A TREATMENT OF PERSISTENT BRONCHIAL FISTULA

AN EXPERIMENTAL AND CLINICAL STUDY

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Celsus [8] is quoted as saying, "Fistulas of the chest are very difficult of treatment, so that sometimes physician, sometimes patient, giving up hope, leaves the case to Nature herself." Some of the instruments used by Hippocrates and Paulus Aeginata are described in the writings of Fabricius ab Aquapendente.[12] He stated that most persons who had received a penetrating wound of the chest had to wear a silver tube for life, and that he knew of patients who had carried tubes for twenty to thirty years. In discussing the treatment, he says the hard skin of the fistula should be removed either by softening or by instruments. Furthermore, "all corruption must be removed and the fistulous tract straightened by cutting the curves with a knife."

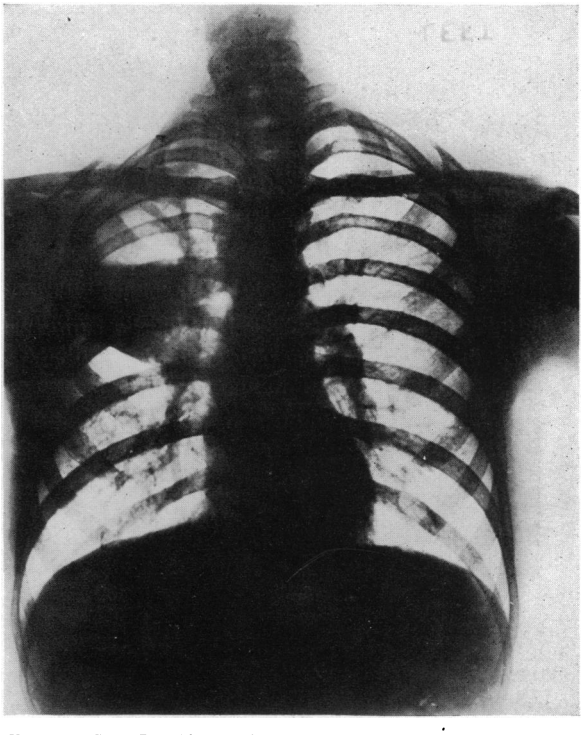

Fig. 1.—Case I. Abscess in right upper lobe showing the fluid level in the erect position.

From these early times, the subject of bronchial fistula has received occasional attention; not, however, until recent years has the subject been given scientific consideration and operative treatment been systematically attempted.

A bronchial fistula is a communicating tract between a bronchus and the pleural surface of the lung or cutaneous surface of the thoracic wall. There are, therefore, two types, broncho-pleural and broncho-cutaneous. On the basis of etiology, Eggers [11] makes the following classification: (*a*) those due to intrapulmonary suppuration; (*b*) those due to external violence which has produced a perforating wound of the chest wall.

It is probable that bronchial fistulas are most commonly encountered in empyema thoracis as a cause or complication of this condition. The major-

ity are small and heal spontaneously. However, in certain cases, a fistula may persist, and be the chief factor of the chronicity of an empyema cavity. A fistula may result from a lung abscess, either spontaneously if the abscess ruptures into the pleural cavity, or following the operative treatment of the abscess. In the same way, suppurative bronchiectasis may be the cause. A fistula not infrequently occurs in pulmonary tuberculosis as a result of tuberculosis cavitation. Other pathological conditions that may be directly or indirectly the cause of bronchial fistulas are: lung abscess caused by the aspiration of a foreign body, actinomycosis, gangrene of the lung, or pulmonary suppuration due to an extension from a neighboring organ.

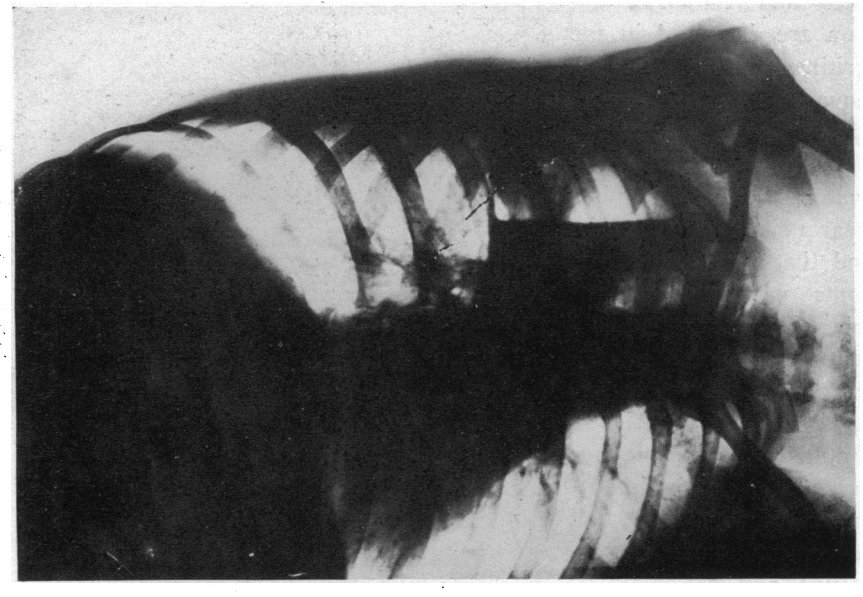

FIG. 2.—Case I. Lateral recumbent X-ray showing the fluid level.

When a fistula has developed, a number of factors may contribute to cause its persistence. Probably the most important is suppuration in the parenchyma of the lung or in the bronchial tree. Wilensky assumes that in a small number of cases the constant presence of low-grade infection in the bronchial tree, with the superposition of repeated attacks of acute inflammation, furnishes an important cause for the constant reinfection of the fistulous tract and failure to heal. An aspirated foreign body or a retained drain may be responsible for the persistence of the fistula. Finally, less apparent factors may be operative; thus a large bronchial fistula which opens into a rigid-walled empyema cavity is peculiarly liable to persist.

The walls of the fistula itself may become sclerosed. The entire tract may become epithelialized and may eventually produce a bronchocutaneous channel.

To the use of Dakin's solution has been attributed the development of some fistulas (Heuer,[23] Stevens [40]). This is said to be especially likely in empyemas due to streptococcus infection in which the surface of the lung is

studded with miliary abscesses. Multiple bronchial fistulas occasionally occur, most often in bronchiectasis.

The diagnosis of bronchial fistula is, as a rule, self-evident. The sudden development of a profuse secretion from an empyema wound together with an increase in the severity of the cough should make one suspicious of the presence of a fistula. If such an opening exists, the irrigation of an empyema cavity with Dakin's solution causes a paroxysm of coughing and the tasting of the solution by the patient. In a larger fistula, the diagnosis is self-evident when air is heard to escape from the wound. This sound is continuous when the patient strains with the glottis closed. In doubtful cases, the diagnosis may be confirmed by X-rays following the injection of lipiodol into the thoracic wound.

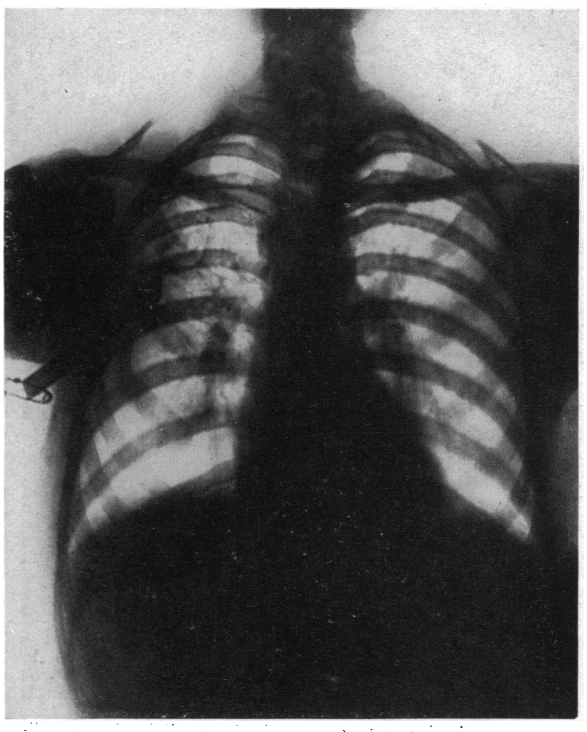

FIG. 3.—Case I. X-ray taken ten days following drainage of abscess.

Most bronchial fistulas will eventually close spontaneously if the underlying lung infection is cleared up. Neuhof [35] feels that this is practically always true. But, it must be emphasized that in many of the cases the processes of repair and closure occur only after a long period of time. Occasionally, a fistula persists indefinitely in spite of the subsidence of the underlying lung infection, especially where a large bronchial fistula opens into a chronic empyema cavity, or where a broncho-cutaneous fistula has formed. It is for such cases, particularly, that the operation to be described is suggested.

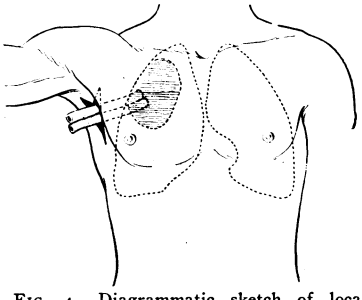

FIG. 4.—Diagrammatic sketch of location of abscess and drainage tubes in place. (From ANNALS OF SURGERY, March 1927.)

It is important before attempting to close a fistula, to verify the presence or absence of an underlying lung infection or a bronchiectasis by the history of the case, the clinical course, and by lipiodol injections. The pres-

ence or absence of a foreign body must be determined before instituting any treatment. Bronchoscopic removal of an aspirated foreign body or the removal of a lost drain by thoracotomy will very often result in rapid closure of the fistula.

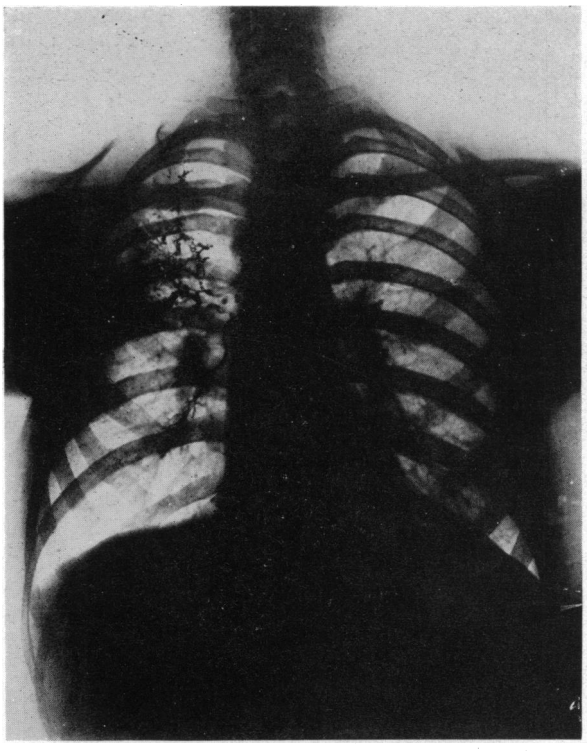

FIG. 5.—Case I. X-ray following injection of lipiodol into axillary sinus showing the presence of a bronchial communication.

Treatment.—The question of closing a bronchial fistula should only be considered after the need of drainage has passed; in other words, when the parenchyma of the lung is no longer acutely inflamed and in the absence of a bronchiectatic cavity. An empyema must be considered and treated as such independently of the fistula. If a bronchial fistula is closed in the presence of an active inflammatory process, an extensive acute pulmonary infection, or even embolic abscesses, for instance, in the brain, may occur.

Numerous methods have been recommended for the closure of bronchial fistulas. The simplest consists in the cauterization of the fistulous opening.

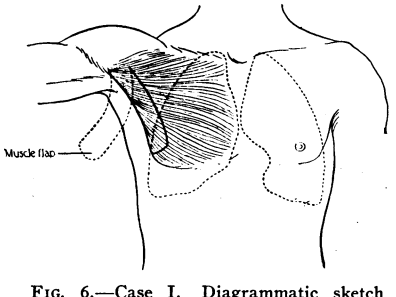

FIG. 6.—Case I. Diagrammatic sketch indicating outline of pedicled muscle flap taken from the pectoralis major muscle. (From ANNALS OF SURGERY, March, 1927.)

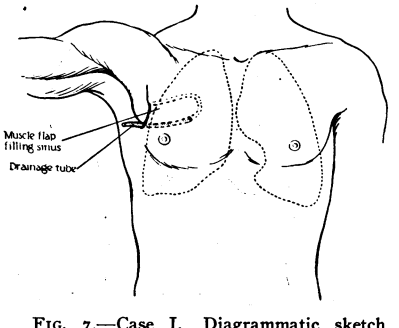

FIG. 7.—Case I. Diagrammatic sketch showing the insertion of the pedicled muscle flap into the cavity with a drainage tube placed beneath it. (From ANNALS OF SURGERY, March, 1927.)

The substances recommended have been numerous, the method usually consisting in local applications of the chemical or actual cauterizing agent to

the fistulous opening, the object of the treatment being to destroy the bronchial epithelium and to produce the formation of granulation tissue. In very small fistulas, this method is often successful. Keller [26] has obtained many closures with the use of gentian violet.

Other methods are based on the fact that many fistulas found in chronic empyema close spontaneously after mobilization of the lung or collapsing operations on the thoracic wall. This is undoubtedly true if the fistulas are small. With larger ones, however, spontaneous closure does not always occur. A striking example of this point is the second case reported in this paper. To close such fistulas, other methods have been employed, as purse-string sutures, or pedicled muscle or skin flaps placed *over the mouth* of the fistula. The insertion of purse-string sutures for the closure of bronchial fistulas is not a promising procedure, because the sutures are introduced in diseased tissue and tied under tension.

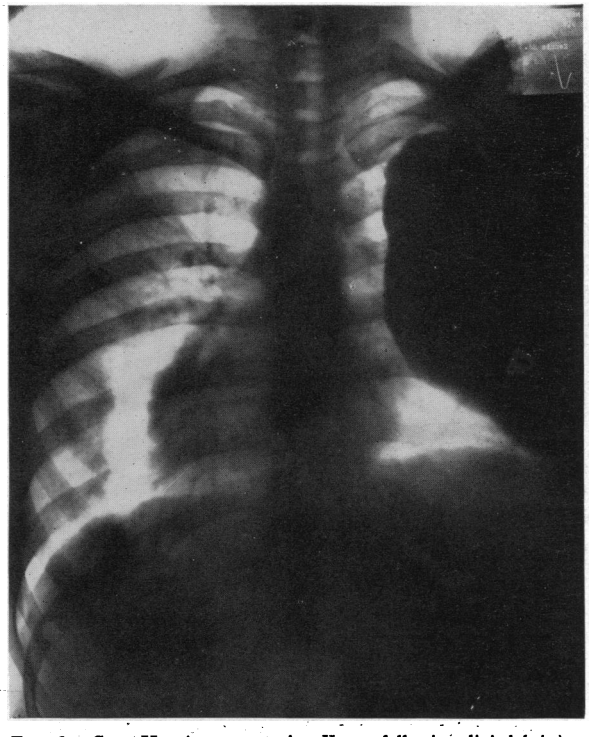

FIG. 8.—Case II. Anteroposterior X-ray following lipiodol injection showing the extent of the empyema cavity.

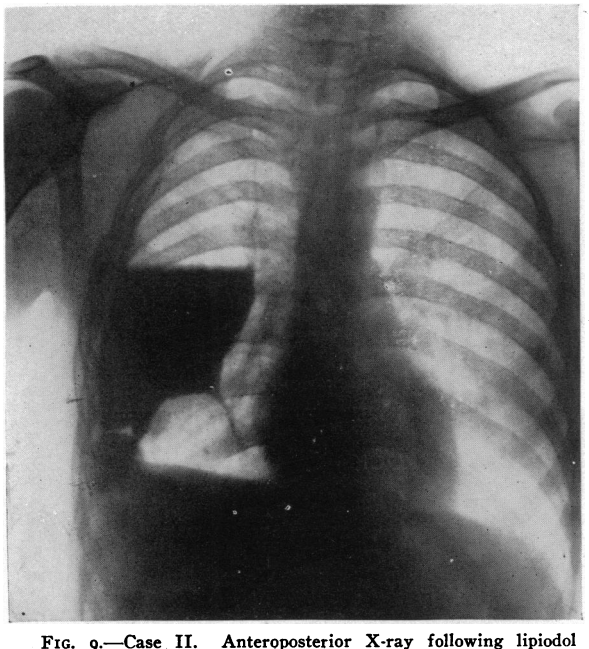

FIG. 9.—Case II. Anteroposterior X-ray following lipiodol injection with the cavity half filled, showing a prolongation of the cavity mesially.

Abrashanoff [1] in 1911 reported the use of a pedicled muscle flap placed *over the mouth* of

FIG. 10.—Case II. Indicates the appearance of the wound following one of the stages of a graded thoracoplasty. (From *American Journal of Surgery*, October, 1927.)

purse-string suture, a free graft of fascia and fat, and a pedunculated flap of skin and muscle. Others have recommended such radical procedures as cautery-pneumonectomy, and lobectomy; the real indication, however, for such procedures being the underlying diseased lung. A few writers have reported good results by the use of radium and Beck's paste.

We offer another method for the treatment of bronchial fistula. Its merits are its simplicity, its wide application, and its uniform success in our hands. As has been emphasized, any underlying parenchymal or bronchial infection or a bronchial fistula. Since that time, many surgeons have made use of this principle. The results have been fairly satisfactory. These operations have usually been performed in conjunction with decortication of the lung or collapse of the chest wall. Others have employed pedicled skin flaps in the same manner. Halstead and Thurston[18] reported the use of a combination of

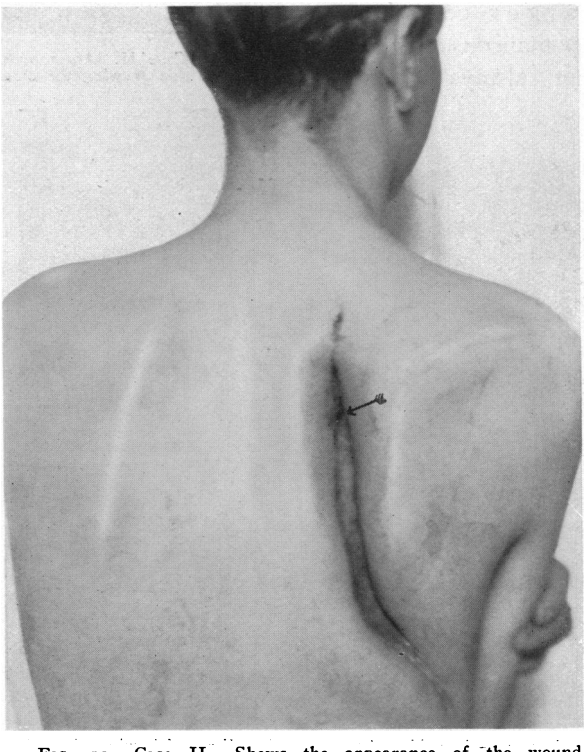

FIG. 11.—Case II. Shows the appearance of the wound before closure of the bronchial fistula. At the upper angle, one may see a dark area which indicates the position of the bronchial fistula. (From *American Journal of Surgery*, October, 1927.)

coëxisting empyema must be treated before operation for the closure of the fistula is attempted. The operation itself consists in the exposure of the fistula through an adequate incision without disturbing the relation of the lung to the chest wall, the fashioning of a pedicled muscle flap from neighboring muscle tissue, the insertion of the end of this flap *into the bronchus* as one inserts a cork into the neck of a bottle, the suture of the sides of the muscle flap to the tissues in the immediate neighborhood to prevent dislodgment, and finally, closure of the operative wound. This procedure has been carried out in three cases, which illustrate different types in which the method may be employed; we report their histories in detail.

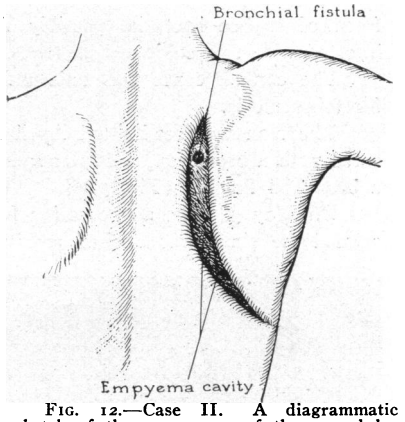

FIG. 12.—Case II. A diagrammatic sketch of the appearance of the wound before the closure of the bronchial fistula.

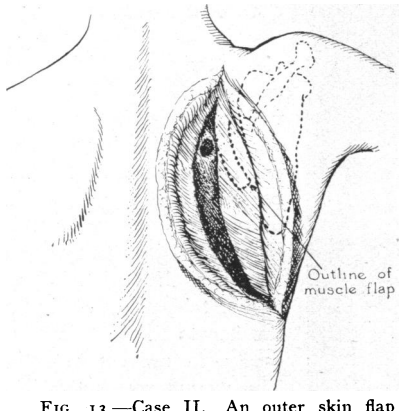

FIG. 13.—Case II. An outer skin flap has been dissected from the underlying musculature and a pedicled muscle flap has been fashioned.

REPORT OF CASES

CASE I.*—P. S., male, twenty-six years of age, was first admitted to the Medical Ward of the New York Hospital in August, 1911, with a diagnosis of incipient tuberculosis. He had physical signs at the right apex, but repeated sputum examinations were negative. Following tonsillectomy soon afterward, all his symptoms cleared up.

He was readmitted January 19, 1926, with the signs and symptoms of a large lung abscess of about three weeks' duration. The amount of sputum expectorated during twenty-four hours averaged eight ounces. The abscess was situated in the right upper lobe. (Figs. 1 and 2.) Repeated examinations of the sputum failed to reveal tubercle bacilli, but showed short-chain streptococci. White blood cells, 14,250, polymorphonuclear leucocytes, 68 per cent. The abscess was drained February 4, 1926. Under local anæsthesia, an incision was made in the right axilla. About two inches of the fourth and fifth ribs were removed. The abscess was found about one quarter of an inch from the periphery of the lung. Considerable fetid pus was evacuated. Two large rubber tubes were inserted for drainage. (Figs. 3 and 4.) A specimen of the lung excised at the time of this operation revealed, upon miscroscopic examination, a mass resembling mycelia with clear spore-like bodies. Occasional branched forms were seen. These masses resembled some

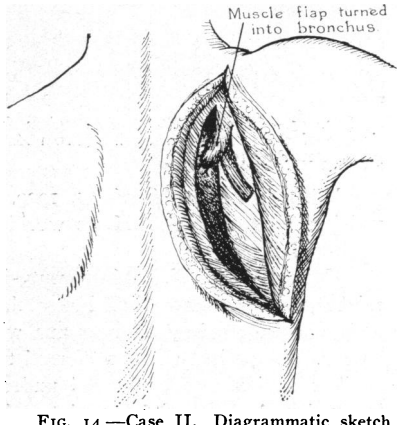

FIG. 14.—Case II. Diagrammatic sketch showing the muscle flap turned into the bronchial fistula as one would place a cork into the neck of a bottle.

* Reported in ANNALS OF SURGERY, March, 1927.

form of higher bacteria, possibly Aspergillus nodularis. Autopsy of a guinea pig injected with two cubic centimetres of the pus showed no lesions.

The convalescence was uneventful. Repeated sputum examinations were negative for tuberculosis.

The man was readmitted April 26, 1926, with a persistent sinus which communicated with a bronchus. X-ray examination after lipiodol injection into the sinus showed a bronchial fistula. (Fig. 5.)

On May 3, 1926, an operation for closure of the fistula was performed. The skin around the sinus was excised and newly-formed bone encircling the opening into the thorax removed. The cavity was about the length of the index finger. Its walls were soft and somewhat friable, and the cavity measured about two centimetres in diameter. The incision was extended along the lower margin of the pectoralis major muscle. A strip of muscle about twice as thick as the cavity, and four and a half inches in length, was dissected free, leaving its upper end attached. (Fig. 6.) This pedunculated flap was then turned into the cavity (Fig. 7) and fixed by two chromic sutures at the outlet. A small rubber tube was placed along the flap to the bottom of the cavity to prevent retention. The wound was sutured except at its central portion, which was packed with gauze. Ethylene anæsthesia; time, twenty-eight minutes. There was no cough after operation, and the wound healed rapidly. The tube was gradually shortened, and was removed on the fifth postoperative day.

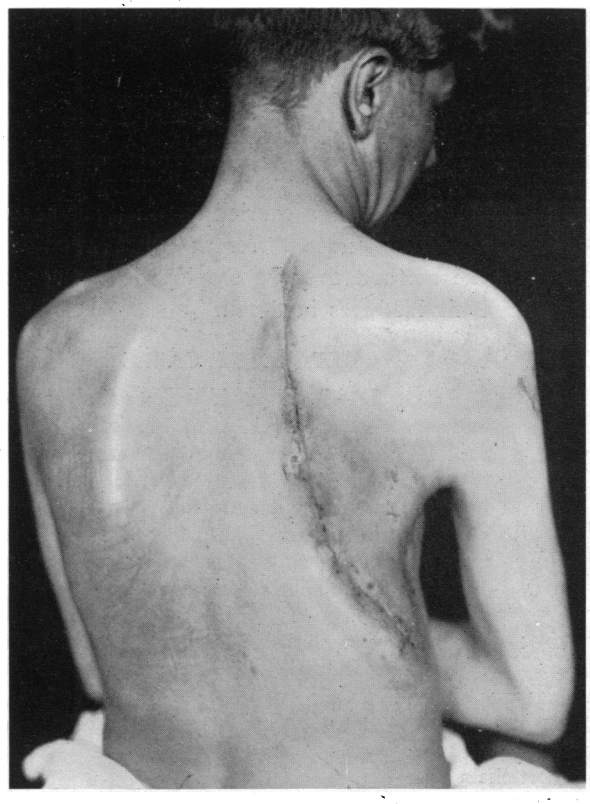

FIG. 15.—Case II. Photograph taken fourteen days following closure of the empyema wound. (From *American Journal of Surgery*, October, 1927.)

When last seen, March 31, 1929, the patient stated he had gained thirty-five pounds and had no complaints. He is working regularly. X-ray examination shows no abnormality of the lung.

CASE II.†—E. K., male, twenty-four years of age, was first admitted to the Medical Ward of the New York Hospital, May 3, 1925, with a right lower lobar pneumonia. This was followed by an empyema which, upon aspiration, cultured streptococcus hemolyticus. The patient was transferred to the Second Surgical Division, and May 16, 1925, a rib resection was performed under local anæsthesia. Two rubber tube drains were inserted and the cavity was later dakinized. Convalescence was uneventful, and the patient was discharged July 1, 1925, to the country, with a small wound draining a small amount of fluid.

† Reported in *American Journal of Surgery*, October, 1927.

He was readmitted July 13, 1925, with the history that he had begun to have fever and increased discharge from the sinus. There was no evidence of encapsulated fluid. On two occasions, the sinus was enlarged. It was evident that there was a large chronic empyema cavity. As the patient was in rather poor condition, two transfusions were given. He was discharged October 4, 1925, to the country, with the recommendation that after his general condition had improved, he was to return for obliteration of the cavity.

He was readmitted May 6, 1926. The cavity had a capacity of sixteen ounces. (Figs. 8 and 9.) X-ray after lipiodol injection showed an extensive empyema cavity. Because his general condition was only fair, it was decided to employ a graded thoracoplasty after the method of Keller. The stages of this procedure were performed May 11, May 22, June 8, and June 24, 1926, and entailed the removal of sections of the tenth, ninth, eighth, seventh, sixth, fifth, fourth, and third ribs. (Figs. 10 and 11.) Between the various stages, the Carrel-Dakin treatment of the wound was used. Following the last operation, there was seen at the upper end of the cavity a large broncho-pleural fistula, measuring two centimetres in diameter. During the subsequent ten days, the entire cavity was packed with gauze saturated with 2.5 per cent. alcoholic solution of gentian violet. The wound was then dakinized and, on successive dressings, it was seen that the superficial lay-

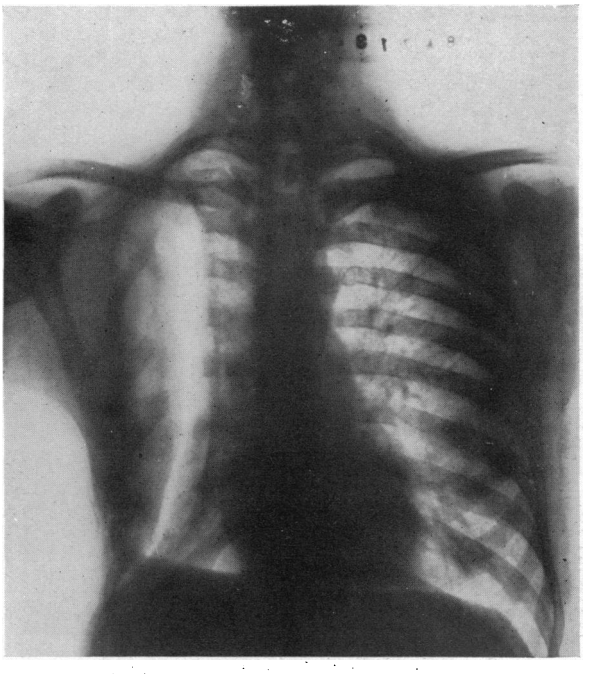

FIG. 16.—Case II. X-ray following closure of the empyema wound showing the layer of air between the visceral pleura and the overlying chest wall.

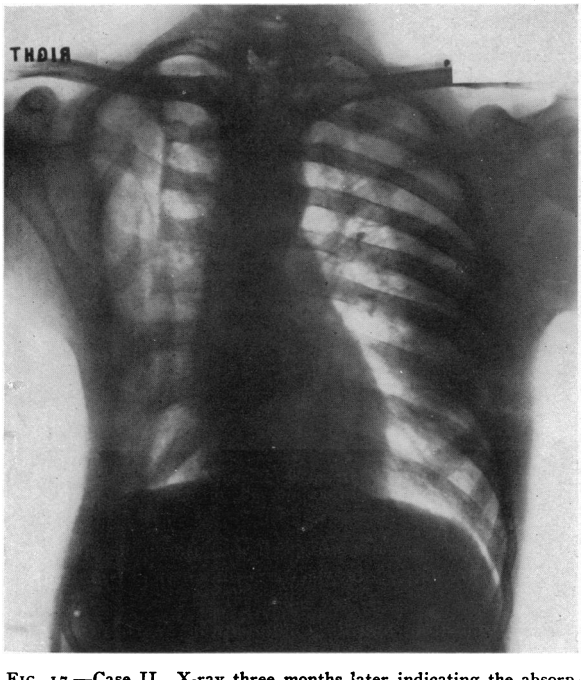

FIG. 17.—Case II. X-ray three months later indicating the absorption of the air noted in Fig. 16.

FIG. 18.—Case III. Indicating the appearance of the wound before operation for the closure of the fistula.

tured to the rim of the opening with interrupted chromic catgut stitches. The visceral pleura was then subjected to discission after the method of Ransohoff. The wound was packed. Ethylene anæthesia; time, twenty minutes. There was no coughing during convalescence. The fistula remained closed, *the muscle uniting by primary union.* Following the decortication, considerable expansion of the lung was noted.

The cavity was then dakinized and after obtaining six successive negative cultures, was closed on September 1, 1926. At this operation, the two skin flaps were well mobilized, the various muscle flaps were freed and sutured together across the cavity, followed by closure of the skin. Two long rubber tube drains were placed between the muscle planes. ers of the thickened visceral pleura peeled off readily. However, extensive dakinization failed to sterilize the cavity and it was felt that the presence of this large bronchial fistula was the cause of failure.

July 17, 1926, the following operation for the closure of the fistula was performed. The skin flap on the outer side of the wound was dissected free and a flap of muscle, somewhat larger in diameter than the size of the fistula, was dissected from the muscles mesial to the scapula. (Figs. 12 and 13.) The edges of the bronchial fistula were freshened with a curette and the pedicled muscle flap was turned *into* the fistula for a distance of one inch, so as to plug the bronchus. (Fig. 14.) It was su-

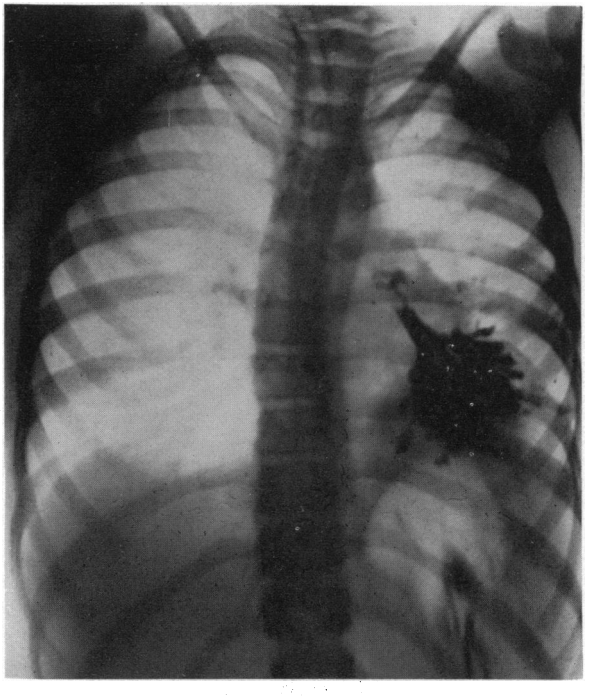

FIG. 19.—Case III. X-ray following injection of lipiodol into the thoracotomy wound, showing the outline of a large branch of the left lower bronchus.

These were removed in forty-eight hours. The wound healed by primary union and the patient was discharged from the hospital eighteen days later. (Figs. 15 and 16.)

When last seen, February 17, 1929, the patient said he had gained thirty pounds in weight, had returned to his former occupation and had no symptoms referable to his cardio-respiratory system. (Fig. 17.)

CASE III.—N. H., girl, thirteen years of age, was first admitted to the Medical Ward of the New York Hospital because of persistent cough, with pain in the left lower chest, of two weeks' duration. This had occurred one week after recovery from a three weeks' illness with pneumonia. Physical examination showed a moderately ill, well-developed and well-nourished girl. Temperature 103° F., white blood cells, 22,250, polymorphonuclear leucocytes 87 per cent., hæmoglobin 74 per cent. Physical examination, confirmed by X-ray, gave the signs of fluid in the left chest. Upon aspiration, purulent material was obtained which cultured Pfeiffer's bacillus. The patient was transferred to the Second Surgical Division and on July 3, 1928, a rib resection was performed. Two rubber tubes were inserted.

FIG. 20.—Case III. Lateral view of the same condition noted in Fig. 19.

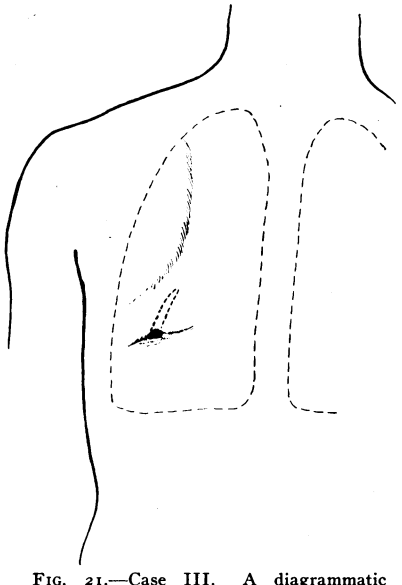

FIG. 21.—Case III. A diagrammatic sketch of the appearance of the wound before closure of fistula.

After operation, convalescence was smooth, except for the fact that the wound continued to drain profusely. On the twentieth post-operative day, it was noticed that irrigation of the wound with saline solution caused severe coughing, and that the patient tasted the salt. She was discharged on the forty-fourth post-operative day with a small granulating sinus and a definite bronchial fistula.

The patient was treated at the Out-Patient Department until September 21, 1928, without any decrease in the discharge from the wound, or tendency to closure of the fistula.

She was readmitted September 21, 1928. Examination at this time showed a granulating

sinus in the centre of the thoracotomy wound which extended inward for about one and a half inches. (Fig. 18.) X-ray after injection of lipiodol showed a bronchial fistula involving a large branch of the lower left main bronchus. (Figs. 19 and 20.) The thoracotomy wound was enlarged October 2, 1928, and there was found a large bronchial fistula adherent to the chest wall. The wound was dressed repeatedly until it became fairly clean. Because of the persistent cough and the failure

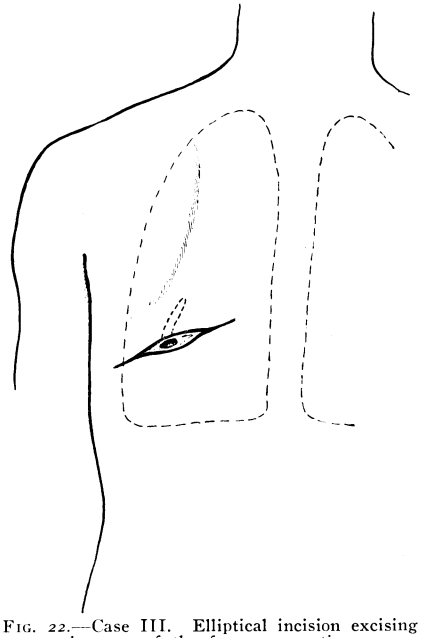

FIG. 22.—Case III. Elliptical incision excising the scar of the former operation.

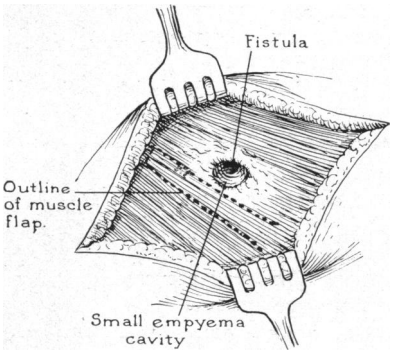

FIG. 23.—Case III. Indicating the outline of the muscle flap to be placed into the fistula. The small empyema cavity is indicated.

of the fistula to close spontaneously, operative closure was decided upon.

October 22, 1928, the following operation was performed: An elliptical excision of

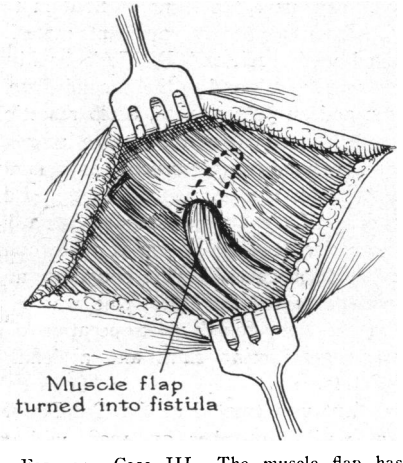

FIG. 24.—Case III. The muscle flap has been inserted into the bronchial fistula.

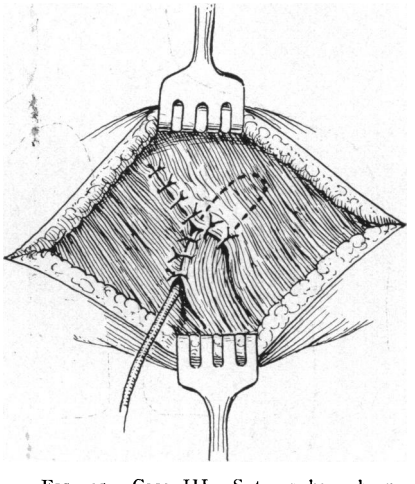

FIG. 25.—Case III. Sutures have been placed anchoring the muscle flap to prevent dislodgment. The small tube drain is indicated.

the previous scar was made (Figs. 21 and 22.) Upper and lower skin flaps were fashioned. The latissimus dorsi muscle was then isolated. An empyema cavity measuring

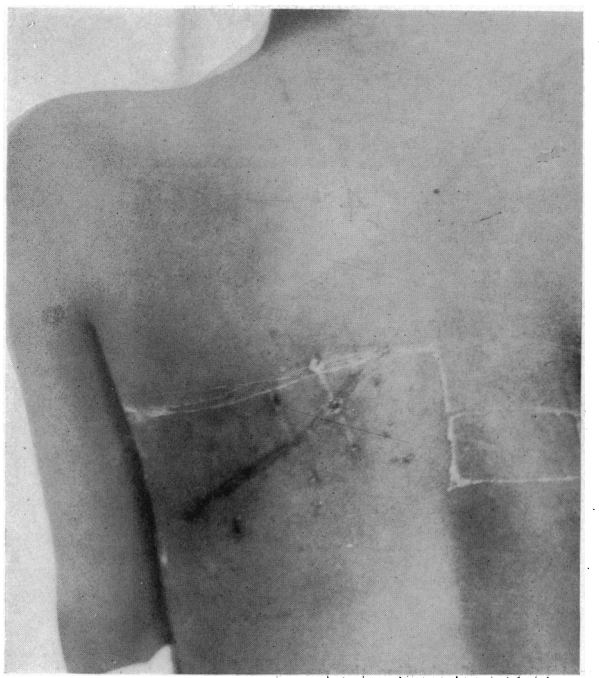

FIG. 26.—Case III. Appearance of wound eighteen days following closure of the bronchial fistula.

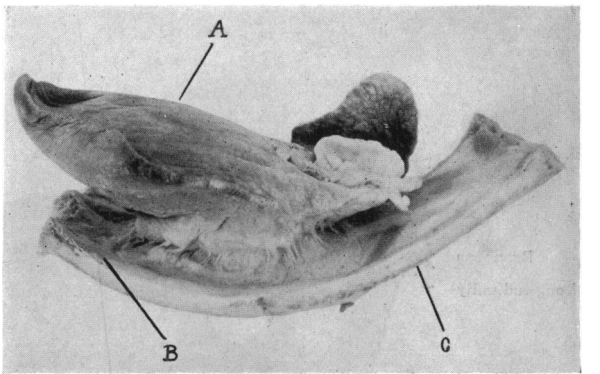

FIG. 27.—Experiment 8 described in protocols. Gross specimen showing lobe of lung adherent to the parietal pleura. The adjacent ribs are included. *A*—Lobe of lung. *B*—Parietal pleura. *C*—Ribs.

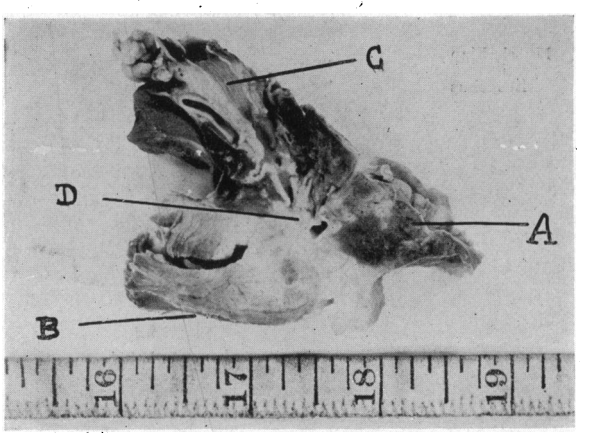

FIG. 28.—Experiment 8. Longitudinal section through the specimen pictured in Fig. 27 after removal of the ribs and excess lung tissue. One may note the pedicled muscle flap, the lobe of the lung, and a large bronchus cut longitudinally and again transversely. The muscle flap may be seen within the lumen of the bronchus. *A*—Lobe of lung. *B*—Pedicled muscle flap. *C*—Bronchus. *D*—Muscle flap in bronchus.

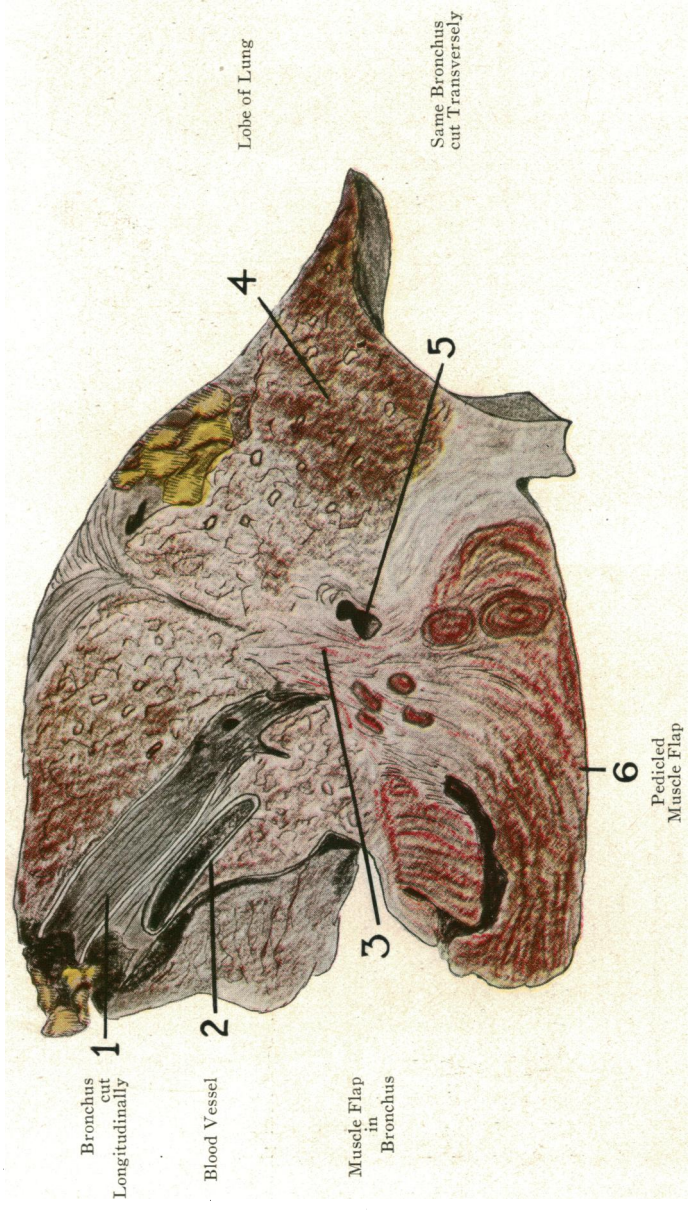

FIG. 29.—A diagrammatic sketch of the gross specimen pictured in Fig. 28, showing the muscle flap in the lumen of the bronchus.

one centimetre in diameter was visualized. At its mesial and upper aspect was a broncho-pleural fistula measuring about one centimetre in diameter. (Fig. 23.) A pedunculated muscle flap taken from the latissimus dorsi was then fashioned. (Fig. 24.) It was longitudinally bisected. The smaller segment was implanted *into* the fistula for a distance of about half an inch, and the latter one into the empyema cavity. The muscle flap was sutured to the surrounding muscular and fascial tissue. (Fig. 25.) Coughing did not cause extrusion of the flap. A tiny rubber tube drain was placed down to the empyema cavity behind the flap and the wound was closed with plain catgut for the deeper structures and silkworm gut for the skin. Ethylene anæsthesia; time, twenty minutes. The arm was immobilized to the side. The tube was removed on the fourth post-operative day. Convalescence was uneventful and the wound healed by primary union. (Fig. 26.) The unusual part of the convalescence was that, following operation, the patient did not cough once, although no sedatives were administered.

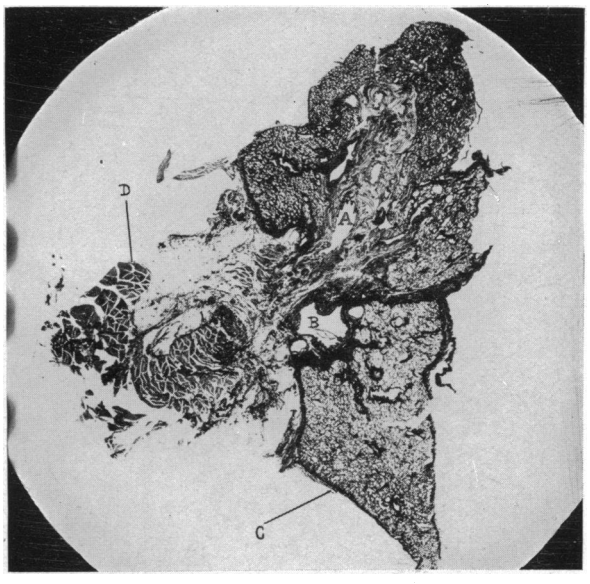

FIG. 30.—Microscopic section of the entire specimen pictured in Fig. 29. (Magnification x 2½.) The pedicled muscle flap enters into the bronchus which has been cut longitudinally at one point, *A*, and transversely, *B*, at another. Beyond is seen lung parenchyma. *C*—Lobe of lung. *D*—Muscle flap.

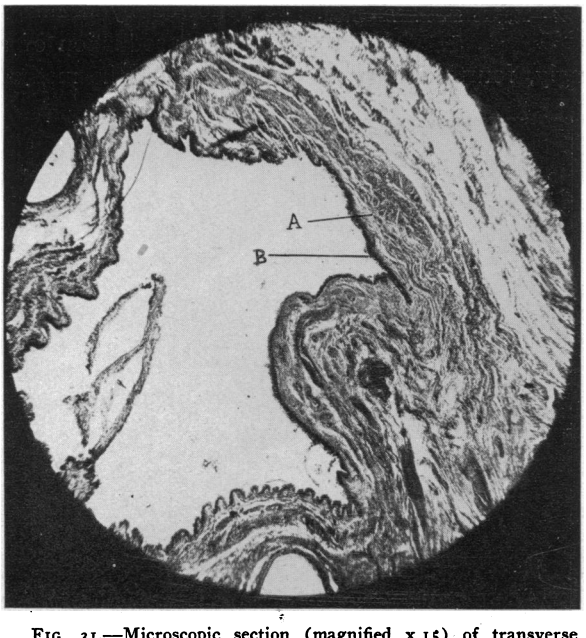

FIG. 31.—Microscopic section (magnified x 15) of transverse section of the bronchus, *B*, seen in Fig. 30. In this section may be seen the intact striated muscle fibres of the muscle flap over which has grown the bronchial epithelium. There is a moderate amount of fibrosis. *A*—Striated muscle fibres. *B*—Bronchial mucosa.

When last seen, April 7, 1929, the patient had gained fourteen pounds, had returned to school, and had had no symptoms referable to her former condition.

EXPERIMENTAL DATA ‡

In order to determine what happens following the performance of such an operation, and to study

‡ From the Surgical Research Laboratories, College of Physicians and Surgeons, Columbia University, Dr. William C. Clarke, Director.

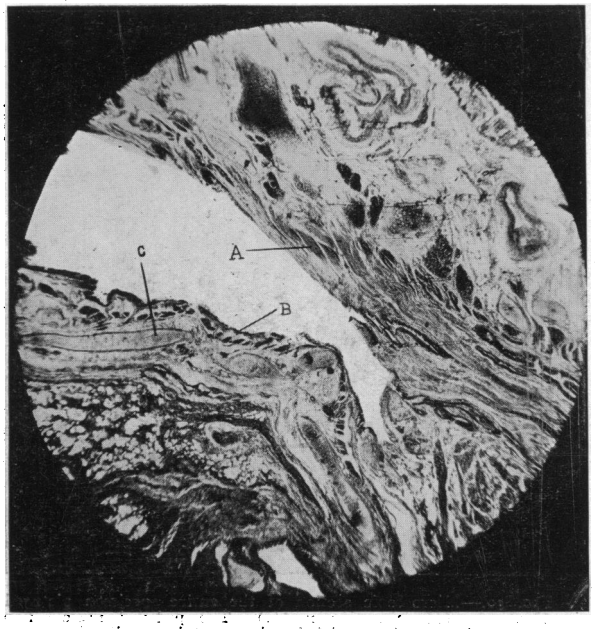

FIG. 32.—Another view of the longitudinal section of the bronchus, *A*, pictured in Fig. 30 (magnified x 15) showing the intact striated fibres of the muscle flap and the outgrowth of bronchial mucous membrane, which has not yet completely covered the flap. The bronchial cartilages are visible. *A*—Muscle fibres. *B*—Bronchial mucosa. *C*—Bronchial cartilage.

the processes of repair, experiments on dogs were undertaken. It was felt that an attempt should be made to simulate, as closely as possible, the conditions found in man with lung or pleural suppuration. From this standpoint, however, the results were disappointing. We were unable to produce chronic pulmonary or pleural suppuration. We were able, however, to determine what happens to a muscle flap which has been plugged into a bronchus. In the beginning, the idea was to produce a lung abscess, to be followed by drainage with the production of a bronchial fistula. Accordingly, fourteen dogs were subjected to the method of Cutler, Schlueter and Weidlein. We tried to follow their technic in detail, but failed to obtain a single instance of lung abscess. This may be attributed to the fact that, although numerous strains of various organisms were used, we did not employ organisms pathogenic for the dog.

The experimental production of an empyema in the dog is quite easy, but because of the high mortality rate and the fact that the production of a bronchial fistula under these conditions was not feasible, this par-

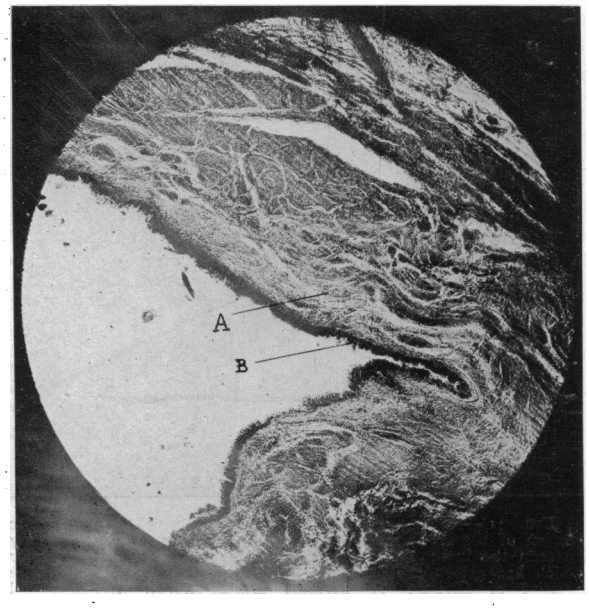

FIG. 33.—A higher power microscopic section (magnified x 90) of the bronchus pictured in Fig. 31, showing the intact striated muscle fibres and the complete regeneration of the bronchial mucosa. *A*—Muscle fibres. *B*—Bronchial mucous membrane.

ticular method was abandoned.

After numerous unsuccessful attempts, a method for the artificial formation of a bronchial fistula was finally evolved. It may be stated incidentally, that it is extremely difficult to produce a bronchial fistula in an experimental animal because of the small size of the bronchial tree, the resulting shock when the pleural cavity is opened, and in view of the fact that experimental animals, especially dogs, rapidly heal any artificially produced pathological lesions.

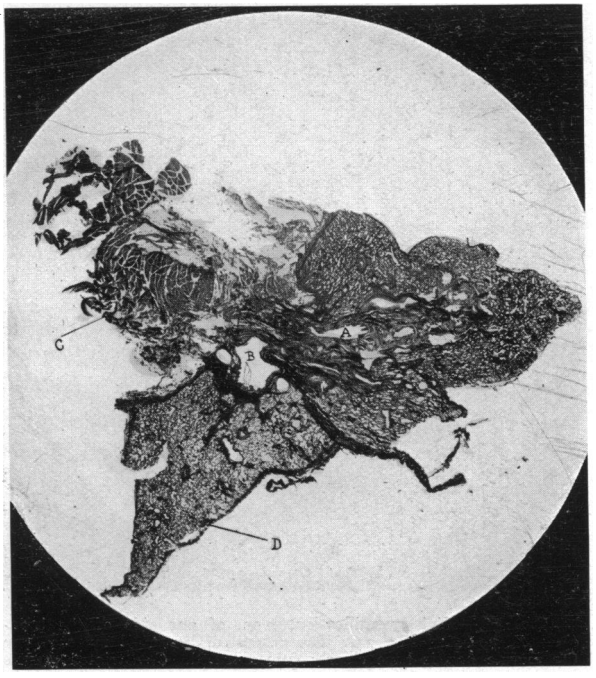

FIG. 34.—Microscopic section cut at a deeper level than that pictured in Fig. 30. The pedicled muscle flap within the lumen of the bronchus is clearly outlined. (Magnification x 2½.) *A*—Bronchus cut longitudinally. *B*—Same bronchus cut transversely. *C*—Muscle flap. *D*—Lobe of lung.

The operative procedure finally adopted was as follows: The animal was anæsthetized with ether. The entire left side of the chest wall was carefully prepared by shaving, scrubbing with alcohol and ether, and painting with 3.5 per cent. tincture of iodine. An oblique incision about five inches in length was made along the course of the sixth rib in the posterior axillary line. The overlying muscles were retracted. The sixth rib was then exposed and removed for a distance of three inches subperiosteally. Its encircling periosteum and the adjacent

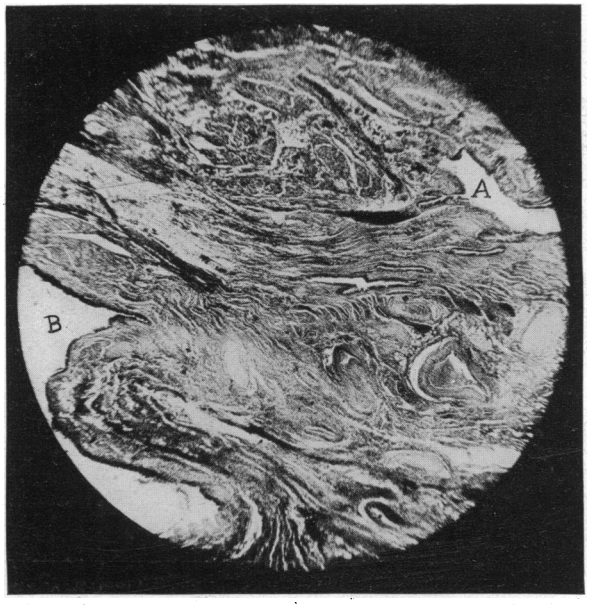

FIG. 35.—Microscopic section of higher magnification, x 15, including bronchus *A* and *B* and muscle flap, pictured in Fig. 34. This shows both sides of the sectioned bronchus with the muscle flap between. The viability of the muscle fibres is noteworthy.

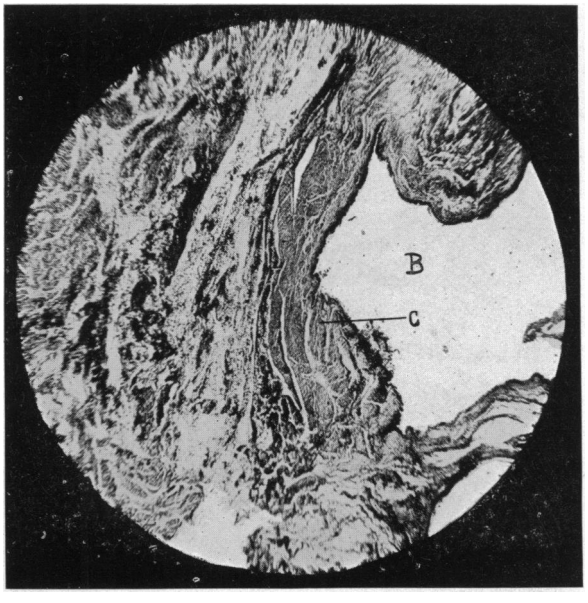

FIG. 36.—High magnification, x 90, of one side of the bronchus, *B*, noted in Fig. 35. The growth of bronchial mucosa over the muscle flap is here clearly demonstrated. *C*—Striated muscle fibres.

intercostal muscles were then very carefully dissected from the parietal pleura and excised, a procedure involving great care because of the ease with which the extremely thin parietal pleura may be perforated. Through the thin pleura can be seen the underlying expanded lung. Using a very fine curved needle and fine silk, stitches were taken in a circumferential manner in such a way as to catch both pleura and lung in each bite. By this method, a lobe of the lung can be sutured to the parietal pleura without producing a pneumothorax. After inserting ten or twelve sutures, involving a surface of the lung approximately one and a quarter inches in diameter, the overlying pleura was excised and the wound was closed by replacing the retracted muscles. The skin and subcutaneous tissues were sutured with fine silk so as to produce eversion of the skin edges. A cotton-collodion dressing was applied followed by a chest bandage and the application of a canvas jacket.

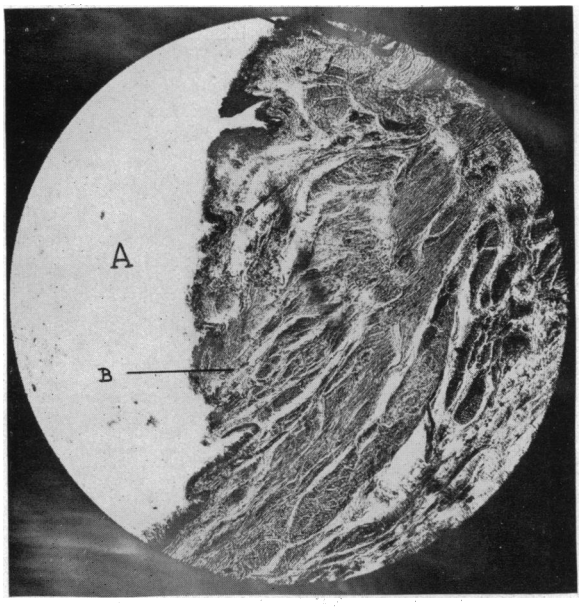

FIG. 37.—High magnification, x 90, of the other side of the bronchus, *A*, pictured in Fig. 35, showing the distribution of the striated fibres of the muscle flap covered by bronchial mucosa. The scarcity of fibrous tissue formation is especially noteworthy. *A*—Bronchus. *B*—Muscle fibres.

Two weeks later a second operation was performed. After careful skin preparation, the scar

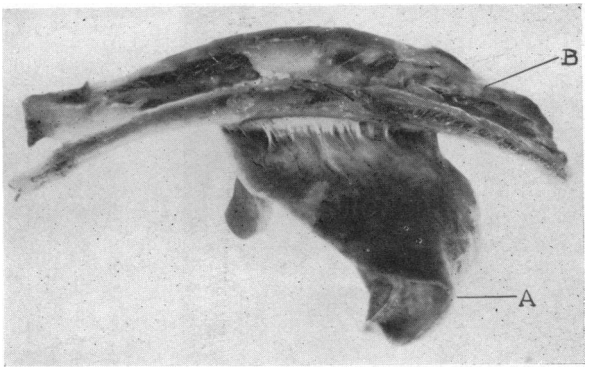

FIG. 38.—Experiment 10 described in protocols. Gross specimen of lobe of lung adherent to the parietal pleura with the adjacent ribs. *A*—Lobe of lung. *B*—Ribs.

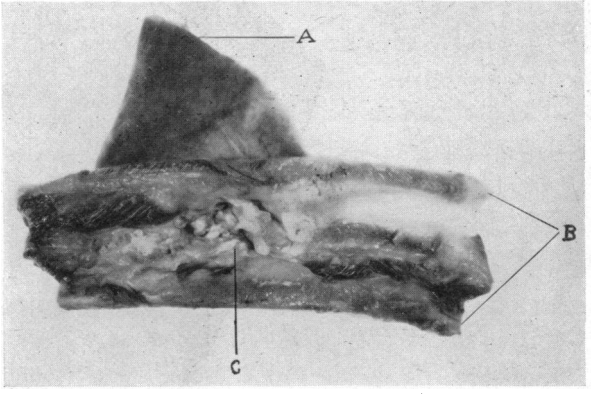

FIG. 39.—Another view of the specimen pictured in Fig. 38, showing the external surfaces of three ribs with the pedicled muscle flap. *A*—Lobe of lung. *B*—Ribs. *C*—Pedicled muscle flap.

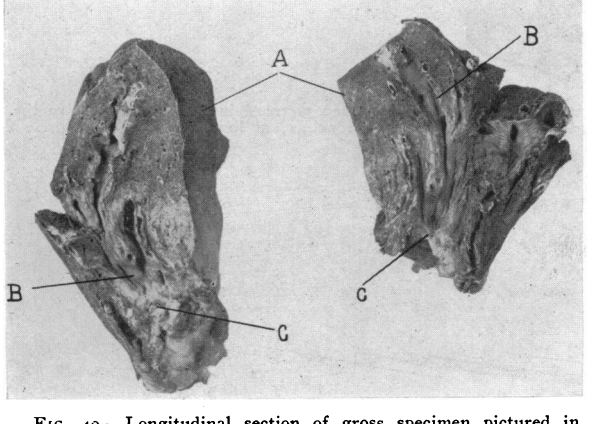

FIG. 40.—Longitudinal section of gross specimen pictured in Figs. 38 and 39, after removal of the ribs and excess lung tissue. Here one may see a large bronchus cut longitudinally, surrounding lung tissue, and at the lower pole the pedicled muscle flap over which there has been a growth of bronchial mucosa. *A*—Lung. B—Bronchus cut longitudinally. *C*—Muscle flap.

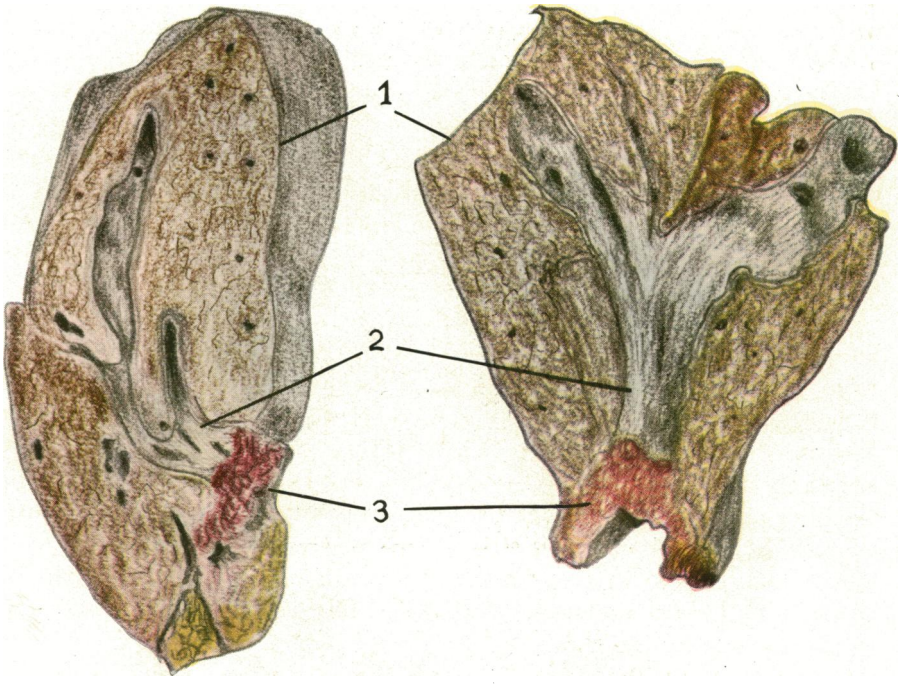

FIG. 41.—Diagrammatic sketch of the specimen pictured in Fig. 40, to clarify the details of the various components. 1—Lobe of lung. 2—Bronchus cut longitudinally. 3—Muscle flap in bronchus.

of the former operation was excised. The overlying musculature was again retracted, exposing the lobe of the lung adherent to the parietal pleura at the rim of the opening. By blunt dissection an opening was carefully made into the substance of the lung and extended deeper and deeper until a fair size bronchus was encountered. Not infrequently, a large pulmonary vessel simulates closely the appearance of a bronchus. Therefore, in each instance, a fine aspirating needle was inserted to determine the contents of the structure isolated. When satisfied that the structure was a bronchus, stay sutures of fine silk were inserted and an opening made into it. By dissecting this structure from its surrounding lung parenchyma, considerable mobilization was obtained. A bronchocutaneous fistula was then formed by suturing the previously mobilized skin flaps to the edges of the opening in the bronchus with fine silk. A sterile dressing was then applied and held in place by bandage and a canvas jacket.

During the following ten days the wound was dressed daily. At each dressing, bronchial secretion which tended to occlude the opening was carefully wiped away. Every other day during this period the bronchus was cauterized with carbolic acid followed by alcohol. The purpose of this procedure was to cause a denudation of the bronchial mucosa. It was necessary to perform the final stage within the ten-day period in order to prevent the spontaneous closure of the fistula.

At this last operation, the scar was excised and the skin separated from the adherent bronchial opening which, by this time, had become fairly well fixed near the periphery of the lung. A pedunculated flap of muscle, corresponding to the size of the fistula, was then fashioned from the latissimus dorsi muscle which had been previously preserved intact. This flap was tubularized by approximating the lateral edges with fine plain catgut sutures. It was then placed deeply *into the bronchus* for a distance of one-half to three-quarters of an inch and held in place by fine catgut stitches placed in the muscle and the rim of the fistula. The remainder of the muscle flap was anchored to the surrounding structures with silk sutures so as to avoid strain on the flap when the animal was up and about. The remainder of the wound was then closed without drainage, care being taken to obliterate all dead spaces. A sterile dressing and canvas jacket were then applied.

While this procedure was carried out in ten dogs, in only two were satisfactory specimens obtained. These dogs lived ten months and one year respectively. Their protocols are herewith appended:

PROTOCOLS

Experiment 8.—No. 9499, female collie. *First stage operation,* December 22, 1927. Ether anæsthesia. Left chest wall prepared as above described. Three inches of the fifth rib excised through an oblique incision. Intercostal muscles and periosteum dissected from parietal pleura and excised, leaving an opening about one and a quarter inches in diameter. Interrupted sutures of fine silk were then placed circumferentially, uniting lobe of lung to the parietal pleura. The overlying retracted muscles were then replaced and the skin closed with silk.

Second stage operation, February 1, 1928. The scar of the former operation was excised. Overlying muscles retracted, exposing adherent lobe of lung. By blunt dissection, a hole was made into the substance of the lung until a large bronchus was isolated. It was aspirated with a fine needle. Stay sutures of silk were inserted and an opening made into the bronchus, approximately three-eighths of an inch in diameter. The bronchus was mobilized by freeing it from its surrounding tissues and sutured to the edges of the skin flaps. The remainder of the wound was then closed with fine catgut for the muscles and silk for the skin.

February 2, 1928, wound dressed. Fistula patent. Bronchial secretion wiped away.

February 3, 1928, phenol and alcohol applied to fistula.

February 5, 1928, phenol and alcohol again applied to fistulous opening.

February 7, 1928, phenol and alcohol again applied.

Third stage operation, February 10, 1928. The scar of the previous operation was excised, freeing the skin edge from its attachment to the bronchial opening. Skin flaps were then fashioned and the latissimus dorsi muscle isolated. A pedunculated muscle flap was then freed and fashioned into a tube measuring about three-eighths of an inch in diameter. It was then turned *into* the bronchus for a distance of one-half inch and anchored to the rim of the bronchial opening with interrupted sutures of fine catgut. The remainder of the muscle flap was then anchored to the surrounding structures by inserting interrupted sutures of silk. All dead spaces were obliterated and the wound closed without drainage.

This animal was killed on February 1, 1929, one year after the last operation. At autopsy, the broad surface of the middle lobe of the left lung was found firmly adherent to the parietal pleura. After separation of the skin and subcutaneous tissues, the muscle flap was isolated. The entire specimen was excised for study. (Fig. 27.)

The adjoining ribs and excess muscle and lung tissue were removed. The plugged bronchus was then isolated by carefully opening the bronchial tree from the main bronchus as a starting point. When the occluded bronchus was seen, the specimen was bisected longitudinally at this point. The cut gross section is shown in Figures 28 and 29. It will be seen that the main portion of the bronchus has been cut longitudinally. Entering into the bronchus is a small muscle flap, and below this point the same bronchus has been cut transversely. The muscle flap was found firmly united to the wall of the bronchus, and, in the gross, there was evidence of the outgrowth of bronchial epithelium to cover the muscle flap. There was little to indicate inflammatory reaction in the adjacent lung parenchyma.

Microscopic sections of the entire cut surface were then made. (Figs. 30, 31, 32, 33, 34, 35, 36, 37.) Dr. Gilbert Dalldorf of the pathological department, at New York Hospital, has kindly examined these sections and his report follows: "The specimen is an equilateral triangle, about four centimetres on each side. The lower part is lung parenchyma and a transverse line separates this from the triangular mass of muscle tissue. At about its mid-point the muscle tissue is seen to enter a distended bronchiole which appears distorted. The muscle is largely intact, but in places, alternates with fibrous tissue. Although the relationship between this bronchiole and the smaller ones is asymmetric and unnatural, all of these structures, however, are normal in the sense that their walls are intact and lined with tall columnar epithelium. The bronchiole which contains the muscle is distended, the lumen measuring roughly three by four millimetres. There is practically no inflammatory reaction either in the lung or the muscle flap. With the operative procedure as described, it seems reasonable to assume from examination of the specimen, that there has been a growth of bronchial epithelium over the sides of the muscle flap lying within the lumen of the bronchus."

Experiment 10.—No. 9731. Male Irish terrier. *First stage operation,* February 28, 1928. Ether anæsthesia. Left chest wall prepared as above described. An operation identical with the one described under Experiment 8 was performed.

Second stage operation, March 9, 1928.—The scar of the former operation was

excised and the adherent lung visualized by retraction of the overlying muscles. A hole was then made bluntly into the substance of the lung until a large bronchus was isolated. This bronchus ran in a somewhat vertical direction. After mobilization from the surrounding lung parenchyma, stay sutures were applied and the bronchus drawn up into the wound, thus creating a Y formation. The edges of the opening in the bronchus, which measured three-eighths of an inch, were sutured to the edges of the skin flaps with silk. The remainder of the wound was closed as above described.

March 10, 1928, wound dressed. Bronchial secretion which tended to plug the opening removed, reëstablishing a flow of air.

March 12, 1928, bronchial secretion removed. Carbolic acid and alcohol applied to the fistula.

March 14, 1928, phenol and alcohol again applied. Fistula patent.

March 16, 1928, phenol and alcohol again applied. Strong flow of air noted.

Third stage operation, March 18, 1928. The scar of the previous operation was excised, liberating the skin edge from its attachment to the bronchial opening. Skin flaps were then dissected and the latissimus dorsi muscle isolated. A pedunculated muscle flap was then formed and split longitudinally. Each segment of the split flap was then rolled into a tube and inserted into the two limbs of the Y-shaped fistula. The flap was then anchored to the rim of the fistula with fine catgut. The remainder was sutured to the surrounding structures to prevent dislodgment. All dead spaces were obliterated and the wound closed without drainage.

This animal was killed on December 26, 1928. At autopsy, the broad surface of the middle lobe of the left lung was found firmly adherent to the parietal pleura. The adjacent ribs, the lobe of the lung, and the overlying musculature were excised *en masse* for study: (Figs. 38 and 39.)

The adjacent ribs and the excess lung and muscle tissue were excised. The plugged bronchus was isolated by careful dissection of the bronchial tree from its origin. When this point was reached, the entire specimen was bisected longitudinally. The gross cut section is shown in Figures 40 and 41. It will be seen that the bronchus has been divided longitudinally. At its lower extremity is a section of the muscle flap which lies firmly united to the interior of the bronchus at this point. In the gross, the outgrowth of bronchial epithelium to cover the surface of the muscle flap is clearly indicated. There is no evidence of inflammatory reaction in the lung parenchyma.

CONCLUSIONS

1. Bronchial fistulas occur most commonly with empyema thoracis and lung abscess.

2. The majority close spontaneously.

3. Persistence of a fistula may be due to suppuration in the parenchyma of the lung or the bronchial tree, the presence of a rigid-walled empyema cavity into which the fistula opens, the formation of a broncho-cutaneous channel or the presence of a foreign body.

4. Operative closure of a bronchial fistula should not be attempted until the need for drainage of a lung suppuration has passed.

5. Very small fistulas will frequently close following the local application of some cauterizing agent.

6. For the closure of a bronchial fistula which persists in spite of conservative measures, an operative procedure is described. This consists in plugging the fistula with a pedunculated muscle flap. The operation is simple, of wide application, and has proved successful in our experience.

7. The production of a bronchial fistula in an experimental animal is attended with great technical difficulties.

8. Although the experimental data herewith reported do not duplicate exactly conditions as found in man, the results obtained indicate clearly the processes of repair following closure of a bronchial fistula by the method described.

9. A muscle flap placed into a bronchial fistula to effect its closure remains viable and is not completely replaced by fibrous tissue. Microscopic examination shows intact muscle fibres at the end of a year.

10. The sections further disclose the growth of bronchial epithelium over the muscle flap.

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