

THE PRESENT STATUS OF THE SURGICAL TREATMENT OF CARCINOMA OF THE LUNG*

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THIRTEEN YEARS have now elapsed since the first total pneumonectomy was performed in the Johns Hopkins Hospital. Previous to that time a diagnosis of pulmonary malignancy was made infrequently and more for academic than practical reasons. Prior to this time no therapeutic measures or methods were available which offered the patient more than palliation. Medicinal and radiation therapy were then, as now, equally ineffective and the disease when so treated was, and is, always fatal.

The surgical treatment of malignant tumors of the lung has been a boon to patients and a lively stimulus to clinicians interested in pulmonary lesions. Because of this increased interest on the part of physicians the diagnosis of tumors of the lung is made much more frequently than in the past, with the result that a greater number of such patients are being referred for operation. In a Medical Center in which a special interest in this type of surgery has been manifested, what seems a disproportionate increase in the frequency of these cases is apt to occur, but it may probably be true that the incidence of primary pulmonary cancer is on the increase.

It is the purpose of this report to record the clinical analysis, preoperative preparation, operative procedure, immediate and remote postoperative results in a series of 327 consecutive cases of carcinoma of the lung which have been referred for surgical treatment, not accounting for those instances in which the patient was obviously inoperable from the standpoint of the clinical findings.

CLINICAL ANALYSIS

Etiology.—Although the etiologic factors involved in the production of cancer are unknown, there is enough data accumulated to draw some conclusion as to the influence of certain factors to which human beings are exposed. In this and other series of cases reported, one fact has been outstanding as probably playing a definite rôle in the production of pulmonary carcinoma, that is the great majority of patients afflicted with this malady are residents of urban districts. In such districts, from the cradle to the grave, the lungs are constantly exposed to many irritating substances, such as dust, dirt, various fumes, gases and other atmospheric pollutions which have a deleterious effect on the lining cells of the bronchial tree throughout its entire extent. It is a well-known fact that miners and, particularly in various places in the world,

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laborers exposed to certain foreign particles in the air, are very prone to develop growths in the lung. It is also fully recognized that individuals who are working in contact with irritating gases, such as chlorine and others, frequently develop epithelial growths in the air passages. Changes in oxygen tension will affect the type of epithelial lining cells, often causing a metaplasia from the cylindrical cell to a flat cell. This morphologic transposition may also be found in the bronchi which are tributaries to areas of infection, such as lung abscess or bronchiectasis. In other words, chronic irritation, regardless of the type, will produce changes in the growth-rate and shape of the cells of the lung which seem to be very sensitive to this pollution of the atmosphere. It will be interesting, now that women are smoking, to see if the much higher ratio of the malignancy of the lung in men, is decreased by an increase in the incidence in women.

Due to the occupational hazards mentioned above as well as habits, a higher incidence of primary malignant tumors of the lung is to be expected in the male than in the female. Table I shows the distribution according to sex of the patients in this series. It is to be noted that there is a much higher incidence in the male than in the female, a ratio of almost 6 to 1 in favor of the males. The incidence of involvement of the right and left sides is approximately the same.

In regard to the age incidence of primary malignant tumors of the lung, this does not vary to any great extent from the age incidence of malignant growths elsewhere in the body. The majority of the patients were in the fourth to sixth decades. Perhaps patients in the second to fourth decades were more frequently affected than would be the case of other viscera; however, this series of cases, although relatively large, is far too small to warrant an exact statement. Twelve of the cases fall into the sixth decade. The oldest patient in this series to be operated upon was 76 years of age and the youngest 19. Age, in itself, seems to offer no contraindication to operation. Not infrequently an older patient from a physiologic point of view is a far better operative risk than a younger one. In this series the older patients were surprisingly unaffected by the operative procedure, including the patient age 76, and generally had uneventful postoperative convalescences. Pulmonary cancer, however, generally speaking, is a disease of advanced age.

Unfortunately for the lay public, physicians as a whole, because of the lack of therapeutic measures to combat such lesions or to effectively treat them, have been less acutely interested in the possibility of malignant growths of the lung than those of other viscera or organs of the body. It is, therefore, important that not only all physicians, but also the lay public, should become cognizant of their respiratory tracts in order that they may at the earliest moment seek confirmation or dissipation of their apprehensions in regard to signs and symptoms originating in their respiratory organs.

It is mandatory that the knowledge of the signs and symptoms originating as a result of malignant tumors of the lung be made known to the public as a whole, just as every woman knows the significance of a tumor of the breast

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and realizes the importance of immediately consulting a physician concerning such a tumor.

In the analysis of this series of patients herein reported, in regard to the most frequent signs and symptoms occurring in such cases of primary cancer of the lung, only those signs and symptoms were included that could be attributed to involvement of the lung itself and not to invasion of contiguous structures or distant metastases. In 71 per cent of the patients in this series cough was the chief symptom. In a nation of heavy cigarette smokers, in which the population supplying the majority of patients breathes the polluted atmosphere of cities, cough is almost universal and is due mainly to nonspecific irritation of the respiratory tract. The important point about coughing that should make one suspicious of the presence of an intrabronchial growth is the departure from the normal for any individual. If in an adult "chronic cough"

TABLE I
DISTRIBUTION ACCORDING TO SEX OF CASES OF
PRIMARY CARCINOMA OF THE LUNG

	Operable	Inoperable
Male.....	84%	86%
Female.....	16%	14%

TABLE II
SIGNS AND SYMPTOMS OF CARCINOMA OF THE LUNG

Cough.....	71%
Hemoptysis.....	63%
Pain.....	50%
Loss of weight.....	39%
Hyperpnea.....	23%
Pneumonitis.....	18%
Fever.....	13%
Tightness in chest.....	3%

the type of cough changes to a spasmodic, productive or nocturnal type, or, again, if a person who has heretofore coughed infrequently suddenly begins to be annoyed by a hacking cough day and night, attention should be focused on the bronchial tree and the presence of a bronchial neoplasm should be suspected. The development of a cough or changes in the character of coughing can portend an extremely serious condition. Until physicians as a whole, as well as the lay public, become more acutely aware of the serious significance of this sign, the opportunity for early and satisfactory treatment of pulmonary neoplasms will be denied to many patients. It is to be noted, again, that the outcome in this condition, unless recourse is had to surgery, is invariably fatal. These symptoms and signs are listed according to the frequency of their occurrence in Table II.

In 63 per cent of our patients expectoration of blood or hemoptysis was associated with coughing. This varied from streaking of the sputum to the

expectoration of large and copious amounts of blood, up to six ounces (180 cc.). In the latter group the accumulation of blood in the mouth was preceded by a "gurgling" in the chest on one side which warned the patient of the impending hemoptysis. In our experience, copious hemoptysis has usually been associated with the adenocarcinoma type of intrabronchial growth. Unless

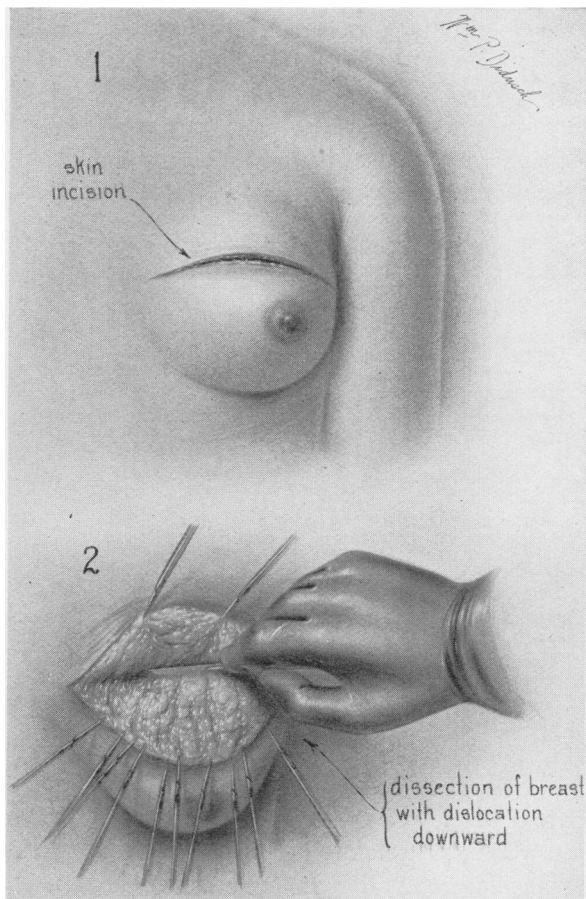


FIG. 1.—Demonstrating the first two operative steps using the anterior approach.

the roentgenograms and sputum examination are indisputably those of tuberculosis or bronchiectasis, hemoptysis must be considered to be due to an intrabronchial growth until this has been ruled out by the many types of examinations at our command. The burden of proof is on the physician who, in any given case, states that hemoptysis is not due to a tumor of the lung. This is true even though a small number of tubercle bacilli may be present in the sputum. Tuberculosis and cancer may be associated, and were in four cases

in our series. Clinical examinations to diagnose an intrabronchial tumor in no way interfere with the treatment of pulmonary tuberculosis; but if a patient bleeding from a tumor of the lung is observed for months in an attempt to prove the case to be tuberculosis, in many instances he will have lost his only opportunity for successful treatment. The discovery that the bleeding was originally from a neoplasm will have come too late.

Although it is uncommon to have pain as a prominent symptom in cancer of other organs, it is third in prominence among the signs and symptoms in patients afflicted with cancer of the lung. Pain arising from an intrabronchial neoplasm must be differentiated from the pain due to direct invasion of contiguous structures. Pain arising from the lung itself is not associated with the respiratory cycle, as is the pain of pleuritis. It is most often described by the patient as a constant dull ache deep in the chest. The frequency with which the actual position of the tumor, as shown by roentgenography, coincided with the location of the level of pain on the chest wall, as indicated by the patient, was surprising. In all probability pain does not arise within the tumor itself but is a result of pressure on the bronchial wall. Persistent pain in the chest, in the absence of inflammatory disease or aspiration of a foreign body, should always lead to careful investigation of the respiratory tract. Pain down the arm or in the chest wall, so characteristically found in the so-called "superior sulcus or Pancoast tumor," is, as a rule, due to direct invasion of the ribs or the brachial plexus or both. This distribution of pain is considered a very unfavorable symptom from the standpoint of operability.

Loss of weight due to cachexia in advanced carcinoma of any organ in the body, particularly the gastro-intestinal tract, is well-known and obvious; but not so easily understood was a striking loss of weight in 39 per cent of the cases of pulmonary carcinoma. This loss of weight was, of course, due in part to coughing, loss of appetite because of hemoptysis and sputum, worry, *etc.*; but the rapid gain of 30 to 50 pounds in a few months after total pneumonectomy for the removal of a relatively small growth remains unexplained.

Fifth on the list of signs and symptoms is hyperpnea, occurring in 23 per cent of the patients. These patients complained of a sudden desire to breathe in deeper breaths, not exactly similar to air hunger but approximating this condition. The deep breathing sensation one experiences when breathing carbon dioxide would seem to be similar. This paroxysmal hyperpnea came on suddenly and lasted for a few seconds or a few hours. The mechanism for this respiratory phenomenon is difficult to explain. It may possibly be caused by a plug of mucus occluding a secondary or tertiary bronchus already partly plugged by an intrabronchial neoplasm, the bronchopulmonary segment of lung, to which the occluded bronchus is a tributary, thus, becoming the site of an obstructive emphysema. Reflex disturbances in the respiratory rate and amplitude are thus set up. With expulsion of the mucus plug the respiratory rate returns to normal. Such unusual changes in the respiratory cycle, even though of short duration, should excite one's curiosity sufficiently to suggest a thorough examination of the bronchial tree.

Eighteen per cent of the patients had suffered from attacks of pneumonitis associated with episodes of fever and all the signs and symptoms characteristic of pneumonia. It was frequently possible to obtain a history of numerous attacks of so-called "pneumonia" in the recent past. The chief characteristic of these attacks was that they occurred at any time of the year, with apparently no tendency toward seasonal incidence, as in the true epidemic pneumonia.

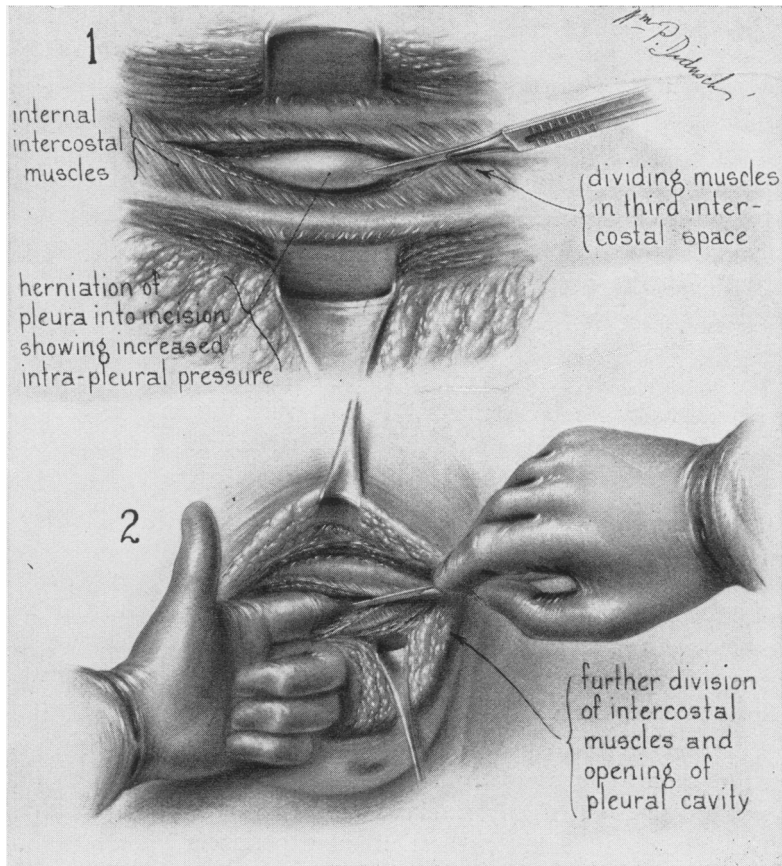


FIG. 2.—Showing entrance to thoracic cavity with minimum amount of damage.

Furthermore, physical signs were atypical and in unusual locations as regards the lung itself. Lobar, broncho or interstitial pneumonia, as a rule, present fairly typical physical signs. This is not the case in pneumonitis due to bronchial obstruction associated with primary carcinoma of the lung. The explanation for these unusual observations is not far to seek when their pathogenesis is considered. When obstruction of a bronchus, whether primary, secondary, tertiary or quaternary occurs as a result of a new growth, alone or in

association with a mucus plug, the bronchial tree peripheral to the point of occlusion becomes filled with mucus. Eventually infection of this bronchopulmonary segment occurs and the clinical syndrome of localized pneumonitis is produced. A portion of a lobe of greater or lesser dimensions, the entire lobe or even the entire lung may be involved. If exacerbations of such a pneumonitis are of sufficient frequency, bronchiectasis, or even an abscess, will at times supervene. Often such an abscess perforates into the pleura and produces putrefaction empyema. The point to be emphasized is that when such an unusual sequence of events takes place, or when any one of the previously-mentioned inflammatory episodes occurs that cannot be explained as a complication of a typical pneumonia or as a result of aspiration of a foreign body, an intrabronchial growth should be suspected. It is the repetitious nature of such pneumonitis which makes it so significant.

In general, it may be stated that there are no characteristic or pathognomonic signs and symptoms of primary carcinoma of the lung. This lesion masquerades as many of the more common disorders of the lung. The onset is often insidious, but the recurrent nature of signs and symptoms previously described should call attention of the patient and the physician to the respiratory tract so that a thorough examination will be carried out. Especially is this true of a patient who has previously had excellent health and in whom, after the second decade, there develops a cough associated with spitting of blood. Too often precious time is lost because of a diagnosis of pulmonary tuberculosis, lung abscess, unresolved pneumonia, bronchiectasis or heart disease. The methods of examination employed to rule out the presence of an intrabronchial growth in no way interferes with the diagnosis or treatment of any of the conditions which are at times mistaken for such a growth.

Diagnosis.—In this series of 327 cases the roentgenograms of the chest were positive in every instance. It is not suggested that a diagnosis of primary carcinoma of the lung could be made from the roentgenographic studies alone, but there was in each case an abnormal shadow which necessitated further study and examination. Thus, it may be stated emphatically that in every instance in which roentgenograms of the chest show a departure from normal, and in which this departure is not in every way characteristic of one of the commoner lesions of the lung, the presence of bronchogenic cancer should be inferred. Unquestionably, the roentgenograms of the chest are the most important and simplest method of examination at our disposal. Even in the earliest stages of growth of a primary carcinoma of the lung the lesion, as a rule, can be discovered. In the early part of the last decade, and even today, it was, and is, disheartening to watch an early lesion develop over a period of months into an inoperable cancer of the lung because physicians who were not, and are not, aware of this danger would advise the patients to “wait and see what happens.” “Coming events often cast their shadows before them”—it is equally true that shadows cast by hilar infiltration due to other conditions, such as tuberculosis and even normal structures, are confusing. However, an infiltrating hilar shadow in a patient past middle age, associated with cough,

hemoptysis and the absence of tubercle bacilli in the sputum almost certainly indicates a bronchogenic carcinoma; most of these carcinomas are located at or near the hilus or root of the lung. The diagnosis of cancer of any organ cannot be definitely made by roentgenologic examination alone, but the more experienced the observer the greater the likelihood of an accurate interpretation. Positive roentgenograms may show a shadow produced by the new growth itself or by an area of atelectasis, bronchiectasis, pneumonitis or abscess caused indirectly by occlusion, by the growth, of a bronchus leading to a bronchopulmonary segment or segments.

In my experience, second to the roentgenogram in importance in yielding information which is helpful in arriving at a definite diagnosis is bronchoscopy. In fact, either by direct vision or biopsy or both a positive diagnosis of primary carcinoma of the lung can be made only in this manner. In 70 per cent of the patients in this series a positive biopsy of the cancer was obtained. A pulmonary new growth in the periphery or even in the hilar lesions confined to the upper lobes may be beyond the vision of the bronchoscopist. Nevertheless, valuable information can be elicited by bronchoscopy even when the growth cannot be seen, such as fixation or deformity, or both, due to pressure of any visible portion of the bronchial tree. The presence of blood or purulent discharge from certain bronchi serve as a lead. In this series of cases there have been no untoward results during or after bronchoscopic examinations.

Bronchography is a useful diagnostic method only to reveal occlusion of a bronchus by a small growth which does not produce a shadow in the roentgenograms of the chest. However, it is a harmless procedure and may be the link in the chain of evidence pointing to the possible presence of carcinoma of the lung.

Aspiration biopsy has a limited field, is often difficult to interpret, and such procedures are not without danger of implanting some cells along the tract of the aspiration needle or infecting the pleural cavity with the same cells, with tubercle bacilli or other pyogenic organisms. Aspiration of the bronchial tree has in some instances revealed cancer cells which could be obtained for microscopic examination.

Exploratory thoracotomy should be resorted to far more frequently in the future than it has in the past. This is, with the present-day anesthetics and surgical technic, a relatively harmless procedure—far more so than exploratory celiotomy and attended with fewer dangerous sequelae, such as adhesions. Exploratory thoracotomy is far less incapacitating than celiotomy. When it has been impossible to arrive at a definite diagnosis by all the means at our disposal this procedure should be performed at once, if a dangerous pulmonary lesion such as primary carcinoma is suspected. In our series of cases no deaths have occurred as a result of simple exploration of the chest. If direct observation and palpation of the lesion does not reveal the true nature, excision of the entire area in the lobe should be performed for immediate microscopic examination, and the diagnosis is made as is customary for questionable cases of carcinoma of the breast. If further discussion of the sit-

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uation with the patient seems advisable, the wound may be closed and the patient returned to his room for further consultation. Later in the week the chest can be reopened and the definite procedure carried out. The old idea that opening the thoracic cage at operation is another form of euthanasia must be abandoned. The impression that all primary malignant tumors of the lung are slow-growing and late in metastasizing is incorrect.

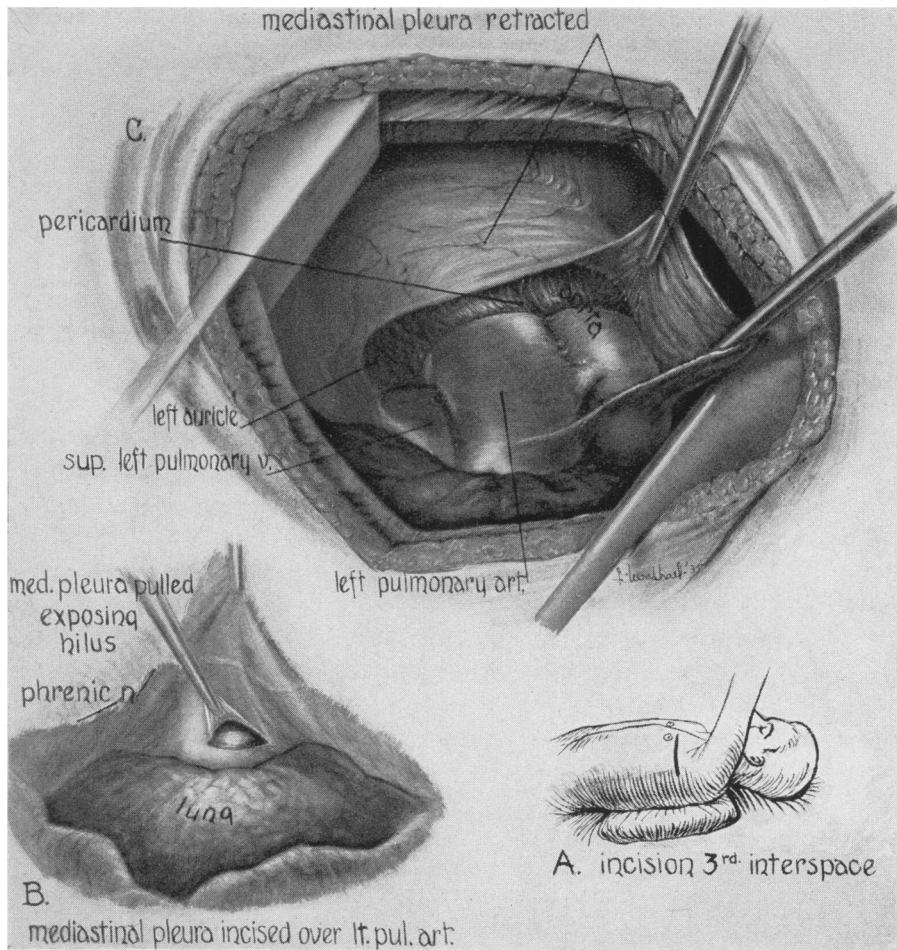


FIG. 3.—Exposure of hilar structures on the left side through anterior approach. Note ease of exposure of pulmonary artery, aorta and pulmonary veins.

Pathology.—The surgical removal of primary carcinoma of the lung in a relatively early stage has brought about changes in our ideas of the origin and nature of the growth of such tumors. In the past practically all the data were based on the autopsy in very late cases, when it was impossible on account of the almost universal involvement of the lung and contiguous structures to determine the nature, origin and progress of the growth within the lung. In this

series of cases the tumors occurred at or adjacent to the hilus, the minority in the periphery of the lung. The latter seemed to spread throughout the area of the lung in which they originated by centrifugal growth, most of them apparently having arisen in the alveolar lining cells. The hilar tumors, all of which were bronchogenic in origin, grew grossly in two separate fashions. The one, an intrabronchial tumor arising apparently from the bronchial mucosa, grew into the lumen of the bronchus and towards the trachea. The centripetal tendency of the growth, occluding completely or partly the primary or secondary

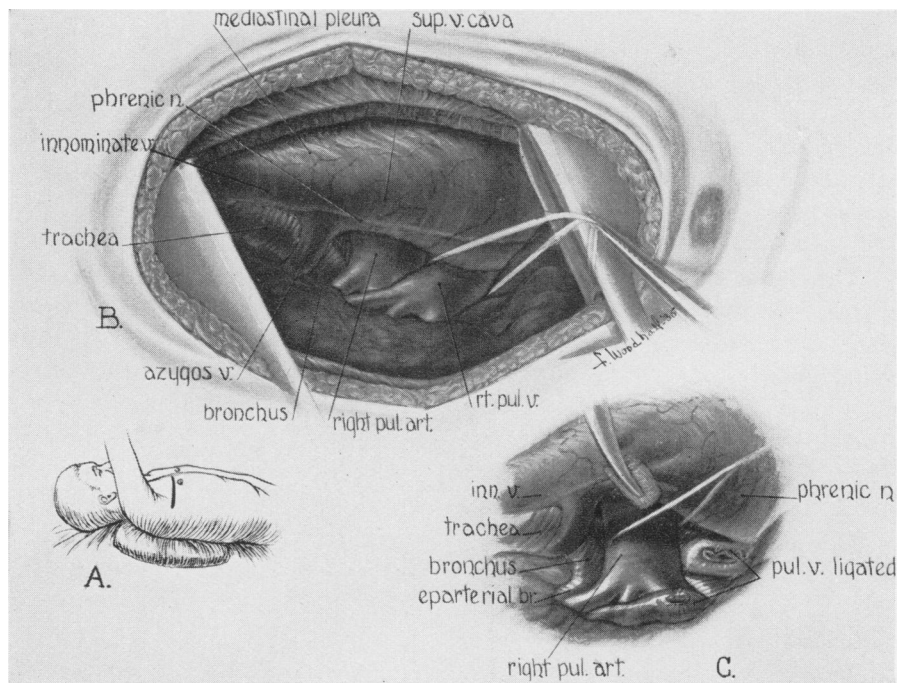


FIG. 4.—Exposure of hilar structures on right side. Pulmonary vessels lying anterior to bronchus are readily demonstrated.

bronchus was characteristic. The other type of hilar growth was an extra-bronchial tumor which, probably arising in the wall of a secondary, tertiary or quaternary bronchus, would break through the wall and grow along outside of, and often completely around, the bronchus. This type of growth, also, showed this centripetal tendency, growing around and about the secondary and primary bronchi and then spreading directly into the mediastinum to involve the structures contained therein.

The clinical course is dependent to a great extent on the method of growth. It is, of course, obvious that the intrabronchial type will produce respiratory difficulties, cough, sputum, and hemoptysis much earlier than the extra-bronchial tumor. The first symptoms caused by the latter method of growth may be, for example, interference with the venous return from the neck owing

to the involvement of the superior vena cava on the right side, or recurrent laryngeal palsy on the left, or Horner's syndrome. Malignant tumors arising in the periphery are, as a rule, asymptomatic. They may be said to arise in the silent area of the lung and as they do not, as a rule, produce bronchial obstruction or erode pulmonary vessels the symptoms and signs are usually those dependent on invasion of the pleura and chest wall and, by direct extension, the brachial plexus.

In 70 per cent of the 112 patients upon whom a total pneumonectomy was performed there were metastases to the bronchial and tracheal lymph nodes. This fact emphasized the necessity of performing a total pneumonectomy with dissection of these regional nodes in order to effect a permanent cure. In the remaining 215 cases that were inoperable, in addition to the metastases in the regional nodes the various organs and structures that were the site of metastases are listed in the order of the frequency of their involvement: supraclavicular and axillary lymph nodes, liver, pleura, pericardium and heart, contralateral lung, osseous tissue, brain and multiple areas in the skin and subcutaneous tissue.

The characteristic histologic structure of the tumor occurring in this series of cases was that of a flat and squamous cell carcinoma and adenocarcinoma. Under these two main headings were included various examples such as oat cell, cylindrical cell and adenocarcinoma thought to be different forms of the same tumor. The adenocarcinoma type is pleomorphic. Sections of the tumor differ depending upon the region from which they were cut. Sixty-five per cent of the cases in this series were composed of a flat or squamous cell cancer and 35 per cent the adenocarcinoma group.

It is interesting to note that the length of life, computed on the basis of the microscopic characteristics of the tumor, showed that those afflicted with the squamous, or flat cell type, lived a greater length of time than those with the adenocarcinoma type.

Treatment.—Preoperative Preparation: For several days preceding operation the patient should be carefully prepared. It has been our custom to treat the patient with intramuscular injection of penicillin 30,000 units, every three hours, avoiding awakening the patient at night. In addition to this penicillin aerosol should be employed. Whether or not some of the sulfonamides should be used has been questioned. It is my personal opinion that for some days, approximately three, sulfamerazine may be administered by mouth. The patients, thus, have a protective blood level of this drug which apparently does no harm. It is merely an added questionable merit and so far we have not been able to observe any demerits.

However, the preoperative preparation which we consider of the greatest importance is the induction of artificial pneumothorax. The advantage of this procedure has been proved over a period of years. In the first place, it must be considered a therapeutic test, particularly in individuals in the fifth or sixth decade in which there may be a certain degree of unrecognized emphysema. Removing the lung at operation without knowing whether or not the patient

can sufficiently oxygenate himself with the remaining lung may constitute a fatal error, and in the past we have experienced this tragic result. The ability of the remaining lung to function sufficiently for the needs of the patient can be established before operation is performed by merely collapsing the lung on the affected side. Various tests, such as oxygen saturation of the blood at body rest and during exercise of various degrees of intensity can be ascertained. For

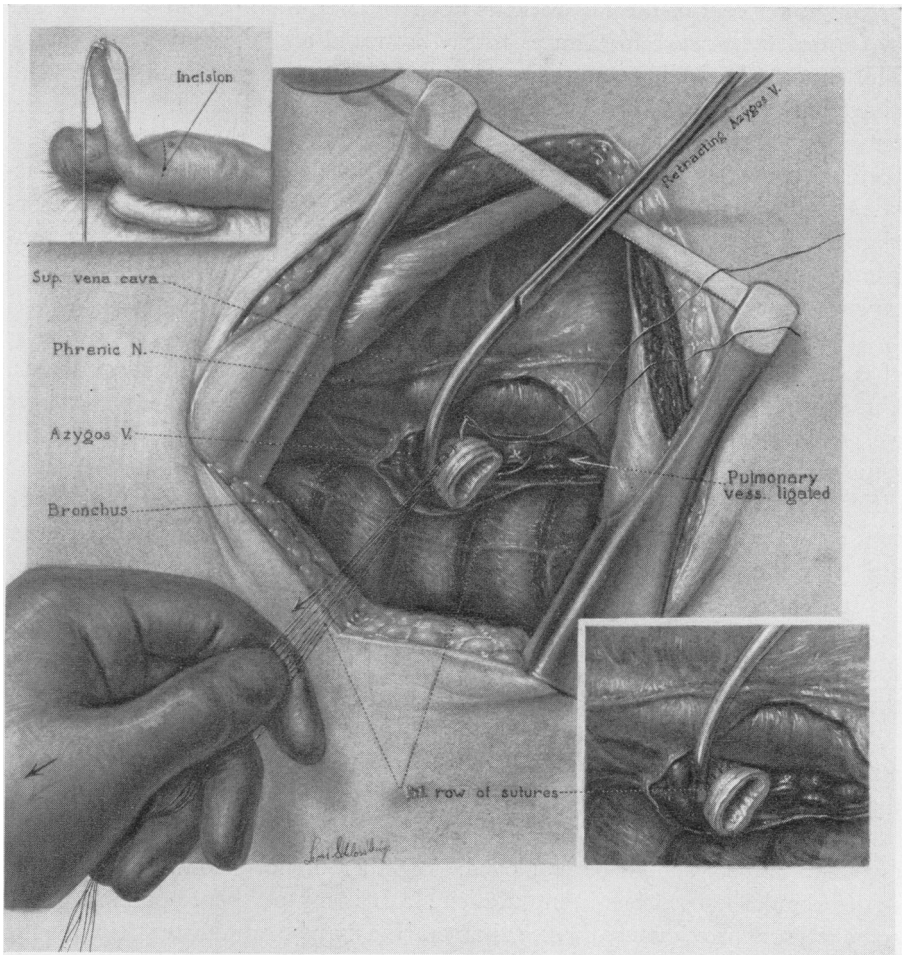


FIG. 5.—Demonstrating placing of interrupted mattress sutures occluding bronchus 1 cm. proximal to cut end. Note cuff-like portion of bronchus distal to suture line.

after all to cure a patient of a malignant tumor of the lung is futile, if the patient is left with insufficient aeration surface to support normal respiration. There are other minor advantages and secondary ones associated with artificial pneumothorax, such as diminishing the size of the lung so that the mechanical handling of this structure is technically made easier at the time of operation. Second, the patient has learned to breathe with one lung previous to operation

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and with the increased intrapleural pressure, thus, avoids pleural shock on opening the thoracic cavity. Third, the blood flow through the collapsed lung is less than through the expanded contralateral lung and, therefore, the strain on the right heart from shifting greater blood flow through one pulmonary artery is graduated. Fourth, the location of a growth as regards the position relative to the mediastinum is often silhouetted and, therefore, located more accurately in the collapsed lung than with an expanded lung.

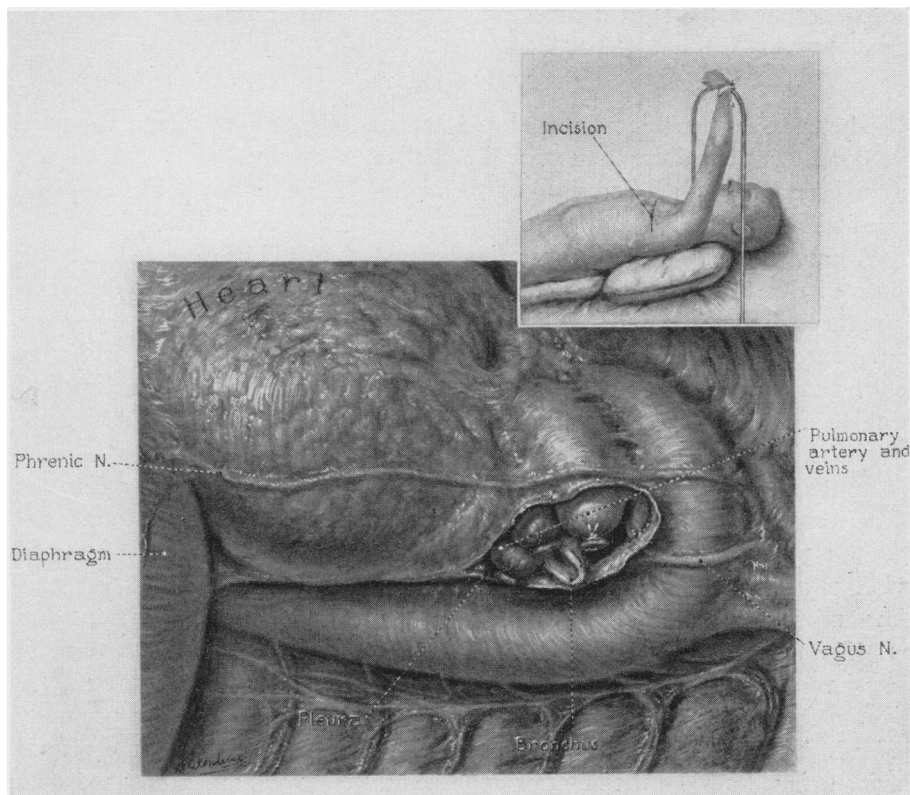


FIG. 6.—Lung amputated, hilar structures ready to be pleuralized, showing relation of pulmonary vessel to bronchus. Open cuff of bronchus visible.

Treatment.—In our present state of knowledge the only efficacious method for treatment of pulmonary carcinoma is by surgical removal of the entire organ, together with the regional lymph nodes. Medicinal and radiation therapy are only palliative, and as these tumors are, as a rule, radio-resistant, radiation therapy is of no benefit. It is interesting to note that in 215 cases of this series which were found to be inoperable at the time of exploration of the thoracic cavity, the average length of life after leaving the hospital was approximately five months, and this in spite of the fact that every type of supportive therapy, and in many instances, radiation therapy, were employed. It is to be emphasized again that the disease runs a fatal course in 100 per cent of the

patients in whom the lung cannot be removed in its entirety by operation. From an anatomic standpoint, the lung lends itself to surgical removal more readily than any other organ in the body, with the possible exception of the breast. From the point of view of the biologic characteristics of primary carcinoma of the lung surgical removal is more apt to be successful because of the relatively slow growth and spread of these tumors as compared to similar tumors in other regions of the body. Finally, the remarkable ability and tendency of the contralateral lung to undergo compensatory changes prevents incapacitation of the patient from a physiologic point of view.

OPERATIVE TECHNIC

The operative technic now employed for one-stage total pneumonectomy in the treatment of malignant tumors is essentially the same, except for closure of the bronchus, as that described by the author in 1933 in the Johns Hopkins Hospital Bulletin.¹

A number of points in the operative technic, as would be expected, are still controversial and as in any other operative procedure a unanimity of opinion as regards the various methods is hardly to be expected. But, after 13 years' experience and having employed this operative technic in 327 cases, of which 112 were total pneumonectomies, it is felt desirable, with the background of this experience to discuss certain steps in the operative procedure which are of special interest.

In the first place, the anterior approach is definitely to be preferred to the posterior or lateral for the following reasons: (a) the width of the intercostal spaces is greater anteriorly than posteriorly and the necessity for resection of ribs is, therefore, as a general rule, not necessary. This reduces the operative time and the general ill effects of the procedure upon the patients (Figs. 1 and 2). The thoracic cavity is more quickly entered with a minimum amount of damage to the chest wall and parieties. The use of a self-retaining retractor gives sufficient exposure so that the question of operability can be promptly judged. The time consumed from the incision to the entrance of the pleural cavity is far less when the anterior approach is employed, and associated with this there is a minimum loss of blood as well as trauma to tissues. If a greater amount of exposure is desired the adjacent intercostal cartilages can be incised and the ribs, usually the third and fourth, can be displaced cephalward or caudalward. Also, by slightly rotating the patient on the operating table, or the table itself, if desired, the incision can be extended laterally so that the maximum exposure can be obtained. If the tumor proves to be inoperable, the minimum of operative trauma has been incurred. The operability can be determined at once with the minimum operative effort. In the event the growth is operable the dissection of the hilar structures, such as the pulmonary artery and veins which lie anterior to the bronchus, is accomplished with far greater ease and facility when the anterior approach is employed (Figs. 3 and 4). The advantage of ligating the pulmonary artery at the beginning of the operation is obvious, the control of hemorrhage is, thus, more certainly

assured and the greater percentage of blood normally contained within the lung is returned to the general circulation *via* the pulmonary veins. Bleeding from any adhesions that may exist between the visceral and parietal pleura is reduced to a minimum. If for any reason it is felt desirable to interrupt the operative procedure and perform the operation in two stages, one can do so after ligation of the pulmonary artery, provided the pulmonary veins have been left intact. If the latter are ligated, the lobe which either one or both pulmonary veins drain, must be removed, for otherwise, gangrene of this portion of the lung will ensue. It is to be noted that the bronchial veins are vestigial in character and do not function sufficiently to even drain off the blood brought



FIG. 7.—Left side of bronchus, plus denuded hilar surface covered with pleura.

to the lung by the bronchial artery, to say nothing of that from the much larger pulmonary artery. When the pulmonary artery, which carries venous blood is ligated collateral circulation through the bronchial artery is at once established. The bronchial artery brings sufficient arterial blood to the lung to maintain this organ in a normal state of nutrition and the circulation through the lung is, thus, changed from a venous to an arterial one. Whereas normally the greater amount of blood flowing through the lung capillaries is venous in character, originating from the pulmonary artery, the blood flowing into the same capillary bed from the bronchial artery is arterial. Stoppage of the blood flow from the pulmonary artery by ligation of the latter, incurs a great increase in

flow from the bronchial artery and, thus, fills the capillary bed in the lung and the branches of the pulmonary artery up to the point of ligation with arterial blood, containing such a high saturation of oxygen that the lung is, thus, rendered essentially functionless as far as further oxygenation of the blood flowing through it is concerned. The development of this collateral circulation *via* the bronchial artery begins after ligation of the pulmonary artery is performed. In the early days simultaneous ligation of one or both pulmonary veins invariably resulted in moist gangrene of the corresponding lobe or lobes because of the vestigial character of the bronchial veins. In the event of ligation of a pulmonary vein that portion of the lung whose venous bed is a tributary to that vein must be removed at the time of operation.

Not infrequently total pneumonectomy may be carried out with a greater degree of safety if a two-stage operation is performed, in which only the pulmonary artery is ligated as the principal objective of the first stage. This is particularly true when the lung is the site of a great deal of infection and extensively adherent. The arterialization of the lung with a flow of more highly oxygenated blood would appear to have a beneficial effect on the pulmonary infection and, therefore, the patient's clinical condition.* Dividing the operation into two stages greatly diminishes the shock of the procedure. It has been found that the pulmonary vessels, the artery and veins, are best ligated with silk, or cotton, and in no instance has this type of ligature been known to cut through the vessel wall.

TREATMENT OF THE BRONCHIAL STUMP

Since 1942, when the method of closing of the bronchus was first reported by the author in the ANNALS OF SURGERY² the bronchial stump has been occluded by the use of mattress sutures of interrupted silk or cotton placed through the bronchus in such a manner that the posterior membranous portion is approximated to the anterior cartilaginous wall, somewhat proximal to the end of the amputated stump, thus, creating a viable cuff from 1 to 2 cm. distal to the suture line which immediately fills with a fibrinous clot that thereafter becomes infiltrated with cells and eventually forms a fibrous plug (Fig. 5).

* In patients suffering from pulmonary tuberculosis ligation of the pulmonary artery has a definite deleterious effect. In eight patients the pulmonary artery was occluded with the idea of bringing about an atelectasis of the lung. The lesions were very extensive in each case and associated with large cavities. However, the change from a lower oxygen tension in the blood flow through the lung following ligation of the pulmonary artery, to the higher oxygen content of the blood flow from the bronchial artery exercised a most marked detrimental clinical and pathological effect on the patient and lung. This was apparent by a more rapid progression of the manifestation of the disease than would have been expected had the pulmonary circulation not been interfered with at all. No atelectasis was produced and cavitation increased rapidly. This unfavorable result was attributed to the fact that the tubercle bacillus flourished in an environment of higher oxygen content. It would be interesting to find out the effect of ligation of only the bronchial artery in pulmonary tuberculosis. The reverse condition of oxygen saturation would then obtain.

One of the more important steps in securing a satisfactory closure of the bronchial stump is to sew a pedicle flap of parietal pleura over the end of the stump of the bronchus approximating the pleura to the rim of the viable cuff. The use of any form of cauterization or traumatization to the end of the bronchial stump has been studiously avoided in order that agglutination of the rim of this cuff and the pleural membrane would be brought about immediately and permanently. Any foreign material such as sutures in the end of this cuff or devitalization of the rim of this cuff will militate against the immediate healing. Therefore, the bronchial stump should be sutured at least a centimeter

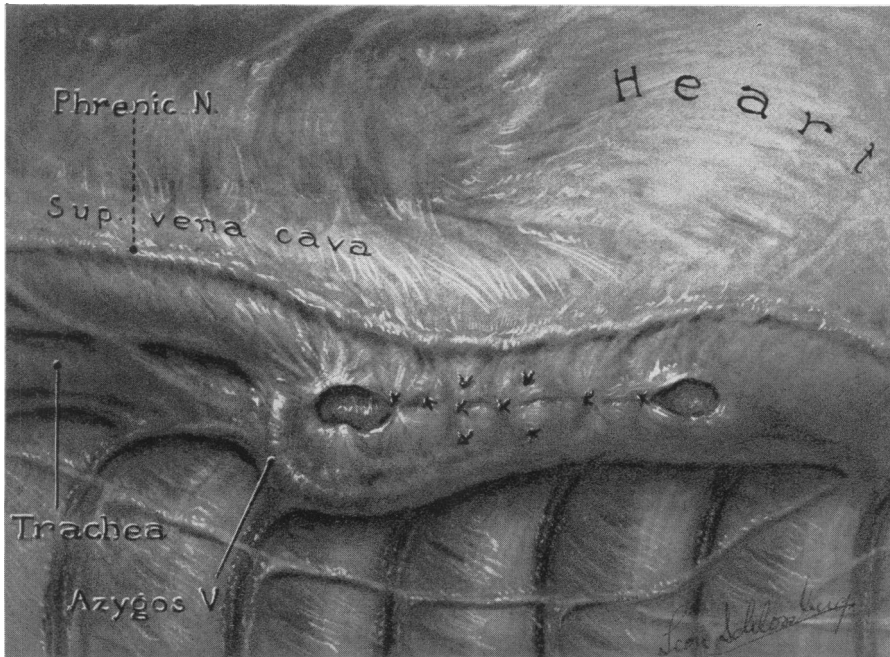


FIG. 8.—Right side of bronchus, plus denuded hilar surface covered with pleura.

proximal, if possible, to the point at which amputation is anticipated. Regardless of the type of suture material or the manner in which it is placed, cutting through the posterior or anterior membranous portion of the bronchus will frequently occur. This has been proved experimentally and at autopsy² (Fig. 6). Unless every opportunity is, therefore, afforded for the bronchial cuff distal to the suture line to heal by the formation of granulation tissue within its walls leakage will follow in a rather high percentage of cases. In the event that the bronchial growth extends up toward the carina, the bronchus and also the lower end of the trachea may be sutured after a diagonal incision in this structure has been made. This suture, as in the bronchus, should be tied sufficiently tight to approximate the walls of the bronchus or trachea, but not enough to cause crushing of the tissue. If so, the sutures will cut. They should also be

placed so that the knots are tied about the cartilaginous rings, that is on the anterior surface of the bronchus or trachea. Healing of the stump takes place at the cut end and the sutures which occlude the lumen of the bronchus, usually from four to six in number, must be considered as only temporary, with their main purpose to exclude the passage of air through the bronchial stump long

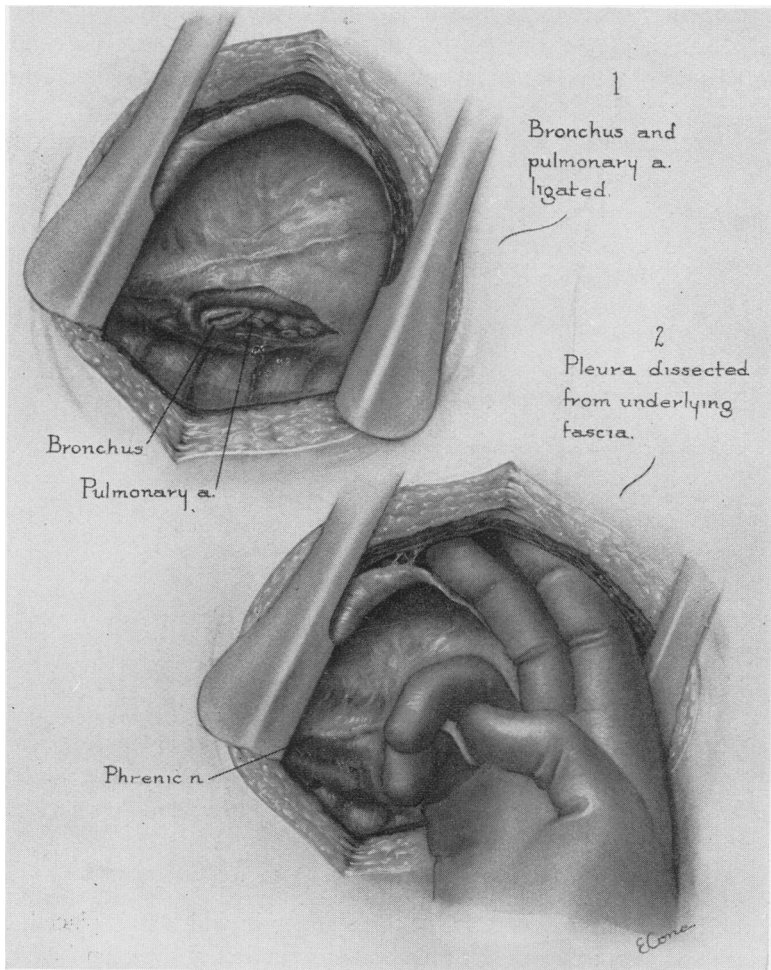


FIG. 9.—Mobilization of pleura over anterior chest wall, developing flap of parietal pleura to cover raw area of hilus. The same method can be used in mobilization of the parietal peritoneum over the vertebral gutter.

enough for the healing of the end of the bronchus to be completed, or sufficiently so, that in the event the sutures cut through, to form a tight and impenetrable occlusion of the bronchial stump that will not open up and allow air to pour into the pleural cavity. The healing of the end of the bronchial stump requires, as a rule, from one to two weeks, varying in different individuals, and seems to be completed in the majority of cases after a period of 10

to 14 days. However, there have been instances in our series in which the stump in one patient reopened after a month, one after three months and one even after eight months. However, these, fortunately, eventually healed and the patient was none the worse off except for the disagreeable experience asso-

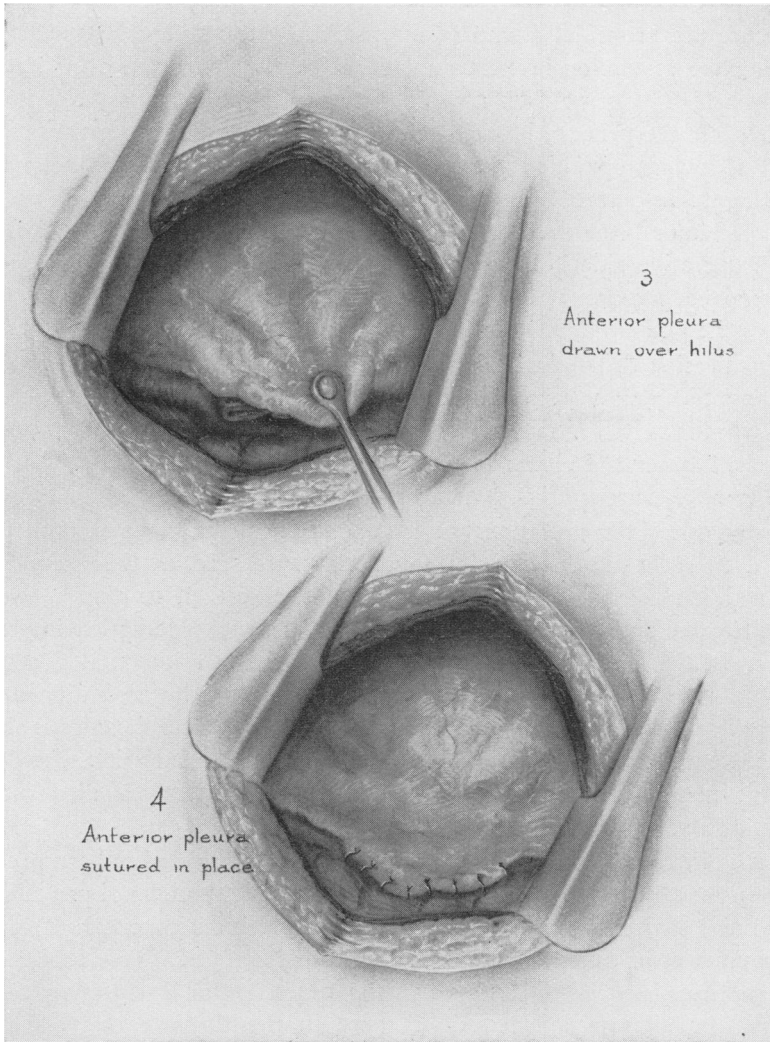


FIG. 10.—Mobilization of pleura over anterior chest wall, developing flap of parietal pleura to cover raw area of hilus. The same method can be used in mobilization of the parietal peritoneum over the vertebral gutter.

ciated with walled-off empyema, which was satisfactorily treated by drainage and irrigation with penicillin.

Interrupted mattress sutures may be employed by stitching the anterior cartilaginous wall laterally, infolding the posterior membranous portion, pro-

viding the cartilaginous rings are incised at the apex of their arc, this in the midline of the anterior surface of the bronchus. This method has been satisfactorily employed in some cases. (Fig. 7—Fig. 8.)

All types of suture material have been used—catgut, silver wire, steel wire, fascia, and others—and it is our opinion that interrupted sutures of silk or cotton would seem to be the material of choice.

Before the bronchial stump is sutured, after amputation of the lung, the inside of the remaining bronchus should be carefully inspected, for not infrequently a blood clot or even a piece of tumor tissue may be dislodged from the lung into the primary bronchus during the course of the operation. Immediately following operation the patient is again bronchoscoped while on the operating table before being returned to the ward. Often small clots and pieces of tumor tissue have been discovered not only in the bronchial stump on the operative side but even in the trachea. If these foreign bodies were not removed, aspiration into the contralateral lung might eventuate in the death of the patient.

Mobilization of the parietal pleura may be accomplished on either side by loosening the pleura from the endothoracic fascia either anteriorly or posteriorly in the vertebral gutter. No difficulty has been experienced in obtaining a sufficient amount of pleura to cover over completely and without tension the entire raw hilar area (Figs. 9 and 10).

At the end of the operation 150,000 units of penicillin have been introduced into the thoracic cavity. The intrapulmonary pressure, as the wound in the chest wall is closed, has been increased to not more than 10 mm. of mercury. The entrapped air is removed to the fullest extent possible by leaving a small catheter in the wound during closure. After the last interrupted suture is placed in the skin all the air that can be is removed by aspiration and the catheter itself is then withdrawn. No drainage of the pleural cavity is thought desirable even in the presence of infection, within the lung itself, and when purulent material has been unfortunately and accidentally spilled into the pleural cavity.

Since penicillin has been available, when gross infection has been present it has been our custom to introduce every other day 50,000 units of penicillin into the thoracic cavity. In addition, the drug is also given intramuscularly up to 50,000 units every three hours. No instances of empyema have been encountered in cases so treated, and, thus, the necessity for performing thoracoplasties to obliterate infected dead space in the thoracic cavity has been avoided.

A word of caution should be given here in regard to the possibility of the development of interstitial pulmonary emphysema as a result of increasing the intrapulmonary pressure either too rapidly or to too great an extent, in an endeavor to hyperdistend the lung on the unoperated side for the purpose of obliterating the dead space in the thoracic cavity on the operative side. Rupture of alveoli within the lung substance itself producing a mediastinal, plus extensive subcutaneous as well as visceral emphysema was encountered in one

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case of diaphragmatic hernia followed by death from cerebral and coronary air emboli, proved at autopsy.

The final proof of the efficacy of any method of therapy naturally is a critical analysis of the immediate and remote results. Of 327 cases of primary carcinoma of the lung, as shown in Table III, 215, or 66 per cent, were inoperable, whereas, 112, or 34 per cent, were operable. This ratio of the inoperable to the operable cases is far higher than it should be, for in the majority of instances the attending physician and even the patients had been aware of a lesion in the lung for many months, and often years, before submitting themselves to operation. Undoubtedly in the future, as the field of thoracic

TABLE III
CARCINOMA OF THE LUNG
Ratio of Operable to Inoperable Cases

	No. of Cases	Percentage
Operable.....	112	34
Inoperable.....	215	66
	327	100

TABLE IV
CASES OF INOPERABLE CARCINOMA
According to Years

	No. of Cases
1934.....	2
1935.....	3
1936.....	9
1937.....	17
1938.....	22
1939.....	14
1940.....	21
1941.....	16
1942.....	22
1943.....	19
1944.....	19
1945.....	37
1946.....	14
Total.....	215

surgery is developed, this disproportion will be reduced. There will always be those instances in which a malignant tumor begins in the periphery of the lung, the so-called silent area, and produces no symptoms or signs until involvement of the pleural or contiguous structures renders the case inoperable. Fortunately, this group comprises only about 10 per cent of the cases of malignancy of the lung, 90 per cent occurring near the hilus, and producing warning signals early in the process of the disease. Unless for palliative reason, to rid the patient of an infected lung due to neoplastic bronchial obstruction, for example, pneumonectomy should not be performed if the tumor has involved contiguous structures. Therefore, inoperability would be manifest by involvement of the parietal pleura or any of the underlying structures.

Table IV reveals the number of cases, *i.e.*, 215, of inoperable carcinoma of the lung which have been subjected to operation from January, 1934 until July, 1946. This number does not include those patients that were clinically inoperable. The clinical findings, which we have found to indicate a spread of the tumor beyond the confines of the lung and, therefore, render the case incurable from a surgical standpoint, are the following: Metastases to the opposite lung or mediastinum, direct metastases to brain, osseous tissue, liver, skin, axillary and supraclavicular nodes, pleural effusion, clear or serosanguineous, continuous pain to shoulder or referred down the arm, Horner's syndrome, left recurrent laryngeal palsy or hemiparalysis of the diaphragm.

TABLE V
PNEUMONECTOMY FOR CARCINOMA OF THE LUNG
Operations and Mortality According to Years

	No. of Operations	No. of Deaths
1933.....	2	0
1934.....	1	1
1935.....	5	1
1936.....	4	2
1937.....	5	0
1938.....	7	2
1939.....	6	2
1940.....	10	0
1941.....	13	3
1942.....	9	4
1943.....	9	2
1944.....	12	2
1945.....	15	5
1946.....	14	1
	<hr/> 112	<hr/> 25

Although the number of cases of inoperable carcinoma of the lung have apparently increased since 1939, when Table IV is compared to Table V, there is very little fluctuation in the ratio of operable to inoperable cases over the same period of time. All patients with lesions of the lung which have been diagnosed probable malignant tumors should be explored regardless of the size or position of the tumor or the age of the patient. In the absence of clinical signs or symptoms of a spread of the disease from within the limits of the lung itself, the question of operability can be determined only by exploration of the chest.

In this series of cases, there have been 107 in which total pneumonectomy was performed for carcinoma of the lung.

Table V represents the number of total pneumonectomies performed each year for carcinoma of the lung, together with the deaths occurring within one month of the operation. All deaths within this time limit were considered in the group of immediate postoperative mortality because of the fact that the patients had remained in the hospital that long and although in some instances death was in no way connected with the actual operative procedure. From

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1933 through 1939 there were 30 cases with eight deaths, or a mortality of 27 per cent. From 1940 through half of 1946, 82 patients were operated upon, with 17 deaths, or a 20.7 per cent mortality. Thus, in spite of an increase in the number of patients there was a 5 per cent decrease in immediate postoperative mortality. Undoubtedly in the future this hospital death rate will be decreased because of several reasons, such as earlier reference of cases by the general practitioners, improvements in operative technic, chemotherapy and anesthesia. In addition, postoperative care has improved remarkably. Penicillin is now given intramuscularly, by inhalations, and intrathoracically, so that the chance of developing a postoperative empyema is almost *nil*.

TABLE VI
PNEUMONECTOMY FOR CARCINOMA OF THE LUNG

	No. of Cases	Total	Percentage
Patients dying after various periods of time:			
Less than 1 month.....	25	25	22
1 month to 6 years			
1 month to 6 months.....	20		
6 months to 1 year.....	10		
1 year, or more.....	6		
2 years, or more.....	2		
3 years, or more.....	3		
4 years, or more.....	1		
5 years, or more.....	1		
6 years, or more.....	1	44	39
Patients living:			
1 month to 6 months.....	12		
6 months to 1 year.....	2		
1 year, or more.....	8		
2 years, or more.....	5		
3 years, or more.....	4		
5 years, or more.....	4		
6 years, or more.....	2		
9 years, or more.....	2		
10 years, or more.....	2		
11 years, or more.....	1		
13 years, or more.....	1	43	39
		112	100

Important as the immediate operative mortality is, and it should be very jealously guarded, the efficacy of the operative procedure should also be judged by the ultimate results. The duration of life following total pneumonectomy for carcinoma of the lung is shown in Table VI. It is to be noted that patients dying after various periods of time are so charted in comparison to patients still living following operation. Those dying following operation who died less than one month afterwards were considered an operative mortality. The total operative mortality of the 112 cases for total pneumonectomy for carcinoma of the lung was 22 per cent. Of the patients who are now dead, but who lived for various periods of time after operation, *i.e.*, from one month to six years, the number surviving the different periods of time was 44. This group of cases made up 39 per cent of the total. Reference must be made to the fact that of the 215 cases of inoperable carcinoma comprising this series,

the average duration of life after exploration of the thoracic cavity was five months, so that even in the group, in Table VI, which are now dead but lived various periods of time following operation, the average duration of life after removing the lung was greater by far than in those patients in which the lung could not be removed. Of the patients living at the present time, 39 per cent of the total, or 43 patients, have survived from one month to 13 years. Of this group, 12 patients have lived five years, or more; one, 13 years; one, 11; two, nine; and two, six. As they are still living there is a possibility they may live for many years. It would seem desirable to call attention to the fact that all these patients, except one who was a professional boxer, have been restored to their normal activities. They have been able to return to their former vocations and even recreations, such as golf, swimming, fishing and hunting. In all except the occasional case, since it has not been found necessary to perform a thoracoplasty, no deformity of the patient is visible from the removal of the affected organ. The remaining lung expands to fill the dead space. This intrathoracic readjustment has been reported in detail elsewhere. If these results are compared to those obtained from the surgical treatment of carcinoma of the thyroid, breast, esophagus, stomach and large and small intestine, reported over a corresponding length of time (13 years) it will be evident that removal of the lung for primary carcinoma offers at least as great if not greater probability of permanent cure as the surgical treatment of carcinoma of any other organ in the body.

Of the group of patients who lived for some time (up to six years) following operation, but who are now dead, the majority were definitely improved by relieving the coughing, hemoptysis and often extensive pulmonary suppuration with its attendant discomfort and manifestations.

CONCLUSIONS

An otherwise fatal disease, primary carcinoma of the lung, can be satisfactorily treated by surgical removal of the entire organ. Surgical measures short of total pneumonectomy are not efficacious. Postoperative mortality and longevity are at least as good as, if not better than, the postoperative results following the surgical treatment of carcinoma of other organs.

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- 2 Rienhoff, William F., Jr., Gannon, James, Jr., and Sherman, Irwin: Closure of the Bronchus Following Total Pneumonectomy: Experimental and Clinical Observations. *ANNALS OF SURGERY*, 116, No. 4, 1942.

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DISCUSSION.—DR. BRIAN BLADES, Washington, D. C.: I fully agree with Doctor Ochsner and Doctor Rienhoff that the indications for exploratory thoracotomy in patients suspected of having a neoplasm of the lung, should be extended. I understood Doctor Ochsner to say that the only contraindication to exploratory operations at his Clinic was evidence of distant metastasis. This brings up the question of whether or not one should