POST-OPERATIVE PULMONARY ATELECTASIS *

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Our continued interest in the subject of post-operative pulmonary atelectasis has served to convince us more firmly in the probability of the statement made in our first report (Annals of Surgery, April, 1924, p. 506), "that the phenomena of pulmonary collapse of varying degrees, together with pulmonary embolism and infarction, are the real etiological factors in post-operative pulmonary complications." We agree with Mastics in his recent estimate that over 70 per cent. of the so-called post-operative and post-anæsthetic pneumonias are varying degrees of atelectasis. We again state our belief that in the small proportion of true pneumonias developing post-operatively, all start as varying degrees of atelectasis, and upon these lesions are engrafted infarction and infection. *Massive atelectasis,* involving more than one lobe of the lung, is usually mistaken for pleural effusion, empyema or pneu-

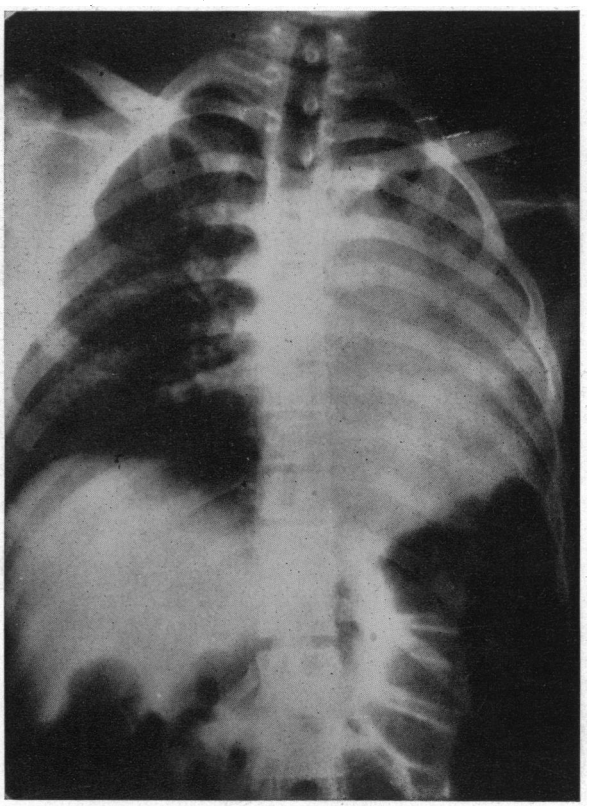

Fig. 1.—C. M., male, white, fifteen years. Pennsylvania Hospital. Forty-two hours after radical right inguinal herniorrhaphy, massive atelectasis left lung.

* A demonstration by motion pictures of the clinical phenomena of post-operative atelectasis and bronchoscopic removal of obstructing bronchial secretion, before the combined meeting of the Philadelphia and New York Academies of Surgery held February 8, 1928.

mothorax. *Lobar atelectasis,* involving but one lobe, is diagnosed lobar pneumonia. *Lobular atelectasis,* involving scattered areas in one or more lobes, receives the diagnosis of bronchopneumonia or pulmonary infarction. The fact that atelectasis has been recognized as a congenital lesion; occurring spontaneously; in bronchial and pulmonary infections; in nonpenetrating wounds of the thorax, abdomen and lower extremities; in increased abdominal pressure, associated with tumors, intestinal distention and peritoneal effusion; in postures immobilizing the thorax and abdomen; in nasal and pharyngeal diphtheria; in foreign bodies in the trachea or bronchi; and following operations upon the abdominal wall, intra-abdominal organs, genitalia and lower extremities, indicates that more than one etiological factor may be involved. In the thirty-three cases of post-operative massive atelectasis whose records we have been able to study we are persuaded that two factors have been constant in this group: first, a thick *vicid bronchial secretion,* and, second, some *inhibition of coughing.* Because of the thick, tenacious character of this bronchial secretion and the inability, or disinclination, of the patient to clear it from the bronchi, it accumulates in the dependent portions of the bronchial tree until at some point or points this stream of mucous completely occludes the lumen. If this occlusion takes place in a small bronchiole, we will have *lobular atelectasis;* if it occurs in a bronchus leading to one lobe, we have *lobar atelectasis;* and if it occurs in a main bronchus of either lung, we will have *massive atelectasis.*

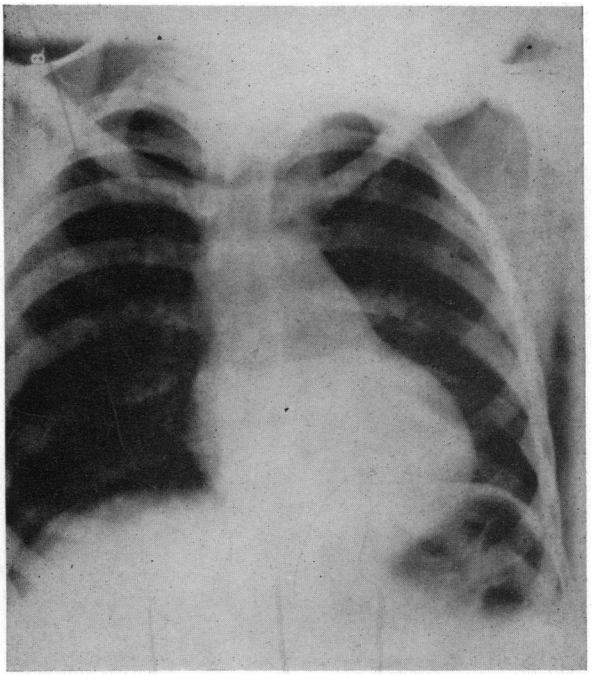

FIG. 2.—C. M., male, white, fifteen years. Pennsylvania Hospital. Röntgen-ray taken fourteen hours after bronchoscopic drainage of the obstructing secretion from left main bronchus.

The mechanism by which such an obstruction may be produced has been recently suggested to us by the experimental work of Archibald, reported before the Association of Thoracic Surgeons at the New York meeting in 1927, upon The Dangers of Cough (*Arch. of Surg.,* vol. xvi, Part 2, No. 1, January, 1928, p. 322). The question was raised by Archibald that if the bronchial secretions are not entirely expelled by the expiratory effort, they might be

drawn further into the bronchial tree by the following inspiratory rush of air. He found that substances of a consistency of mineral oil were drawn further into and probably reached the terminal alveoli of the lungs after a number of coughing spells stimulated by mechanical irritation of the pharynx, while substances of greater consistency and viscosity, such as mucus and sputum, were expelled by the first expiratory effort and cleared from the bronchial tree and were rarely drawn further into the bronchi. It is conceivable that when the viscosity of the bronchial secretion is not sufficient to insure its complete expulsion by the expiratory cough, nor sufficiently fluid to be drawn into the terminal bronchioles, it will move backward and forward at expiration and inspiration and definite waves will be created upon its surface. There is one point, of course, where the expiratory and the inspiratory wave meet and here a form of tidal bore may be created which can be compared to the wave produced by the meeting of tides in a narrow bay. This suggests to us an explanation of the piling up of the stream of vicid bronchial secretion into waves, one or more of which finally reach the opposite wall of the bronchus and because of its viscosity, sticks and completely occludes the lumen of the tube. With recurring coughing and marked inspiratory efforts this mass of secretion is drawn further into the bronchus and complete obstruction is maintained.

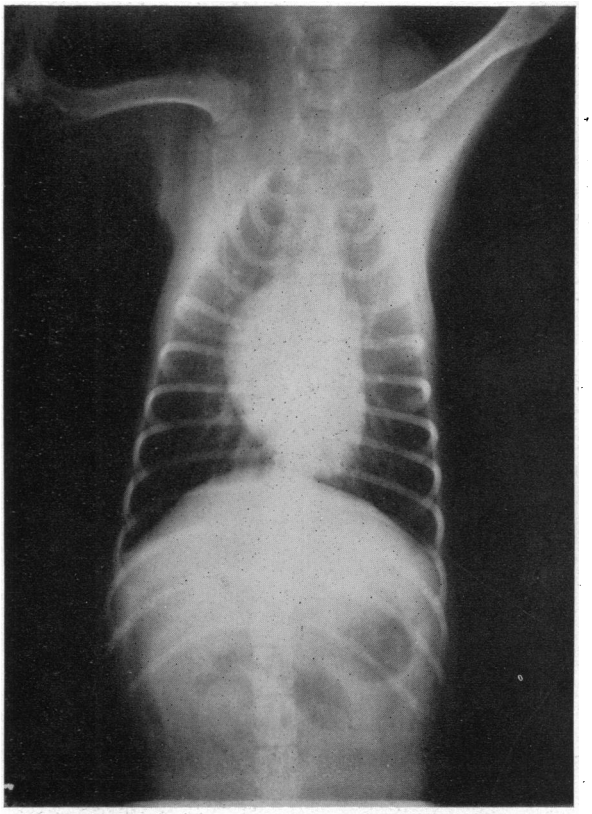

FIG. 3.—Dog 456. Laboratory of Surgical Research, University of Pennsylvania, Philadelphia. Röntgen-ray taken by Doctor Pendergrass, twenty-four hours before the exploratory laparotomy and experimental production of massive post-operative pulmonary atelectasis of right lung.

Clinically we have demonstrated that if this obstruction can be overcome by making the patient cough, by a change of position, as suggested by Santee, by vigorous shaking, and in young children, by actual spanking, and an airway be established past this point or points of obstruction, the patient may, temporarily at least, free the bronchial tree of large masses of secretion and thus

reinflate the pulmonary tissues. In eight cases we have found it necessary deliberately to aspirate through a bronchoscope the obstructing portion of this bronchial secretion, and in each case immediate aeration and reinflation of the pulmonary tissue distal to the point of obstruction has followed.

The similarity of the atelectasis found by Chevalier Jackson in foreign body obstruction of the bronchi to that of post-operative massive atelectasis was discussed with Jackson by Leopold and Lee in 1923. Leopold suggested a condition of drowned lung to account for the density of the Röntgen-ray shadow found in post-operative massive atelectasis. Drowned lung was described by Johnson as an accumulation of a fluid exudate in the bronchi and air vesicles distal to the partially obstructing foreign body. The air enters and leaves until such a time as the vesicles become filled with exudate. In such a lesion there would be no actual decrease in the size of the lung, no true atelectasis, and, therefore, no displacement of the heart such as we find in the classic picture of massive atelectasis.

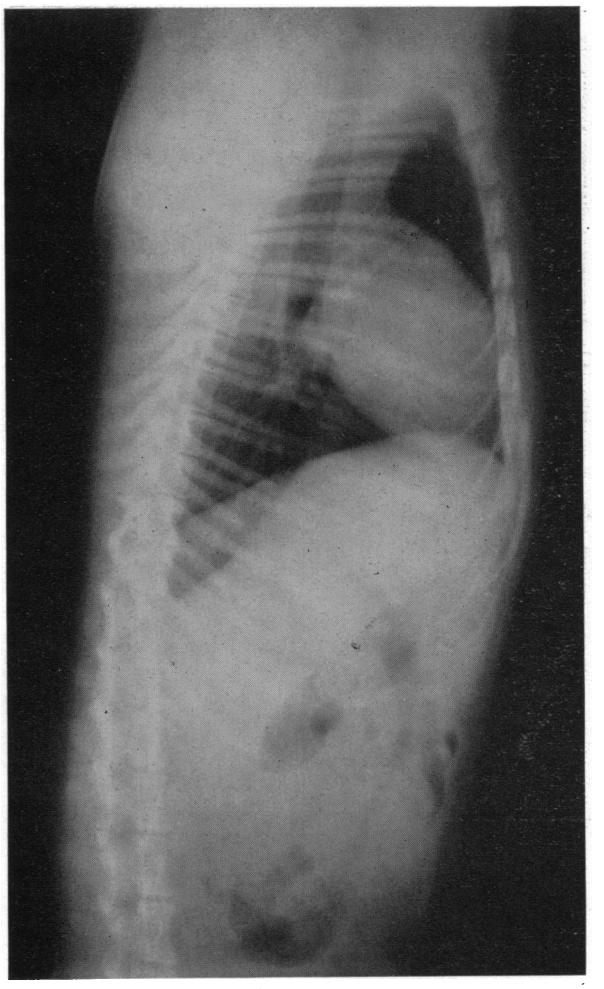

FIG. 4.—Dog 456. Laboratory of Surgical Research, University of Pennsylvania, Philadelphia. Röntgen-ray taken by Doctor Pendergrass, twenty-four hours before the exploratory laparotomy and experimental production of massive pulmonary atelectasis of right lung—normal.

Recently at the Pennsylvania Hospital we have had presented an unusual opportunity in a case of massive post-operative pulmonary atelectasis of the left lung following a radical right inguinal herniorrhaphy under ether anæsthesia. During the administration of the anæsthetic there was more mucus in the respiratory tract than usual, an observation which is very common in this group we have studied. About twenty-four hours after the operation breath-

ing became peculiarly distressing. It was quite evident that it was voluntarily restrained because of the pain in the operative wound. The temperature began to rise and there was a slight midsternal pain. Forty-two hours post-operatively, the respiratory distress was more marked, and the cough was short, shallow and but slightly productive of a tenacious sputum. At this time there was distinct displacement of the heart to the left of its normal position, and the clinical diagnosis of massive atelectasis of Doctor White was confirmed by Röntgen-ray examination by Doctor Bishop. Ten hours after the onset of these clinical symptoms and three hours after its confirmation by Doctor Bishop, Doctor Clerf drained through a bronchoscope from the left main bronchus 9 c.c. of the usual characteristic, thick, tenacious bronchial secretion. Bacteriologic examination of this secretion gave a pure culture of pneumococcus. There was immediate relief following this bronchoscopic drainage, more complete and satisfactory than in any of the previous cases in which this had been attempted. The fact that in the other cases forty-eight hours was the shortest interval between the onset of the symptoms and the bronchoscopic drainage was the explanation we gave for the more satisfactory results at this time. (See protocol No. 2 of Doctor Clerf.) This specimen of bronchial secretion was kept upon the ice for the next twenty-four hours until it was possible to provide the setting for its introduction into the main bronchus of a dog. In order

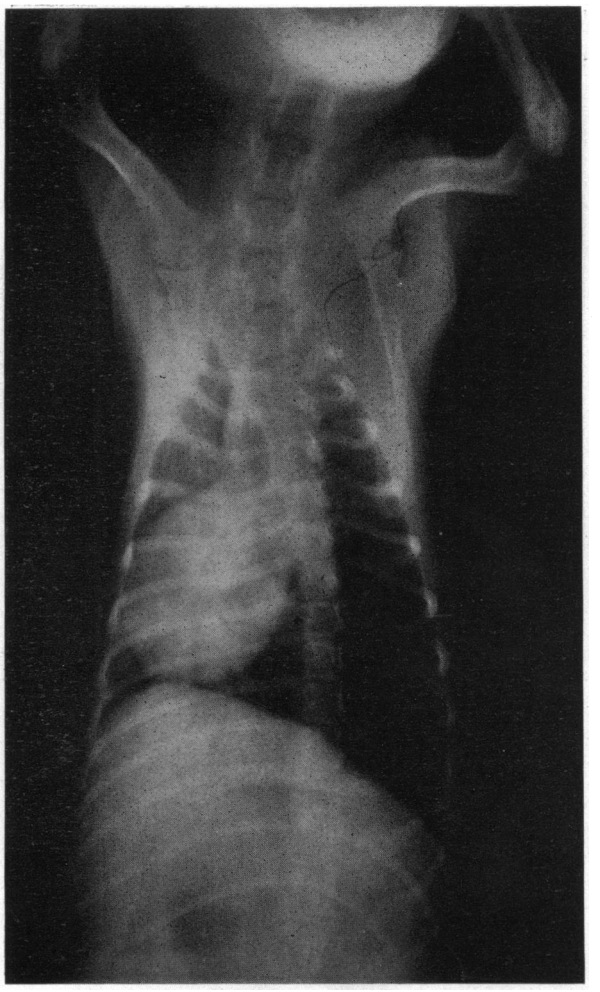

FIG. 5.—Dog 456. Laboratory of Surgical Research, University of Pennsylvania, Philadelphia. Röntgen-ray by Doctor Pendergrass, three hours after exploratory laparotomy and the bronchoscopic introduction of 7 c.c. of the obstructing secretion removed by Doctor Clerf from the left main bronchus of the patient, C. M. (Fig. 1) with massive post-operative atelectasis.

that all of the suspected etiological factors be provided, the dog was first narcotized with morphia, etherized, and then an operative incision was made through the upper half of the right rectus muscle, entering the abdominal cavity. This wound was closed by continuous layer sutures of silk and then strapped with broad adhesive plaster which encircled the lower portion of the costal arches, as we dress so many of our upper abdominal wounds. The dog was then laid upon his right side and after cocainizing the nasopharynx the bronchoscope was introduced into the main bronchus of the right lung and 7 c.c. of the secretion previously removed from the left main bronchus of the patient was introduced into the right main bronchus of the dog. At first there was definite coughing and struggling, which fortunately resulted in the drawing of the secretion into the deeper portions of the bronchial tree. At this point Doctor Ravdin introduced intraperitoneally 250 mgm. of sodium amytal, with the object of producing a deep narcosis and eliminating the cough reflex. This was promptly followed by a deepening narcosis and the disappearance of the cough reflex. With the loss of the cough reflex, respiratory efforts became deeper and the entire mass of bronchial secretion was drawn into the right bronchus. A few minutes after the completion of the introduction of the bronchial secretion and following the removal of the bronchoscope, definite respiratory distress developed. This distress was so marked that it seemed for a time that the dog was about to die. The respiratory movements finally became regular and rhythmic and before the dog was placed in the kennel Doctor Ravdin said that the movements of the right side of the chest were almost lost, while those of the left side were very much exaggerated, and there was distinct bulging and a visible increase in the size

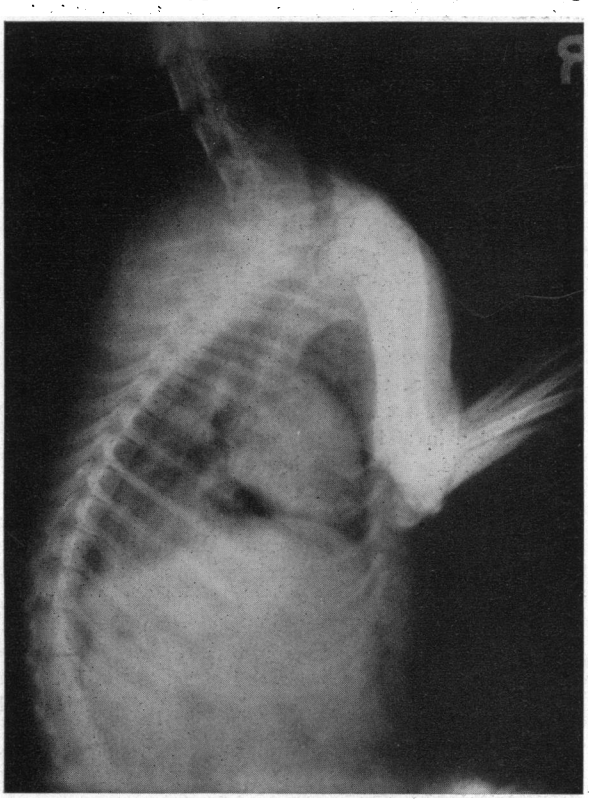

FIG. 6.—Dog No. 456. Laboratory of Surgical Research, University of Pennsylvania, Philadelphia. Röntgen-ray taken by Doctor Pendergrass three hours after exploratory laparotomy and the bronchoscopic introduction of 7 c.c. of the obstructing secretion removed by Doctor Clerf from the left main bronchus of the patient C. M., (Fig. 1) with massive post-operative atelectasis.

of the left half of the thoracic cavity. The dog was kept on his right side for three hours, at the end of which time a Röntgen-ray examination made by Doctor Pendergrass at the University Hospital showed that there was complete atelectasis of all lobes of the right lung with transposition of the heart to the right beyond the spine. (See protocol No. 4 of Doctor Pendergrass.)

Although various substances have been tried to produce experimentally pulmonary atelectasis, as far as we know this is the first successful attempt in which the obstructing bronchial secretion from a clinical case of post-operative massive atelectasis has been used to produce it in an animal. We feel that this opens a field of experimental research which will make it possible to evaluate the various etiological factors which have been suggested.

PROTOCOL No. 1.—Abstract of history of Doctor St. Claire, Pennsylvania Hospital. Cosmo Manelli, male, white, single, fifteen years of age. Pennsylvania Hospital.

January 7, 1928.—The patient was operated upon by Doctor Lee at about 2 P.M. today and a radical herniorrhaphy performed upon a right inguinal hernia. During the operation there was more mucus in the respiratory tract than usual and by the following afternoon, twenty-four hours later, there was a definite cough, which, however, was restrained because of the resulting pain in his operative wound. There was a slight rise in temperature at this time.

January 8, 1928.—The patient complained this evening about 11 P.M. of severe midsternal pain and some discomfort in his chest. He would put his hand over the left side of his præcordia and point to it as the site of his discomfort.

January 9, 1928, at 8 A.M., approximately forty-two hours after the operation, his distress was more apparent and his cough short, embarrassed, frequent, and but slightly productive of a tenacious sputum. He complained of pain in his left axillary region which extended to his præcordia with each attempt at coughing. The fever has risen slowly and steadily during the night and his sleep was definitely interfered with. One dose of elixir terpene hydrate with ¼ grain of codeine sulphate was his only medication. At the time of this examination, 8 A.M., there was distinct displacement of the heart to the left. This was between 2 and 3 cm. to the left of its normal position. There was hyperresonance in the left anterior chest which blended with gastric tympany. Posteriorly the findings are those of consolidation. There was some impairment, distant tubular breathing over the lower half of the left chest and posterior to the posterior axillary line. By noon of this day the apex was felt in the fourth interspace behind the fold of the left pectoralis major muscle. The whole anterior portion of the left chest was hyperresonant above this point and merged into the gastric tympany below. Posteriorly the whole left chest posterior to the posterior axillary line was impaired to percussion and there was distinct tubular breathing and egophony. The short, painful cough was increased and restlessness was very apparent at this time. There was a look of anxiety accompanying the restlessness. Cyanosis gradually appeared during the morning and by noon it was quite evident in the lips, ears and under the finger nails. At noon the contrast between the freely moving right chest and the comparatively fixed left chest was striking. At 2 P.M. the right border of the heart to percussion was to the left of the left border of the sternum (the compensating right lung was probably encroaching sufficiently to give a false right cardiac border). At this time Röntgen-ray examination was made. The fluoroscopic examination showed the typical picture of massive atelectasis of the left lung. The whole left chest was dark, in contrast to the right chest. The right diaphragm moved freely and with greater excursion than normal. It was impossible to recognize the dome of the left diaphragm because of the density of the shadows. Displacement of the heart was sufficient to place the right border beneath the sternum. On deep inspiration the heart displacement was increased toward

the left side, so much so that the right border was distinctly to the left of the left border of the sternum. This was for a distance of a few millimetres. An X-ray picture taken at this time was interpreted by Doctor Bowen as follows:

"X-ray No. 62537, Chest: Rather typical collapse of the left lung. There is, however, less displacement of the heart toward the left than we usually expect. There is practically no displacement of the trachea to the left. The lateral movement of the heart with respiration is sufficient to warrant the diagnosis. Presumably, the lack of displacement is due to a rather unusual amount of fluid in the collapsed lung."

PROTOCOL No. 2.—Doctor Clerf. January 9, 1928, 5:45 P.M., Pennsylvania.

A dose of morphia, gr. ¼, and atropine, gr. 1/150, were given hypodermically and preparations made for bronchoscopy.

With the patient on the operating table a moving picture was started to show the patient's efforts to expel the obstructing bronchial secretion. This moving picture was continued during the bronchoscopic drainage.

Doctor Clerf's report of the bronchoscopic drainage is as follows:

"A large quantity of thick, tenacious mucoid secretion was coughed up through the bronchoscope as soon as it was introduced into the trachea; the left main bronchus seemed completely filled with secretion. In all 9 c.c. were aspirated and collected in a Lukens tube. The mucosa of the trachea, the orifice of the right main bronchus and the left bronchus with its subdivisions were inflamed. The lumen of the left bronchus seemed practically normal in size. Because of the continuous coughing efforts of the patient, it was difficult to make any observations regarding bronchial movements.

Bronchoscopic diagnosis: Acute tracheobronchitis. Plugging of left bronchus and subdivisions with thick, tenacious secretion. Secretion aspirated.

Remarks: The 9 c.c. of secretion collected does not represent the total quantity. Approximately three c.c. were coughed up through the bronchoscope and several additional c.c. were coughed up into the pharynx at the time of the laryngoscopy. The character of the secretion differs somewhat from that usually observed in these cases. It is grayish in color and contains many tiny air bubbles. As observed by Doctor Lee, this is probably due to the fact that bronchoscopy was performed very shortly after the onset of the collapse, approximately ten hours."

Surgeons: Dr. Louis Clerg, Doctors Lunn and St. Claire.

In addition to the secretion which was obtained directly through the bronchoscope the moving picture shows very clearly the coughing up of several mouthfuls of this same vicid secretion after the bronchoscope was removed. In other words, after the bronchoscope had established an airway beyond the point or points of obstruction, the patient himself was able to clear the obstructed bronchial tree by his own voluntary efforts at coughing far more thoroughly than we were able to aspirate the material through the bronchoscope. The bronchoscope was of peculiar value in overcoming the obstruction and establishing the airway, but it was the patient's own efforts which were most productive in clearing the bronchial tree of its secretion.

PROTOCOL No. 3.—Dr. Gabriel Tucker. January 11, 1928, Dog No. 456.

Bronchoscope was introduced by the Jackson technic, local anæsthesia used, 4 per cent. cocaine to the larynx. The mucosa of the tracheobronchial tree was normal. There was no abnormal secretion. Secretion provided from the lung of a patient with massive collapse (Cosmo Manelli) (by Doctor Lee and Doctor Clerf) was introduced into the right main bronchus, and the larger bronchial subdivisions were filled with the secretion as high in the tracheobronchial tree as the carina. With inspiration no lumen appeared past the secretion, showing that it was completely obstructed. The preliminary morphine narcosis and ether anæsthesia was reënforced by the intraperitoneal injection of sodium amytal. This completely abolished the cough reflex. Before the bronchoscope was withdrawn the cough reflex could no longer be excited by intrabronchial manipulation. Careful inspection was made to insure that the secretion was placed only in the right lung.

Bronchoscopic Finding.—Mucosa of the tracheobronchial tree normal. Complete occlusion of the right main bronchus and its branches by bronchial secretion provided by Doctor Lee and Doctor Clerf from a patient with massive atelectasis.

PROTOCOL No. 4.—Doctor Pendergrass. January 12, 1928, Dog No. 456.

Control Films: Heart is in the midline. Both lungs aerated normally. No increased densities were seen.

Three hours after insufflation of material into the right bronchus: There is almost a complete atelectasis of the entire right lung, especially the right upper lobe and to a less extent the right lower lobe. The heart is displaced to the right.