating connective tissue were bands and tubes of cylindrical and cubical epithelium, and also fragments and concentric figures of thickened elastic fibers. On the 93rd day the whole lung contained diffuse, and on the 39th and 256th days—circumscribed zones of proliferating connective tissue. In three rabbits, on the 72nd, 128th, and 197th days encapsulation of the focus was accompanied by the formation of a wide leukocyte barrier around the necrotic area of the lung, in which the structure of the alveoli and the homogeneous yellow mass of "turpentine oil" could still be distinguished. On the outside of the leukocyte barrier there were masses of proliferating connective tissue, separated from it in places by a lining of cylindrical and cubical epithelium. In areas where no epithelial lining was present, groups of leukocytes in the form of abscesses were present in the connective tissue. When stained by Gram's method, Gram-positive cocci could be seen among the leukocytes, arranged in chains of different length. The remains of the oleogranuloma could be seen in the proliferating connective tissue (Fig. 2), together with fragments of thickened elastic fibers and undifferentiated bands and tubes of cubical and cylindrical epithelium. Around the focus, beyond the proliferating connective tissue,

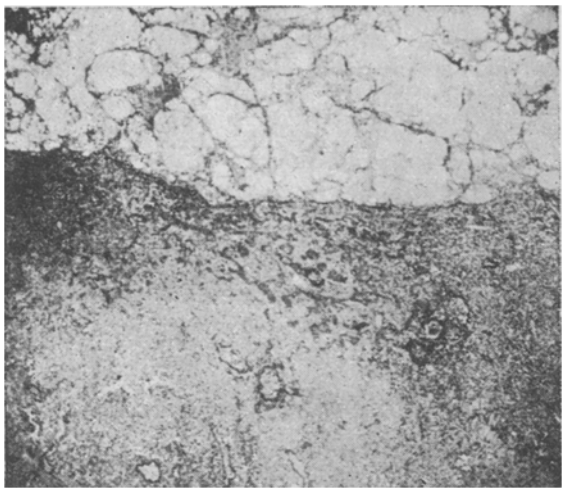

Fig. 1. Anemic infarct, separated from the oleogranuloma and its connective-tissue capsule by a leukocyte barrier and granulation connective tissue. Stained by van Gieson's method. Magnification: Eye-piece 4, objective 8.

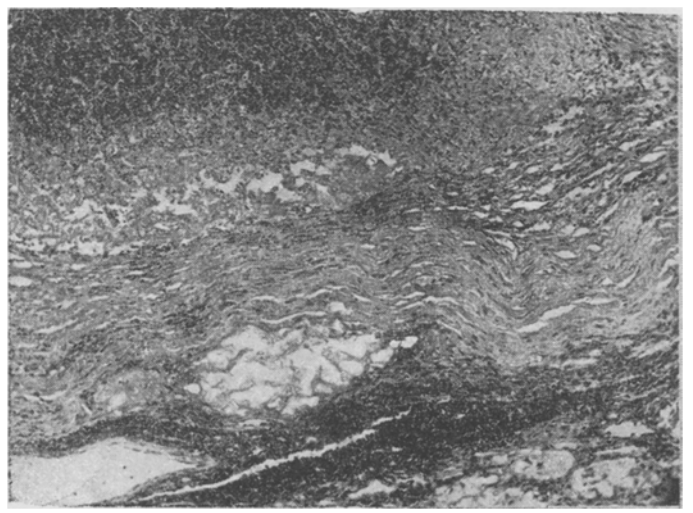

Fig. 2. Liquefaction of connective tissue at the border with the leukocyte barrier surrounding necrotic tissues. Foci of oleogranuloma can be seen along the connective tissue fibers. Stained by van Gieson's method. Magnification: Eye-piece 4, objective 8.

there were no changes in the lung tissue, the arteries and veins were dilated and contained erythrocytes, and the alveoli were frequently lined with cubical epithelium. Many dilated blood vessels were seen in the pleura and its connective-tissue adhesions.

Second series. In most cases the right lung was aerated and without adhesions to the parietal pleura, while in two rabbits (2nd, 7th day) a focal pneumonia was present. The left pleural cavity contained multiple adhesions between the lobes themselves, and between them and the parietal pleura. The lung was usually reduced in size, and only on the 33rd day was it enlarged, resembling a bag of pus. Microscopic investigation showed that the left lung in every case contained a focus of necrotic tissue, surrounded by a wide leukocyte barrier. Palely stained walls of alveoli and the homogeneous mass of "turpentine oil" were distinguishable in the focus of necrosis. Outside the leukocyte barrier was a connective-tissue capsule, lined in places with cylindrical or cubical epithelium; groups of leukocytes were seen among its fibers in the form of abscesses. Among the leukocytes when stained by Gram's method, chains of different lengths of Gram-positive cocci could be seen. Peripherally to this focus of necrosis, on the 2nd and 7th days after ligation of the pulmonary artery a focus of hemorrhagic infarction of varying size could be seen, and at later stages, a focal (206th or 207th day) or diffuse pneumosclerosis occupied almost the whole lung (33rd, 129th, 140th days). Among the connective-tissue fibers could be seen elastic fibers, forming spirals and concentric figures, and also tubes of cubical and cylindrical epithelium and bands of undifferentiated epithelium. At the border between the proliferating connective tissue and the residual lung tissue, alveoli lined with cubical epithelium could be seen on the 7th and 140th day. In the areas of residual lung tissue the arteries and veins were dilated and filled with blood. In every case many vessels distended with blood could be seen in the pleura and adhesions.

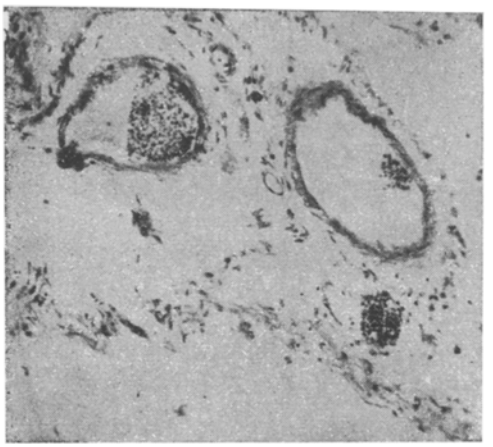

Fig. 3. Grossly distended blood vessels in adhesions. Stained by van Gieson's method. Magnification: Eye-piece 4, objective 16.

Hence, ligation of the pulmonary artery in the presence of either an infected or an aseptic focus did not contribute towards the spreading of the inflammatory process from the focus to the lung tissue or to the pleura (in the form of suppurative pleurisy and empyema), which we observed repeatedly in the control experiments. Circulatory disorders developed around the focus after ligation of the pulmonary artery, with the subsequent formation of a diffuse or focal pneumosclerosis. The pneumosclerosis developing as a result of ligation of the pulmonary artery apparently immured the focus of necrosis arising from injection of "turpentine oil" and prevented the endobronchial spread of the inflammation and its spread to adjacent regions. At the same time the focus of necrosis developing after injection of "turpentine oil" persisted until the 237th and 256th days, and ligation of the pulmonary artery did not bring about the eradication of this focus. The accompanying complications in the form of perifocal nidi of suppurative inflammation and abscesses were in every case associated with secondary Gram-positive infection. The high incidence of complications of this nature in the experiments with added infection supports the view that this infection was secondary. It seems that secondary infection took place more easily because of the increased difficulty of ridding the lung of foreign matter and disturbance of the function of the tracheobronchial tree; under these circumstances the right lung often became infected.

Certain differences could be found between the changes arising in the lung after ligation of the pulmonary artery in the presence or absence of a pre-existing focus of inflammation [5]. After ligation of the pulmonary artery in the intact lung, the commonest sequelae were circulatory disorders, total infarction, diffuse pneumosclerosis affecting the whole lung, and less frequently, a focal pneumosclerosis. The circulation in the lung with diffuse pneumosclerosis was carried on by the bronchial artery and also by the vessels of the adhesions in pleura. In focal pneumosclerosis, besides dilated vessels in the adhesions and pleura, arteriovenous anastomoses and communicating arteries distended with blood were also observed, i.e., the blood supply was largely provided by the bronchial artery.

When the pulmonary artery was ligated in the presence of a focus of inflammation, a total anemic infarct was never observed; the oleogranuloma and the focus of necrosis following injection of "turpentine oil" and their connective-tissue capsule did not undergo secondary necrosis as a result of disturbance of the circulation. Anemic or hemorrhagic infarcts of different sizes developed in the surrounding, hitherto unchanged lung tissue. Evidently at the

moment of ligation of the pulmonary artery the blood supply in the focus of inflammation arising after injection of "turpentine oil" was provided by the bronchial artery and, mainly, by the vessels of the adhesions and pleura; when the pulmonary artery was ligated the blood supply was adequate and no new foci of necrosis were formed in this region. The anemic infarct developed in the hitherto unchanged part of the lung, which was supplied mainly by the pulmonary artery. It is interesting that the areas of lung tissue in a state of atelectasis did not undergo circulatory necrosis, presumably because their blood supply, like that of the parts of the lung not taking part in the function of gas exchange, was provided mainly by the bronchial artery.

In certain animals focal pneumosclerosis developed after ligation of the pulmonary artery in a lung with a preexisting focus of inflammation as a result of disturbance of the circulation, but no dilated communicating arteries and arteriovenous anastomoses were observed, because the blood supply in these cases was evidently provided mainly by the vessels of the adhesions and pleura. Many arteries and veins of normal structure, filled with blood, were always found in the unchanged part of the lung; the possibility was not excluded that blood could enter the branches of the pulmonary artery within the lung by way of communicating anastomoses at the hilum of the lung. This question could be answered by a serial investigation of the hilum of the lung.

Hence, ligation of the pulmonary artery in our experiments was not followed by aggravation of the disease in an inflammatory focus and did not facilitate the spread of infection to the lung tissue but, on the contrary, it prevented its spread as a result of the development of pneumosclerosis in the surrounding tissue. It should, however, be remembered that perifocal nidi of necrosis may arise after ligation of the pulmonary artery; conditions favoring secondary infection of foci of inflammation and progression of the pneumosclerosis are also created. Secondary infection of the lung with a ligated pulmonary artery, as in a lung with a normal circulation, may lead to the development of suppurative inflammation and subsequent abscess formation. The possibility of this complication must always be borne in mind when the pulmonary artery is ligated for therapeutic purposes.

SUMMARY

The pulmonary artery was ligated in the lung with an existing aseptic (10 rabbits) or infected inflammatory focus (8 rabbits). In both experimental series ligation of the pulmonary artery did not promote any spread of the inflammatory process from the focus along the pulmonary tissue. Circulatory disturbances with a subsequent appearance of diffuse or focal pneumosclerosis developed around the focus after ligation of the pulmonary artery. Complications in the form of perifocal purulent inflammation and abscesses, developing in a number of cases, were connected with secondary infection of the lung.

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