Experimental Massive Pulmonary Collapse*

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Interest in atelectasis has in recent years been revived by the increased recognition of its frequency. It has been demonstrated that complete obstruction of the air passage supplying a unit of the lung which does not also communicate with another air passage will produce atelectasis.1-3 It has been shown4 that this is due to absorption by the body fluids of the gases contained in that part of the lung.

The process of collapse of a lung following complete bronchial obstruction consumes a considerable amount of time, but in some cases of undoubted atelectasis the collapse occurs quite rapidly.5,6 For this reason, and because bronchial breath sounds may sometimes be heard over the dull area, it has been hypothesized that collapse of the lung may occur rapidly from causes other than compression of the lung or bronchial obstruction.7 What these causes are has not been explained. Jackson8 has suggested that rapidly occurring atelectasis is due to the presence of a one way valve in the bronchus, and states that he has seen bronchoscopically such valves in action. The objection has, however, been made that an obstruction would in every case cause absence of breath and voice sounds and diminished tactile fremitus over the affected area.

The anatomy of the respiratory tract does not seem to fit in with the idea of active collapse, but rather with the conception of passive collapse. The muscle fibers are arranged in a geodesic network around the bronchi and bronchioles, terminating in sphincters at the entrances to the alveoli,9 and their contraction cannot collapse the lung. These muscle fibers do not surround the alveoli and are not present in the human pleura.10 The elastic fibers, on the other hand, are arranged in the longitudinal axis of the bronchial tree, for the most part, and surround the individual alveoli. They are present in large numbers in the pleura.9 This arrangement is an ideal one for expelling air from the lung, and this is in fact its purpose, the expulsion of tidal air being largely accomplished by this tissue during normal respiration. Elastic tissue, of course, has no power of active contraction.

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If the muscle fibers of the human respiratory tract can completely occlude the bronchial tree by their contraction, an atelectasis might eventually be produced by a long continued spasm, if death from asphyxia did not occur first. It has been pointed out already, though, that the muscle fibers do not surround the alveoli or exist in the pleura, so the air in the alveoli would be trapped rather than expelled, and the atelectasis would be of the slowly appearing type seen in complete bronchial obstruction. It is common knowledge that spasm of the bronchial musculature causes difficulty in expiration rather than collapse of the lung.

It being therefore evident that it is difficult to correlate the idea of active pulmonary collapse with the physical mechanics of respiration or with the anatomy of the lung, I set out to de-

FIGURE 1: Roentgenogram 40 minutes after insertion of plug in right diaphragmatic lobe bronchus.
termine the validity of the one way valve conception of rapid pulmonary collapse.

A 10 kilogram dog was anesthetized with nembutal and the bronchial tree inspected bronchoscopically in order to be certain that no abnormality was present. A roentgenogram of the lungs and a bronchogram were made to rule out the possibility of pre-existing pulmonary lesions. A rubber plug was then inserted into the main bronchus of the right diaphragmatic lobe. It was
found that after 40 minutes no perceptible collapse has occurred (Fig. 1). This was in agreement with the results of previous investigators.

A valve permitting air flow in one direction but not in the other was constructed (Fig. 2). It will be noted that this is not nearly as perfectly functioning a valve as was used by Van Allen and his co-workers. This type of valve was used because in our opinion perfectly functioning, air tight, one way valves rarely are formed accidentally in the lung. A 10 kilogram dog was anesthetized with nembutal and a roentgenogram of his lungs made (Fig. 3). Bronchography was not performed on this animal in order that the opaque media might not interfere with radiographic study of the lungs. The bronchi were inspected bronchoscopically and the valve inserted in the left main bronchus in such a way that air could escape from the lung but could not re-enter it. Four minutes after the insertion of this valve (as soon as was possible) a roentgenogram of the lungs was made (Fig. 4). Mediastinal shift to the left and collapse of the left lung were already present. Thirteen minutes after insertion of the valve the collapse of the left lung and mediastinal shift had increased. Roentgenograms made 24 minutes (Fig. 5) and 49 minutes after insertion of the valve showed increasing collapse of the left lung and increasing mediastinal shift, so that collapse was nearly complete at the end of 49 minutes.

Other similar experiments demonstrated an interesting phenomenon. Sometimes atelectasis would not occur for a considerable time, due to the inefficiency and unreliability of the valve used. When it did finally occur, though, the collapse was quite rapid, as in the experiment described above. This sequence of events was obviously the result of the valve's beginning to work properly, and answers the question of how a one-way valve can suddenly develop in the bronchus. It is merely a case of a potential valve becoming an actual one.

Being satisfied that a one-way valve could produce rapid pulmonary collapse, I attempted, by physical examination of the experimental animals, and variation in the location of the obstruction, to determine why bronchial breath sounds are heard over areas of atelectasis in some cases. It was found that the breath sounds of these animals were not similar enough to those of humans for any conclusion to be drawn. Bronchial breath sounds were heard over the atelectatic areas, but the normal breath sounds of dogs contain so pronounced a bronchial element that we considered these findings to be inapplicable to humans. It was therefore necessary to wait for such cases to appear in the hospitals and determine the reasons in each case.
Figure 3: Roentgenogram before insertion of one-way valve.

Figure 4: Roentgenogram four minutes after insertion of one-way valve.

Figure 5: Roentgenogram 24 minutes after insertion of one-way valve.
In a series of over 3,000 cases in which there was radiographic evidence of pulmonary abnormality only two clear cut cases of atelectasis with transmission of bronchial breathing were noted, cases of compression atelectasis being disregarded. In one of these the bronchus supplying the right upper lobe was completely occluded. Bronchial breath sounds were transmitted in this case from the trachea into the airless lung tissue and thence to the chest wall.

In the second case the left lower lobe bronchus was occluded and the left lower lobe consequently atelectatic. The left upper lobe was extensively diseased, and bronchial breath sounds were transmitted from it through the lower lobe to the chest wall.

Many cases were seen in which atelectasis and pneumonitis coexisted in the same lobe, and in which bronchial breath sounds were heard, but the difficulty of accuracy of observation in such cases made it impossible to use them in the series. The observations of Van Allen and his co-workers on collateral respiration are of importance in such cases.1-3 Many cases of postoperative pneumonia show radiographic evidence of complete or partial atelectasis. Several factors contribute to bronchial obstruction in such cases. There is abundant opportunity for aspiration of secretions. Respiratory movements are lessened and the cough reflex abolished, and finally, manipulation of the abdominal viscera causes reflex contraction of the bronchi.11

When a bronchus becomes occluded, normal drainage cannot occur, and pneumonitis begins.12 Collateral respiration is cut off by the pneumonitis, and atelectasis results. If chemotherapy or antibiotic therapy is instituted, the pneumonitis may clear up, collateral respiration be re-established, and a normal x-ray picture be seen, even though the obstruction is still present. It is important to remember that although atelectasis is evidence of bronchial occlusion, absence of atelectasis is not evidence of a patent bronchus. Bronchoscopy should never be cancelled because the physical signs of obstruction have disappeared.

In view of these observations, I feel that if atelectasis without bronchial occlusion ever occurs it must be excessively rare. Every case of atelectasis should be bronchosoped, regardless of the presence or absence of what are usually considered to be signs of bronchial occlusion. Atelectasis itself is evidence of bronchial occlusion.

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SUMMARY

1) It has been demonstrated that occlusion of the air passage supplying a unit of the lung which does not also communicate with another air passage (by collateral respiration) will result in atelectasis by absorption of the trapped air.

2) Some cases of atelectasis occur with a rapidity which would preclude absorption of the trapped air as a cause. Since the anatomy of the lungs and the dynamics of respiration make any cause of collapse other than bronchial obstruction unlikely, experiments were performed to determine whether a valvular obstruction would produce rapid atelectasis. It was found that a one-way valve properly placed in the bronchus did produce rapid collapse of the corresponding portion of the lung.

3) The author believes that practically all cases of atelectasis can be explained on the basis of bronchial obstruction.

RESUMEN

1) Se ha demostrado que la oclusión de la vía de aire de una parte del pulmón que no comunica con otra parte del pulmón por respiración colateral, dá por resultado la atelectasia por absorción del aire atrapado.

2) Algunos casos de atelectasia ocurren con una rapidez que descarta la posibilidad de la absorción como causa.

Puesto que la anatomía de los pulmones y la dinámica respiratoria eliminan toda otra causa que no sea la obstrucción bronquial, se hicieron experimentos para determinar si obstrucción valvular produce rápidamente atelectasia. Se demostró que la válvula de sentido irreversible colocada adecuadamente en el bronquio, produce colapso rápido en la región correspondiente.

3) El autor cree que prácticamente todos los casos de atelectasia pueden explicarse por el mecanismo de la obstrucción bronquial.

REFERENCES