The Electrosurgical Method of Closed Intrapleural Pneumolysis in Artificial Pneumothorax

RALPH C. MATSON, M.D.
PORTLAND, ORE.

Reprinted from the Archives of Surgery
December, 1929, Vol. 19, Part II, pp. 1175-1192

Reprinted from the Archives of Surgery
December, 1929, Vol. 19, Part II, pp. 1175-1192

THE ELECTROSURGICAL METHOD OF CLOSED INTRAPLEURAL PNEUMOLYSIS IN ARTIFICIAL PNEUMOTHORAX*

RALPH C. MATSON, M.D.
PORTLAND, ORE.

It is generally admitted that artificial pneumothorax is not only the most widely applicable method of collapsing the lung in the treatment of pulmonary tuberculosis but also the most valuable. Unfortunately, pleuritic adhesions are almost invariably present in cases in which the patients require pneumothorax treatment and constitute the greatest obstacle to a satisfactory end-result.

As a result of experience in the treatment of approximately 1,400 patients with pulmonary tuberculosis with artificial pneumothorax during the past eighteen years, my co-workers and I are convinced of the importance of establishing a type of pneumothorax which within a few months will give the diseased lung sufficient functional rest, collapse or compression to render it no longer a source of tuberculotoxemia or tubercle bacilli-laden sputum.

The importance of a satisfactory collapse of the lung is strikingly shown in the accompanying table. A careful review of the clinical records and stereoroentgenograms in 245 cases in this series reveals that the primary cause of failure of treatment with pneumothorax in 40 per cent of the cases was the presence of adhesions, which prevented a satisfactory collapse of the lung. In most of these cases, a temporary improvement followed pneumothorax treatment in spite of insufficient collapse of the lung. Consequently, the treatment was continued sometimes for prolonged periods, in the hope of stretching the offending adhesions and securing a good collapse of the lung. Sooner or later, however, either extension of disease took place to the opposite lung, intestines or throat, or some complication as empyema, spontaneous pneumothorax or obliterating pneumothorax occurred, compelling discontinuation of pneumothorax treatment. Unfortunately, the cases were then too far advanced to utilize other methods for collapse of the lung.

While adhesions are present in the majority of patients selected for pneumothorax treatment, according to our experience, a satis-

---

* Read at the Twelfth Annual Meeting of the American Association for Thoracic Surgery, held in St. Louis, Mo., April 25-27, 1929.

* From the Department of Thoracic Surgery, Portland Open Air Sanatorium, Milwaukie, Ore., and the Department of Medicine, University of Oregon Medical School.

factory pneumothorax can be established in 40 per cent of the cases. In a similar percentage (40 per cent), however, the character of adhesions will prevent the necessary collapse or compression of the lung to provide adequate functional rest or closure of cavities; and in the remaining 20 per cent, pleuritic adhesions will prevent any introduction of gas. Thus, pneumothorax treatment will prove efficient in considerably less than half the cases wherein it is indicated.

The phthisiotherapeutist recognizes the value of thoracic surgery. In those cases wherein no gas can be introduced, he now more often takes advantage of the surgeon's ability to bring about collapse of the lung by a phrenic neurectomy or thoracoplasty instead of subjecting the patient to prolonged and unsatisfactory sanatorium care. However, the fate of cases presenting pleuritic adhesions, which prevent efficient collapse of the lung, leaves much to be desired.

The usual procedure in cases of this type is to keep up the pneumothorax frequently, month in and out, and sometimes even year in and

Comparative Value of Artificial Pneumothorax in Cases in Which Adhesions Did Not Prevent Adequate Functional Rest and Closure of Cavities, and Those in Which Adhesions Did Prevent Sufficient Collapse of the Lung to Close Cavities or Give the Necessary Functional Rest

Observations on 850 Cases. Jan. 1, 1911 to Aug. 1, 1925

Character of Pneumothorax	Clinically Well, Per Cent	Arrested, Per Cent	Dead, Per Cent
Satisfactory collapse, adhesions not preventing closure of cavites or adequate rest of the lung	48	20	21
Partial collapse, adhesions preventing satisfactory closure of cavities or adequate rest of the lung	13	13	50

out, especially if there has been some reduction in the quantity of the twenty-four hour sputum or its germ content, or if the patient has made some clinical improvement in spite of roentgenograms showing definitely that adhesions are preventing a satisfactory collapse of the lung. Admittedly, a small percentage of the patients in such cases recover, but the vast majority do not. The greatest indictment against the phthisiotherapeutist today, aside from not using collapse therapy as a whole to the extent it is indicated, is the continuation of a useless pneumothorax for prolonged periods, denying the patient the advantages of other recognized operative procedures.

Opinion will differ, of course, as to what constitutes a satisfactory pneumothorax. However, it is not to be decided only by the degree of collapse or compression shown in the roentgenogram, nor by the mere presence or apparent absence of adhesions per se. In one case, there may be only a thin layer of gas between the lung and the chest wall and the pneumothorax may be satisfactory, while in another case, there may be an enormous pneumothorax with displacement of the mediastinum, heart and diaphragm and with little lung tissue visible;

and yet, because of an uncollapsed cavity held open by adhesions, the patient may continue to expectorate sputum containing tubercle bacilli. It is a common observation of every phthisiotherapeutist that a single string or slender band adhesion extending from the partially collapsed lung to the thoracic wall frequently holds open a cavity and renders pneumothorax treatment a failure.

As a result of our experience, we have become convinced that pneumothorax will not give a satisfactory end-result if, after several months' trial, stereoscopic films reveal the presence of adhesions, the nature of which is preventing sufficient collapse of the lung or compression to bring about a satisfactory reduction in the amount and bacilli content of sputum from the diseased lung.

Careful roentgenologic study of adhesions in pneumothorax will show that they are more often distributed over the more diseased parts of the lung, being found almost invariably over superficial cavities. Consequently, the very part of the lung which is in greatest need of collapse is the least likely to receive it in an adequate measure.

Early in our experience with pneumothorax, we recognized the necessity of a satisfactory pneumothorax, but considered open operations or closed operations with the original Jacobaeus instruments too dangerous. We advocated instead that the adhesions be stretched by increasing the intrapleural pressure in order to secure a good collapse. Study of our end-results shows that this method was unsatisfactory, because not only did we seldom get a good collapse, but spontaneous pneumothorax was 40 per cent more common in cases in which we had resorted to the stretching of adhesions. The marked increase in spontaneous pneumothorax was undoubtedly due to tearing of the parenchyma of the lung or liberation of tuberculous foci from torn adhesions.

Four years ago, after Unverricht had developed his new thoracoscope, we again adopted the method of closed pneumolysis in all suitable cases. The general impression among phthisiotherapeutists and surgeons is that few cases are suitable for the operation. In studying the clinical records of stereoscopic films in ninety-one cases in a former series of patients now dead in whom adhesions prevented closure of cavities, we found that 40 per cent were suitable for pneumolysis early in their pneumothorax career; had they been operated on instead of being subjected to prolonged pneumothorax treatment, probably 50 per cent would be alive and well.

The value of the closed method of pneumolysis seems, by many, to be the least appreciated of any of the methods for collapse of the lung. This procedure is neglected for two reasons: The phthisiotherapeutist generally lacks the necessary surgical training and judgment, while the surgeon frequently lacks clinical experience in tuberculosis and

knowledge of pneumothorax as a background. Both are unwilling to spend the necessary time to perfect the technic. Thus, the surgeon favors the open method of pneumolysis, or thoracoplasty, while the phthisiotherapeutist clings to his partial pneumothorax. Both fail to appreciate the improvement in the technic of cutting adhesions, and many still retain the impression that it is dangerous.

These dangers are largely technical. Formerly, one worked pretty much in the dark with poor instruments and equipment. We, ourselves, went through this period and gave up the method, as we considered it dangerous and of little utility. Today, however, we have improved instruments and a more refined technic, and while the operation may be technically difficult, it is at least not dangerous when properly done.

If collapse therapy is indicated, it is our policy to try artificial pneumothorax. If a satisfactory collapse of the lung is not obtained within a few months, and it is shown on serial stereoscopic films that adhesions are preventing a satisfactory collapse, we consider a pneumolysis at once.

During the past four years, the patients in 45 per cent of our cases in which there was unsatisfactory collapse have proved suitable for the operation. If not suitable, we consider other methods of collapse instead of continuing a comparatively useless pneumothorax.

The technic, indications and contraindications for intrapleural pneumolysis, as well as the selection of cases and end-results, have been covered in a previous contribution.[1] It was pointed out in a former communication that the cauterization of adhesions by the galvanocautery is objectionable because of the heat, smoke, pain and reaction to operation. Perhaps its greatest shortcoming is the character of the cutting produced because tissue is destroyed for a short distance around the cautery. Thus, blood vessels are severed without any previous obliteration, and unless a dull red heat is used, undue bleeding may occur. In addition to these reactions, if too much heat is used, there is also the danger of tissue necrosis occurring, which may involve the parenchyma of the lung, tuberculous cavities or tuberculous foci, thus liberating infection, or the necrosis may invade blood vessels and cause serious secondary hemorrhage. Furthermore, while the time required for the cautery to heat and cool after the current is thrown on or off is short, it nevertheless has its disadvantage, as occasionally a moment's delay, rendering the cutting instrument active or inactive, may result in serious consequences. Moreover, the shaft of the cautery sometimes becomes extremely hot and may cause a sloughing at the point where it passes through the thoracic wall. The hot cautery shaft may also damage lung

1. Matson, R. C.: Cauterization of Adhesions in Artificial Pneumothorax by the Jacobaeus-Unverricht Method of Closed Pneumolysis, Am. Rev. Tuberc. **19:** 233 (March) 1929.

tissue or the pericardium on which it may rest, during operation, unobserved by the operator who is giving his attention to the cutting alone.

All of these difficulties and dangers were serious, objectionable features which prevented successful results in many instances.

The successful utilization of electrosurgical methods in operations on the brain and in treatment for cancer stimulated much experimentation on our part to apply these methods to intrathoracic surgery, in an effort to lessen the difficulties and reduce the hazards incident to the use of the galvanocautery. We applied the electrothermic principle for the severing of adhesions, and as a result of its advantages over the galvanocautery, we are utilizing electrocoagulation and cutting in all cases presenting the difficuties that we have outlined.

During the utilization of this new principle over a period of the past two years, we have repeatedly performed operations by this method which would not have been attempted with the galvanocautery, and the comparative safety of the method over the galvanocautery procedure, with the results obtained, have created a strong conviction that the electrocoagulation and cutting will replace the galvanocautery. The application of the method intrathoracically, however, involves difficulty of control of bleeding not present in any open operation. While hemostasis in an open operation can be obtained by well known and easily applied surgical methods, it is obvious that these same procedures cannot be applied in such operations as the closed pneumolysis.

Aside from the anatomic relationship of large blood vessels and important nerve trunks to pleural adhesions or to the pericardium, it is of vital importance to know whether the adhesion to be cut contains blood vessels, compressed lung tissue, diseased foci or the prolongation of a cavity. Cutting into the prolongation of a cavity or compressed lung tissue is avoidable. Cutting into tuberculous foci in adhesions can be efficiently dealt with; but hemorrhage is one complication not always avoidable, and if it is at all profuse, it is a most unpleasant experience for the operator.

It is my prime purpose in this paper to discuss the utilization of electrosurgery for cutting adhesions in artificial pneumothorax by the closed method under thoracoscopic control, with especial reference to control of bleeding.

It is to be hoped that this paper will not encourage those without experience in this new branch of surgery to undertake too difficult operations at first, as the operation might result in failure and thus bring about unjust criticism of an otherwise valuable procedure. One sometimes hesitates, therefore, to describe a new technic, as it may make inexperienced operators too venturesome.

The usual source of bleeding during the process of cutting adhesions is from blood vessels collateral from the intercostals. One meets with

two types of vessels: those situated subpleurally, which can usually be detected by thoracoscopic examination and easily controlled, and those situated in the interior of adhesions, from which profuse bleeding occurs at times. In the case of the former, bleeding may be easily controlled by electrocoagulation; or, if the galvanocautery is used, before the blood vessels are cut they may be thrombosed by the application of the flat surface of the cautery. Dangerous bleeding, however, comes from blood vessels situated in the interior of adhesions, particularly in those which are dense and well organized. This dense type of adhesion is found in cases in which the patients have been subjected to prolonged and sometimes even short periods of pneumothorax treatment, particularly if the patient is of a fibroplastic constitution with a tendency for productive changes to take place in the tissues following pneumothorax treatment.

The latter type of vascular adhesion is more often found in the costovertebral gutter, at the apex of the lung and anteriorly near the costochondral junction. Densely organized adhesions in these areas should be approached cautiously because blood vessels of considerable size may be situated in their interior, the presence of which is not always possible of determination until they have been cut into.

Bleeding occurring during the cutting of cord and band adhesions, if the adhesions are not densely organized, usually stops after the adhesion has been cut through and the stump contracts. In well organized tissue, however, little retraction takes place, and bleeding may be a source of considerable anxiety to the surgeon. Therefore, it is obvious that the ideal method of severing adhesions must provide efficient hemostasis.

The objections to the galvanocautery in connection with hemostasis have already been pointed out. A detailed description of the physical characteristics of currents employed in electrosurgery will not be discussed. However, an understanding of the effects of the high frequency currents employed in the electrothermic method of cutting adhesions is necessary to apply this new procedure intelligently.

Briefly, the cutting effected by the electrothermic method is not a true cutting but a molecular disintegration of the tissues produced by a high frequency undamped current, an arc being formed at the point of contact between the tip of the electrode and the tissue.

It has been found that the form of high frequency electric current which results in the best cutting of tissue with least charring is that generated by the utilization of thermeonic tubes used in radio broadcasting, which give sustained oscillations of uniform amplitude at a rate of 600,000 per second. Even with an apparatus generating this form of current, it will show an impairment in cutting if the rate of oscillations is considerably increased or decreased. Based on this rate of oscillation, the theory is advanced that the cleavage of the tissue is accomplished not by mechanically cutting or by cauterization, but by a cellular disruption

resulting from the reaction of the cells to a sustained vibration transmitted at their own inherent vibration rate. The little sparking and resultant film of coagulation is secondary and subsequent to the cleavage of the tissue. Thus, two separate and distinct functions may be observed. One is the transmission by the operating electrode of the oscillations to cause cleavage, and the other is the slight sparking as the needle breaks contact with the parted tissue. If properly adjusted and handled, this results in a slight film or coagulation sufficient to check capillary bleeding but not sufficient to cause sloughing or charring with the danger of subsequent hemorrhage.

The ideal current for cutting, therefore, is recognized as that having a uniform sustained amplitude of 600,000 oscillations per second.

On the other hand, the best form of high frequency electric current for the generation of heat as used in coagulation is that having a damped oscillation of a long decrement. This current is generated from suitable apparatus containing spark gaps, condensers, etc. An apparatus properly designed delivering currents having long decrements will result in a clean blanching and dehydrating of the tissue when properly applied for coagulation, but apparatus of improper design may have a short decrement of the oscillating currents which will result in a brown or black burning of the tissue when applied for coagulation. The rate of oscillations of this form of current is usually about 1,250,000, but the rate of oscillation is not so important as the form of the trains or the decrement.

Two distinctly opposite forms of current are utilized in electrosurgery: One is ideal for cutting and the other for coagulating. To get the best results, it is essential to employ apparatus furnishing these two forms of current obtainable at the will of the operator and in the strength suited to the work. There are devices which will deliver cutting characteristics from a generator by means of a spark gap. This current, however, is a compromise between the two ideal currents and consists usually of a damped oscillation having short decrement and having the trains of oscillation crowded together. The peaks of the resultant current may simulate the oscillations of the undamped oscillations, but there are present the superimposed short oscillations which tend to cause undue heating when used for cutting. Similarly, this form of current even when differently adjusted is far from the ideal for coagulating. In practice, apparatus delivering the latter form of current is likely to be somewhat erratic and require adjustment from time to time in the course of operation. In other words, there is no assurance that it will respond to the requirements of the moment. In important surgical work, when hesitation, delay or trial cannot be tolerated, obviously nothing but the ideal currents for cutting and coagulation should be employed.

In our work, we have utilized the Wappler Wyeth Endotherm with special instruments which I have designed for intrathoracic use (fig. 1).

In the use of the coagulating current, a blunt electrode held in contact with the tissue and a small amount of current turned on will result, within a few seconds, in a blanching, dehydrating or coagulation in a circle around the blunt point. This will expand until the process near the point is carried to the degree of burning which would be manifested in a little sparking and by the formation of carbon. Obviously, it is desirable to stop before that state has arrived. On cutting through the center of this coagulated area with the operating electrode, it will be found that the depth of the coagulation is about equal to the radius. Thus, in using the blunt electrode, the area of the visible destruction may be used as a gage of its depth. Coagulation may be employed for hemostasis, if necessary, by clamping the tissue or vessel with the intrathoracic hemostat and switching on the coagulating current.

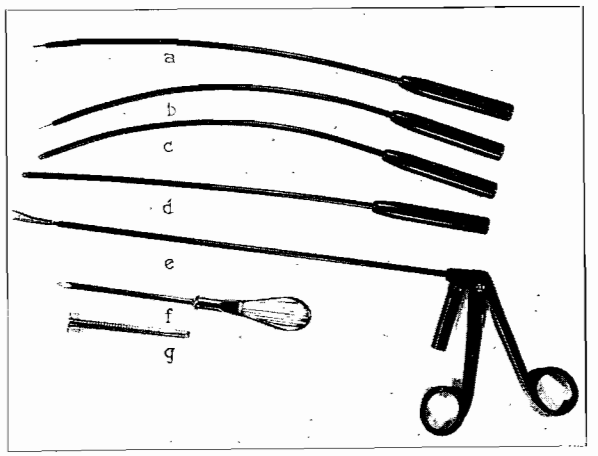

Fig. 1.—Author's instruments for the electrosurgical method of cutting adhesions: *a*, cutting electrode; *b*, pointed electrode for electrocoagulation; *c* and *d*, blunt electrodes for electrocoagulation; *e*, intrathoracic hemostat; *f*, trocar, and *g*, flexible cannula.

In the use of the cutting currents, considerable practice, first on meat and later on live animals should be exercised before an attempt is made to use them on the human body. In practice, it is best not to apply to the tissue to be cut more than a short portion of the operating electrode, the tip or only a few millimeters of the edge. If a larger portion is used, it will impair the cutting quality. Neither pressure nor traction should be used; in fact, this is objectionable. The operating electrode should be merely touched against the tissue, preferably at the point, and the action is that of following through the cleavage thus made. A little practice is required to get the sense of touch which is entirely different from that of traction or pressure of surgical cutting.

The amount of coagulation on the incision walls depends on the relation between the strength of the current employed and the speed of the passage of the electrode across the tissue. A little experimentation will soon teach the nature of the results expected. For example, with the cutting strength set at number 3 of the selective switch of a Wyeth Endotherm, an incision can be made at a fairly rapid rate without more than the film of coagulation, whereas hesitation or slow movement would result in charring. If slow movement is necessary, the cutting strength should be cut down to avoid charring. To make deep incisions, it is better to avoid attempts to make them with one stroke but rather to go over the same incision again using the point of the operating electrode and avoiding further contact with the tissue already parted. If bleeding spots show up after cutting by the proper current, the apparatus may be switched over to the coagulating current and the bleeding spot "touched up" with the operating electrode sufficiently to check the bleeding. In larger surfaces showing oozing of blood, the same current may be used. Increase in the strength and holding of the electrode at a slight distance from the tissue causing sparking to the tissue will result in sealing by surface coagulation. In case of more profuse bleeding, the blunt coagulating electrode or hemostat should be used as already referred to.

In our series of 130 cases of intrapleural pneumolysis, we have encountered three profuse hemorrhages. The first was encountered early in our experience. It occurred during a clinical demonstration of the cutting of adhesions with the galvanocautery, according to the method of Jacobaeus-Unverricht. The patient was unfit for such a demonstration as the operation was difficult, because there were many adhesions to be cut. Frequent interruption, caused by letting others view the work through the thoracoscope, markedly delayed the operation, which was being done cautiously with only a minimum heat in the cautery because of vascular adhesions. The patient's state of mind, as a result of conversation, made it necessary to speed up the work, whereupon the heat in the cautery was increased to a moderate cherry-red glow. All went well for a short time, when suddenly a gush of blood smeared the lens, obstructing all view. The thoracoscope was quickly withdrawn and wiped clean; but on reintroduction, the lens at once again became covered with blood. Knowing the exact site of the bleeding vessel, we were able to change the patient's position on the table so that blood no longer fouled the lens and the bleeding vessel could be clearly seen. The hemorrhage was eventually controlled by cauterizing tissue immediately surrounding the vessel and also by touching the vessel itself with the tip of the cautery. Two liters of blood were aspirated from the pneumothorax three days later. The patient suffered no inconvenience as a result of the accident, but the harrowing experience is yet so vivid in

the mind of the operator that he is convinced that this type of operation is not appropriate for clinical demonstration to groups. Demonstrations should be confined to a selected, interested few.

Two other hemorrhages occurred in our recent series, and while profuse for a moment, they were easily controlled by electrocoagulation.

In case 6557, a woman, aged 25, referred for pneumolysis, had been under pneumothorax treatment for nine months. Stereoscopic films showed an uncollapsed cavity in the upper lobe of the right lung suspended by a cord adhesion attached to the anterior end of the third rib and by two string and one band adhesion attached between the second and fourth ribs posteriorly in the costovertebral gutter.

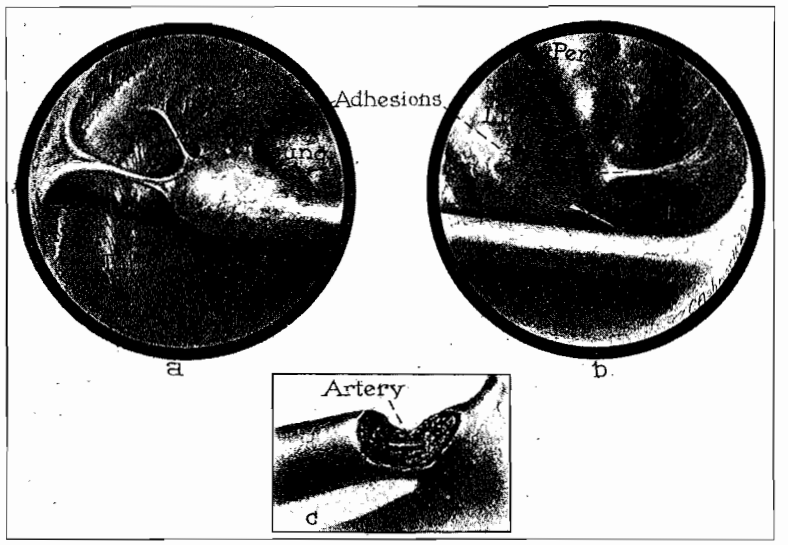

Fig. 2 (case 6557).—*a,* thoracoscopic view of cord and band adhesions attaching apex of the lung to costovertebral gutter; *b,* view of cord adhesion attached to anterior end of fourth rib, also adhesions between pericardium and chest wall and small string adhesions extending from the lung to the anterior chest wall and *c,* partially cut cord adhesion (shown in *b*) attached to the anterior end of fourth rib, showing site of blood vessel.

Thoracoscopic examination (fig. 2) confirmed these observations. The posterior adhesions were cut with the operating electrode after electrocoagulation and without anything unusual happening, as was expected. The cord adhesion anteriorly was then carefully studied. It was round, approximately 1 cm. in diameter (a minor affair from the standpoint of size alone). There were no blood vessels visible on its surface. It was densely organized and sensitive up to 3 cm. from the chest wall when all sensation disappeared. On slight coughing or clearing of the throat on the part of the patient, the adhesion increased

in diameter up to approximately 4 cm. from the chest wall, suggesting that it contained either the prolongation of a cavity or lung tissue, the former being suggested by previous stereoscopic film study. Pulsation of an expanding type was noted at the attachment of the adhesion to the chest wall, but not beyond 1 cm. from the chest wall. The pulsation was synchronous with the cardiac systole and not transmitted from the moving lung. A zone of electrocoagulation was made around the adhesion 2.5 cm. from the chest wall so as to avoid lung tissue and get as far away as possible from the chest wall.

The adhesion proved to be densely organized on cutting. Little contraction of the cut surface took place. Small blood channels were encountered as the cutting proceeded, which was always preceded by

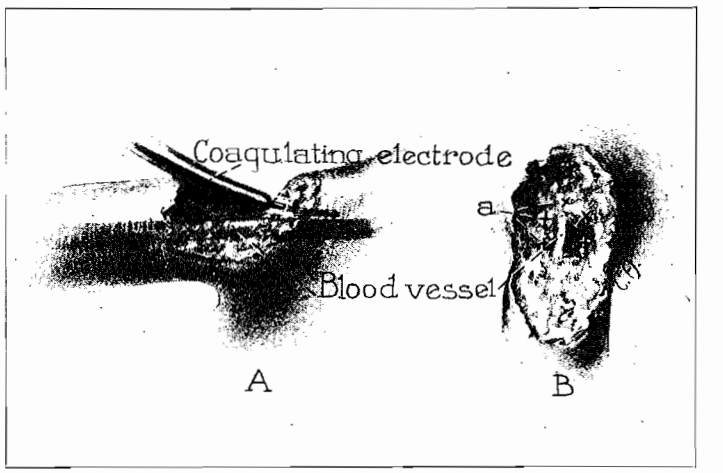

Fig. 3 (case 6557).—*A,* pointed electrode in position for deep coagulation of blood vessel and *B,* blood vessel for deep coagulation showing site of punctures (*a*).

electrocoagulation. Suddenly, near the center of the adhesion, a blood vessel was cut into which had not been obliterated by the electrocoagulation, no doubt because of the density of the tissue and because the electrocoagulation current was not sufficiently intense. A stream of blood was projected across the pneumothorax cavity to the lateral thoracic wall. The lens, fortunately, was so placed that it did not become smeared with blood. The author's blunt electrode was placed on the bleeding vessel. But electrocoagulation at this point only made matters worse as the bleeding became more profuse, whereupon the pointed electrode was introduced into the tissue close to the wall of the vessel and the coagulating current increased for depth; this controlled bleeding immediately (fig. 3). The adhesion was cut through without further loss of blood. The patient suffered no unfavorable result from the

bleeding. Two hundred and fifty cubic centimeters of blood was aspirated from the pneumothorax the following day. The operation was a complete clinical success.

I am certain that the hemorrhage in this case would have been a serious matter if we had been obliged to rely on the galvanocautery for control. As a matter of fact, I do not think we would have attempted cutting this adhesion with a galvanocautery.

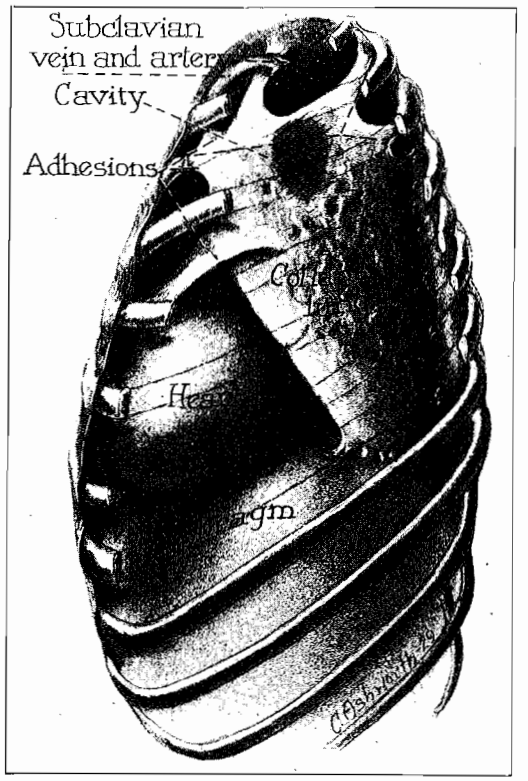

Fig. 4 (case 6500).—Diagram showing distribution of adhesions between partially collapsed lung and chest wall as revealed by thoracoscopic examination.

In the third case, no. 6500, a woman, aged 24, referred for pneumolysis, had been under pneumothorax treatment for ten months. At first, the quantity of sputum became diminished and then remained stationary, averaging from 40 to 60 cc. in twenty-four hours during the last two months of pneumothorax treatment, when she also developed tuberculosis of the larynx and extension of disease to the opposite lung.

Stereoscopic films showed a large cavity in the upper lobe of the left lung. There were many band and cord adhesions attached posteriorly in the costovertebral gutter and to the dome of the pneumothorax cavity

above the first rib. There were several cord and band adhesions attached to the anterior end of the first, second and fourth ribs.

Thoracoscopic examination revealed conditions shown in figure 4. All of the adhesions were densely organized and contained numerous subpleural blood vessels. At the first operation, a large band adhesion attached to the anterior end of the fourth rib, as well as a band adhesion holding the lung to the aorta (fig. 5), and two string adhesions at the apex were cut. One of the latter was attached to the wall of the subclavian artery, while the other was attached 4 mm. from the vessel (fig. 6*a*). No bleeding occurred, hemostasis being perfectly controlled by electrocoagulation, and no reaction followed the operation.

At the second operation, two large band adhesions, one attached to the first intercostal space (fig. 6*b*) and the second to the third rib in

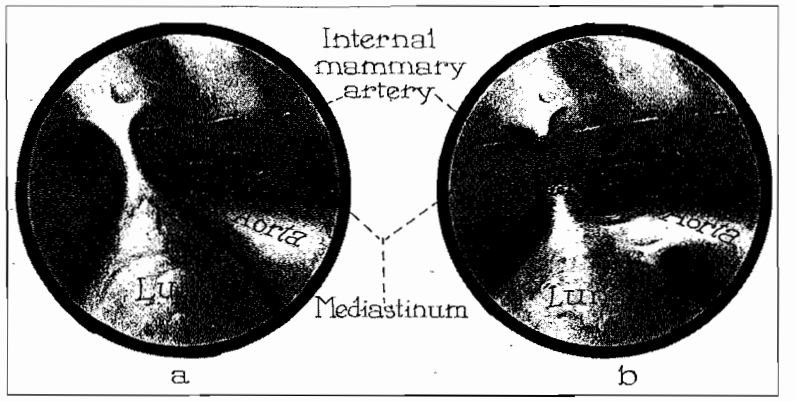

Fig. 5 (case 6500).—*a*, thoracoscopic view of band adhesion attached to anterior portion of second rib; *b*, view of same after cutting adhesion, showing band attached to the aorta.

the costovertebral gutter, were cut, again without bleeding or unfavorable complications.

At the third operation, two dense cord adhesions attached to the anterior end of the first and second ribs were cut. All of these operations were technically difficult, but bleeding was perfectly controlled by electrocoagulation, which alternated with the cutting. Following the operations, each of which was done at intervals of two weeks, an improved collapse of the lung was noted on stereoscopic films after each operation. The quantity of the patient's sputum was gradually reduced to 15 cc. as shown by daily measurement.

At the time of the previous operations, thoracoscopic study of the remaining adhesion showed that it was attached to the dome of the pneumothorax approximately 1 cm. distant from the subclavian artery just before this vessel crossed over the first rib. Furthermore, collateral

blood supply was seen emerging from beneath the subclavian artery and entering the base of the adhesion near its center. This collateral blood supply probably came from the arteria cervicalis profunda, which in this case may have been a branch of the subclavian artery instead of the costocervical trunk (fig. 7*a*). The adhesion was admittedly of a dangerous type, one we would not have considered cutting with the galvanocautery. Our success with electrosurgery, however, encouraged us to attempt it by the latter method, as the quantity of the patient's sputum had remained stationary at 15 cc. daily, and both stereoscopic film study and thoracoscopic study showed the remaining adhesion to be of great technical importance. Undoubtedly a satisfactory collapse of the lung (on which the patient's recovery depended) would not be obtained until it was severed.

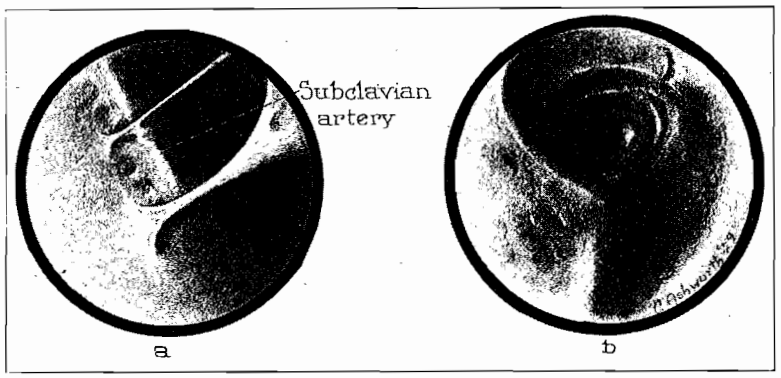

Fig. 6 (case 6500).—*a*, thoracoscopic view of two string adhesions extending from apex of the lung to the dome of the pneumothorax. One is attached to the parietal pleura covering the subclavian artery and the other is attached 4 mm. from the vessel; *b*, band adhesion shown in roentgenogram after cutting with endotherm.

The band was therefore carefully electrocoagulated on its outer surface, but because of its position, it was impossible to study its inner surface or put an electrode in a position to do an electrocoagulation of that surface. A line of electrocoagulation was made 2 cm. from the chest wall on the outer surface, and cutting followed with the undamped current, of moderate intensity, first, from the posterior edge toward the center and then from the anterior edge toward the center. As the center of the adhesion was approached from either side, the band was found to be more and more densely organized with tough bands of fibrous tissue between which were numerous blood channels. Owing to the dense character of the tissue, little retraction of the cut surface took place, and it was constantly necessary to resort to the coagulating current to control bleeding. On further approaching the site of the collateral blood supply,

after cutting through a particularly dense band of fibrous tissue, a sudden profuse hemorrhage took place. For a time it seemed uncontrollable, and preparations were made for blood transfusion and thoracotomy for the purpose of placing a clamp directly on the bleeding vessel. Fortunately, just at the moment when failure to control bleeding seemed imminent and no further time was to be wasted by attempting to control it with electrocoagulation currents, the method of puncturing around the blood vessel and doing a deep coagulation proved successful, and all bleeding stopped.

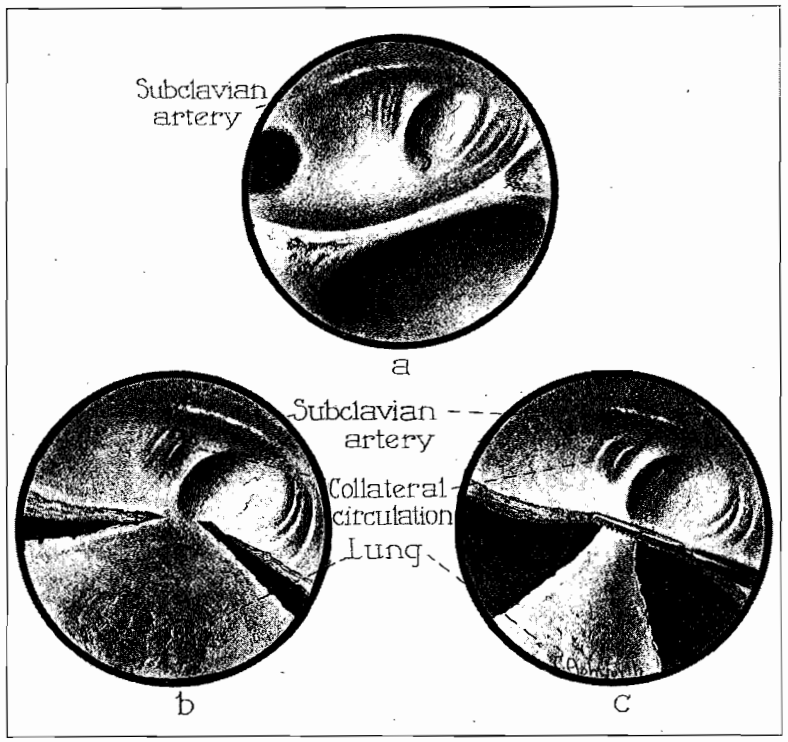

Fig. 7 (case 6500).—*a*, thoracoscopic view of apical adhesion; *b*, same adhesion partially cut; *c*, intrathoracic hemostat clamped on vascular remains of adhesion for purpose of electrocoagulation before cutting.

It seemed reasonably certain that the vessel had not been severed but only cut into, and that the remaining portion of adhesion contained other blood vessels of a dangerous size. Lack of confidence in being able to control bleeding prompted us not to attempt further operation, at least until some more certain method of hemostasis could be developed.

The patient suffered no unfavorable symptoms as a result of the hemorrhage, except a slight febrile reaction which lasted three days. The pneumothorax cavity was filled with carbon dioxide gas, and the intra-

pleural pressure was considerably increased over former inflations. Forty-eight hours after operation, 400 cc. of bloody exudate was aspirated.

The quantity of the patient's sputum remained unchanged by the operation, as was expected, and for four weeks following operation, the daily quantity of sputum remained 15 cc. Anticipating such a course and convinced that a method must be found for cutting the offending band without danger of hemorrhage, I devised an intrathoracic hemostat which

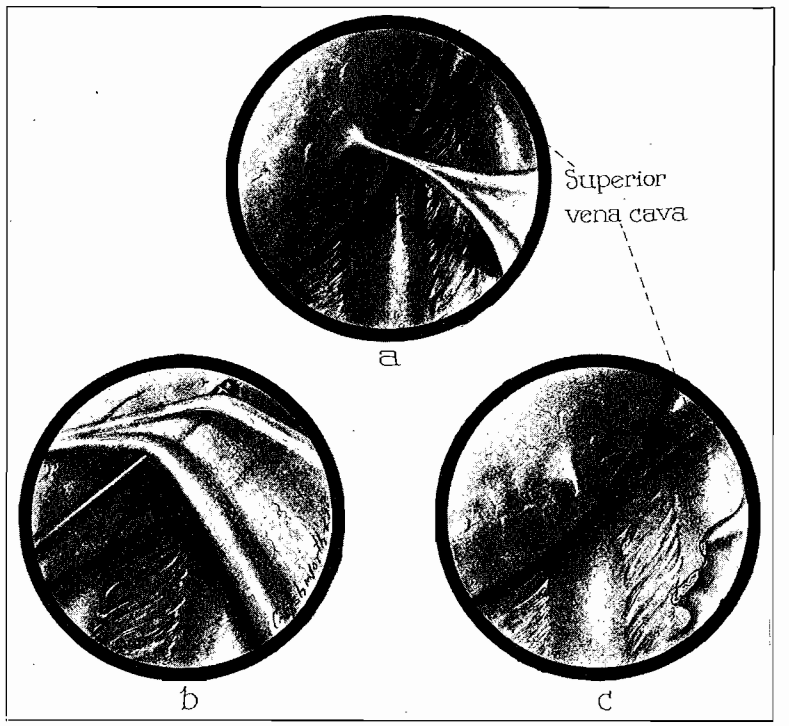

Fig. 8 (case 6172).—*a,* thoracoscopic view of a string adhesion, 5 mm. wide extending from the upper lobe of the right lung near the interlobar fissure to the lateral chest wall; *b,* method of examining structure of adhesion with author's blunt electrode; *c,* view of adhesion after cutting showing retraction of stumps.

was insulated so as to throw the coagulating current to the jaws of the hemostat. After the instrument was tested with satisfactory results, the final operation was decided on.

The thoracoscope was introduced in the first intercostal space midclavicular line. A superb view of the remaining uncut band was seen (fig. *7b*). The collateral blood supply was seen as on previous examination. The adhesion had every indication of extreme vascularity. There was no necrosis at the site of previous cutting, and the cut surface was

clean. The intrathoracic hemostat was introduced in the third intercostal space midaxillary line and its jaws clamped down on the remaining portion of the adhesion which was then thoroughly electrocoagulated (fig. *7c*). Cutting was then carried out without any loss of blood, no further electrocoagulation being necessary. Complete collapse of the lung followed.

The quantity of the patient's sputum promptly diminished, so that after two weeks the daily quantity ranged from 0 to 3 cc. During the course of these operations, a progressive improvement also took place in the opposite lung and larynx.

Fig. 9 (case 6489).—Thoracoscopic view of adhesion attached to anterior mesial aspects of chest wall and mediastinum and reflected over the aorta, after having been almost completely cut through.

The danger of thrombosis of the vessel from heat of the galvanocautery and inflammatory reactions, as well as sloughing of tissue, has been pointed out in connection with cutting adhesions situated close to large blood vessels. In numerous cases, we have cut adhesions so situated which would not have been attempted with the galvanocautery. The following cases illustrate the value of electrosurgery in such cases.

In figure 8 (case 6172) is shown a thoracoscopic view of the apex of the right lung showing a fan-shaped adhesion extending from the apex of the lung to just above the sternal end of the first rib. The superior vena cava was 2.5 cm. distant from the point where the adhesion should be cut. In this case, some sudden unexpected movement

or coughing paroxysm on the part of the patient could easily have resulted in damage with a heated galvanocautery so close to a large blood vessel, for in spite of shutting off the current at the time the unexpected act was committed, the cautery could still remain sufficiently hot to do damage, whereas with the endotherm the instant the current is off, it is inactive and incapable of doing damage.

Figure 9 (case 6489) shows a thoracoscopic view of a dense band adhesion with its base attached to the anterior mesial aspects of the pneumothorax cavity and reflected over the aorta to which it was attached, showing cutting effected by the endotherm after electrocoagulation. This operation was executed without the loss of blood, and while extensive, it was not followed by inflammatory reaction on the part of the pleura. Complete collapse of the lung followed, and the patient's convalescence was uneventful.

In this case the operation was extremely difficult and prolonged, and without electrosurgery it would have been impossible to carry it out safely. It could not have been done with the galvanocautery except at a great risk.

COMMENT

1. Intrapleural pneumolysis is an operation of great utility. When it is properly done it is not dangerous and will convert a useless pneumothorax into an efficient one, thus saving the patient from thoracoplasty.

2. My experience with the electrosurgical method has given me confidence in this method of cutting adhesions. Control of bleeding is the most dangerous problem and requires thorough knowledge of the character of the currents used. Electrosurgical cutting is accomplished without heat or smoke to disturb the view. There is a minimum of tissue reaction afterward, and while more complicated and technically more difficult than the galvanocautery method, it is without doubt a notable advance in this branch of surgery, which is being more widely employed.

3. Intrapleural pneumolysis by the closed method is not a fool-proof procedure with either the galvanocautery or the electrothermic method. The operator must be familiar with the appearance of the pleural cavity and at all times perfectly orientated regarding the nature of tissue to be cut. This training in the use of the thoracoscope in the pleural cavity is just as important to the surgeon or phthisiotherapeutist as a thorough knowledge of the cystoscopic image is to the urological surgeon. The operator should have experience with pneumothorax and must have surgical training.

Acknowledgment is due Mrs. Henry F. Chaney, who, by a grant to the Portland Open Air Sanatorium, aided in this work.

Grateful acknowledgment is hereby made to my associates, Dr. Ray W. Matson and Dr. Marr Bisaillon, for valuable assistance and many helpful suggestions.