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CHAPTER ONE

THE SURGICAL TREATMENT OF PULMONARY TUBERCULOSIS

FRANK F. ALLBRITTEN, JR., M.D.

The surgical collapse of a tuberculous lung is a comparatively recent method of treatment for pulmonary tuberculosis. Since "rest, time and money" often have proved inadequate for cure, more formidable measures have been adopted to limit function, to produce rest, and to allow healing of the diseased portion of the lung. Effective surgical measures have been evolved by processes of logical thought, trial and error, evaluation and revision. These methods have been suggested and perfected by a great number of men, each adding some significant contribution. Co-operation and interchange of ideas between surgeons engaged in thoracic surgery have resulted in the evolution of the more effective procedures now utilized for surgical collapse of the lung.

The indications and contraindications for operation, the operative procedures and the postoperative care to be described in this chapter have been developed by various investigators and are selected because they have proved to be logical, and because they have been found to be followed by satisfactory results. Since this type of therapy still is in the process of evolution, it is emphasized that none of the procedures described necessarily represent the final stage in development. The literature has been freely utilized in the compilation of this chapter and pertinent illustrations have been borrowed. Only modern procedures have been described. The pioneer work of De Cerenville, Brauer, Friedrich, Wilms, Sauerbruch, Tuffier, Archibald, Hedblom and many others contributed the basic principles. Alexander, O'Brien, Jacobaeus, Eloesser, Semb, Graham, Churchill and Monaldi added to them developed technic and clarified indications. The names of the originators of certain methods described in this chapter have been omitted only because there remains an uncertainty concerning their identity.

The surgical treatment of pulmonary tuberculosis requires a knowledge of thoracic surgery as well as of the pathogenesis of the disease. The general surgeon should not attempt thoracic work until he has acquired the necessary knowledge to enable him to care for any operative complication that may arise. The training needed in thoracic surgery cannot be mastered in a short time. The immediate postoperative care of the patient in this field of surgery demands the direct and constant attention of the surgeon, who must accept responsibility for the welfare of the patient during the entire period of surgical treatment.

The co-operation of the internist and surgeon in selection of suitable patients and of procedures is highly desirable. In general, the plan of initiating surgical collapse with the least radical procedure which probably will be effective should be used. However, a revocable pro-

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cedure should be avoided if it is obvious that permanent collapse ultimately will be necessary to insure cure. The choice of treatment depends upon the course of the disease in the individual patient, the clinical condition and response to conservative treatment.

With the improved results following collapse therapy, the percentage of patients subjected to this treatment is increasing. In some large sanatoria 70 to 80 per cent of all patients receive some form of collapse therapy. A well regulated regimen including rest in bed continues to play an important part in the actual healing of the tuberculous lesion and should be continued for a minimal period of six months after collapse of the diseased area has been accomplished. Collapse does not heal tuberculous lesions but only promotes their healing.

The fundamental principles of medical treatment of tuberculosis should not be forgotten. Surgical collapse is only an adjunct and not a substitute for medical treatment. Surgical collapse does not change the pathogenesis of the disease but permits the natural reparative processes to occur.

The procedures described in this chapter are classified as revocable procedures, or those not producing permanent collapse of the lung, and irrevocable procedures, or those producing permanent collapse of the diseased area of the lung. The *revocable* procedures are phrenic nerve crush (phrenemphraxis), extrapleural pneumolysis, closed intrapleural pneumolysis, open intrapleural pneumolysis, closed cavity drainage and open cavity drainage. The *irrevocable* procedures are phrenicotomy or phrenic nerve exeresis, scaleniotomy or scalenectomy, supraperiosteal pneumolysis, thoracoplasty and resection of the lung.

Treatment by artificial pneumothorax is not considered in this chapter inasmuch as it usually falls under the direction of the internist.

Phrenic Nerve Interruption

Phrenic nerve interruption, whether temporary or permanent, is a procedure designed to produce relaxation and some degree of rest of the lung by paralyzing the hemidiaphragm. When the motor innervation of the diaphragm is interrupted, the denervated muscular plane relaxes and rises into the thoracic cage above it. The extent of the rise of the paralyzed hemidiaphragm depends upon a number of factors such as the pressure above it, e.g., pneumothorax, the upward pull of an adherent, contracting lung, the resistance of an indurated lung, and fixation of the diaphragm by adhesions or pleural thickening. The change in the position of the diaphragm is not immediate but occurs over a period of a few weeks, during which time there is an increased diaphragmatic muscular relaxation.

The rise of the hemidiaphragm is usually between 2 and 6 cm. The measurements can be made from a fixed point to the top of the diaphragm in stereoscopic pairs of roentgenograms taken in full inspiration before and after nerve interruption. Fluoroscopic evidence of phrenic paralysis is seen in the paradoxical diaphragmatic movement of the paralyzed hemidiaphragm during respiration (Kienböck's phenomenon); on inspiration the involved side of the diaphragm ascends and on expiration it descends. Paradoxical movement can be made

more evident by a rapid and deep sniff (Hitzenberger's test) or by attempting inspiration with the mouth closed and the nares held shut (Bittdorf's phenomenon).

Indications.—Considering the relaxation and rest given by paralysis of the hemidiaphragm, it is evident that only selected cases will be suitable for phrenic nerve interruption. Through clinical trial it has become evident that relaxation may be produced in diseased portions in the apex of the lung as well as in the basal parts, and good results may be expected in both areas in properly selected cases. The kind of lesion that may be favorably affected is the productive or early fibrotic type of tuberculosis in which the fibrous tissue has not lost its ability to contract. Cavities up to 4 to 6 cm. in diameter may be closed by hemidiaphragmatic paralysis, providing they have a thin wall of contractile, young fibrous tissue. It is obvious that old, thick-walled, fibrotic cavities can never be closed by relaxation alone but need compression as well. In general, the results are more favorable in early cases than in late cases, as would be expected from the type of fibrous tissue in each instance. (Fig. 1.)

It was formerly considered that phrenic nerve interruption should be performed only on patients with unilateral tuberculosis. But it has now become established that patients with early bilateral disease often will be benefited by phrenic interruption on the more markedly diseased side. Simultaneous bilateral nerve interruption cannot be done safely. It is my opinion that hemidiaphragmatic paralysis should not be permanent before thoracoplasty, and if a temporary interruption has been done it is usually advisable to await return of diaphragmatic function before proceeding with collapse by thoracoplasty. The use of phrenic nerve interruption as an adjunct to other procedures has a definite place in the treatment of tuberculosis and each case must be judged by its specific indications.

The interruption of the phrenic nerve can be temporary or permanent. At one time the advantages of temporary over permanent interruption were not appreciated. In recent years it has become the general practice to temporarily interrupt the phrenic nerve rather than to permanently destroy its function. This has marked advantages since it is impossible to anticipate the response of any patient to such a procedure. Some receive little or no benefit and it may be necessary to carry out an additional procedure for surgical collapse. If a permanent interruption has been produced, sufficient respiratory reserve may not remain to enable the proper procedures to be added. This must be considered particularly in patients with bilateral lesions. However, if the phrenic nerve has been interrupted only temporarily, diaphragmatic activity will again be resumed following regeneration of the nerve, a greater respiratory reserve will be established, and the proper type of surgical collapse can be accomplished later. If the temporary interruption of the phrenic nerve has proved to be of benefit, it can be continued either as a re-established temporary interruption or as a permanent interruption. It is certain that the larger number should be only temporary interruptions. In occasional instances permanent interruption may be indicated but this must be given careful consideration since it is an irrevocable procedure.

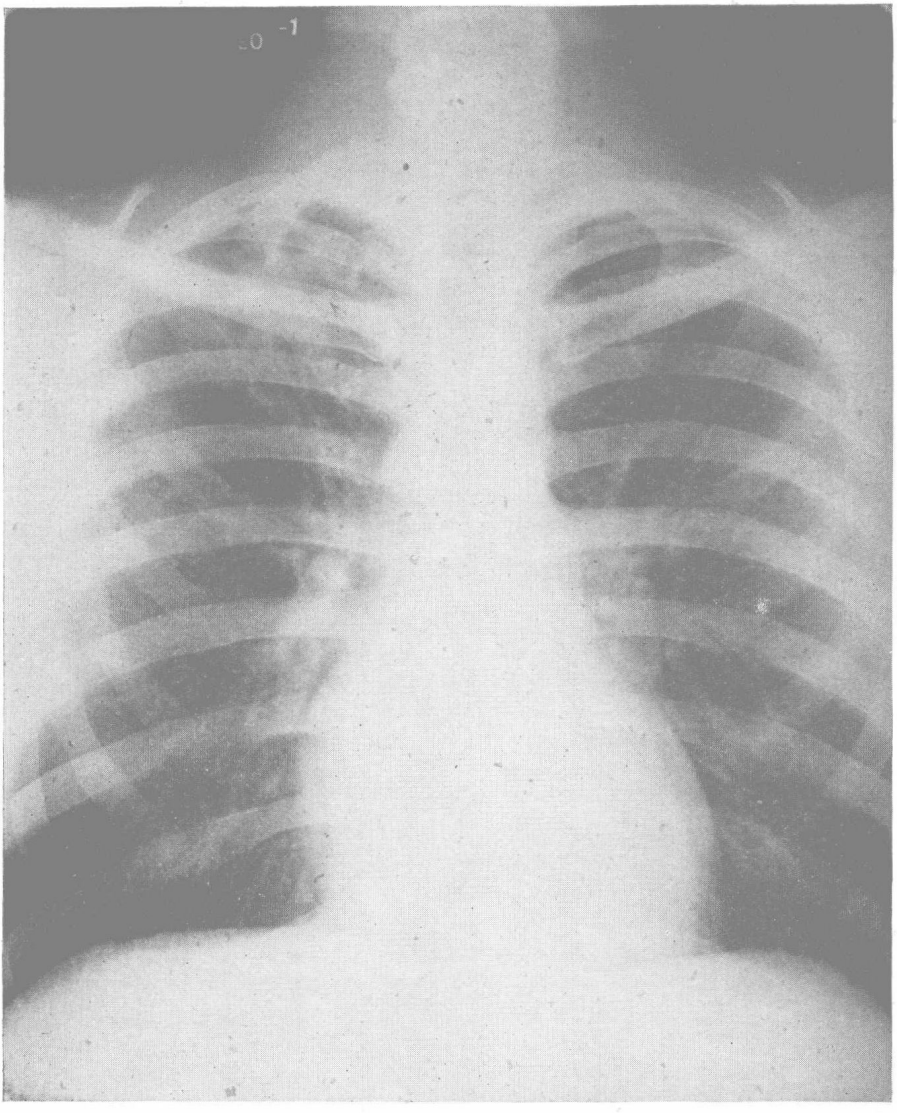

FIG. 1, A.—Phrenic crush and scaleniotomy. Male, age 25. Occupation, student nurse. June 1941 pleuritic pain, productive cough, sputum contained tubercle bacilli. Roentgenogram June 20, 1941, showed an infiltrating lesion of apical portion of right upper lobe with cavitation, minimum fibrosis. There was only slight improvement with bed rest and a temporary right phrenic paralysis, and a scaleniotomy was done September 3, 1941.

Temporary Interruption (Phrenemphraxis).—PREOPERATIVE PREPARATION.—The night preceding operation a mild barbituric hypnotic should be given. The preoperative sedation should be sufficient to enable the patient to arrive at the operating room co-operative and unafraid. Pentobarbital sodium 0.2 Gm. (3 Gr.) given two hours before operation, and morphine sulfate 0.01 Gm. (0.15 Gr.) given one hour before operation, is usually satisfactory. If the patient has a productive cough, drainage by posture and coughing should be insisted upon early in the morning before operation.

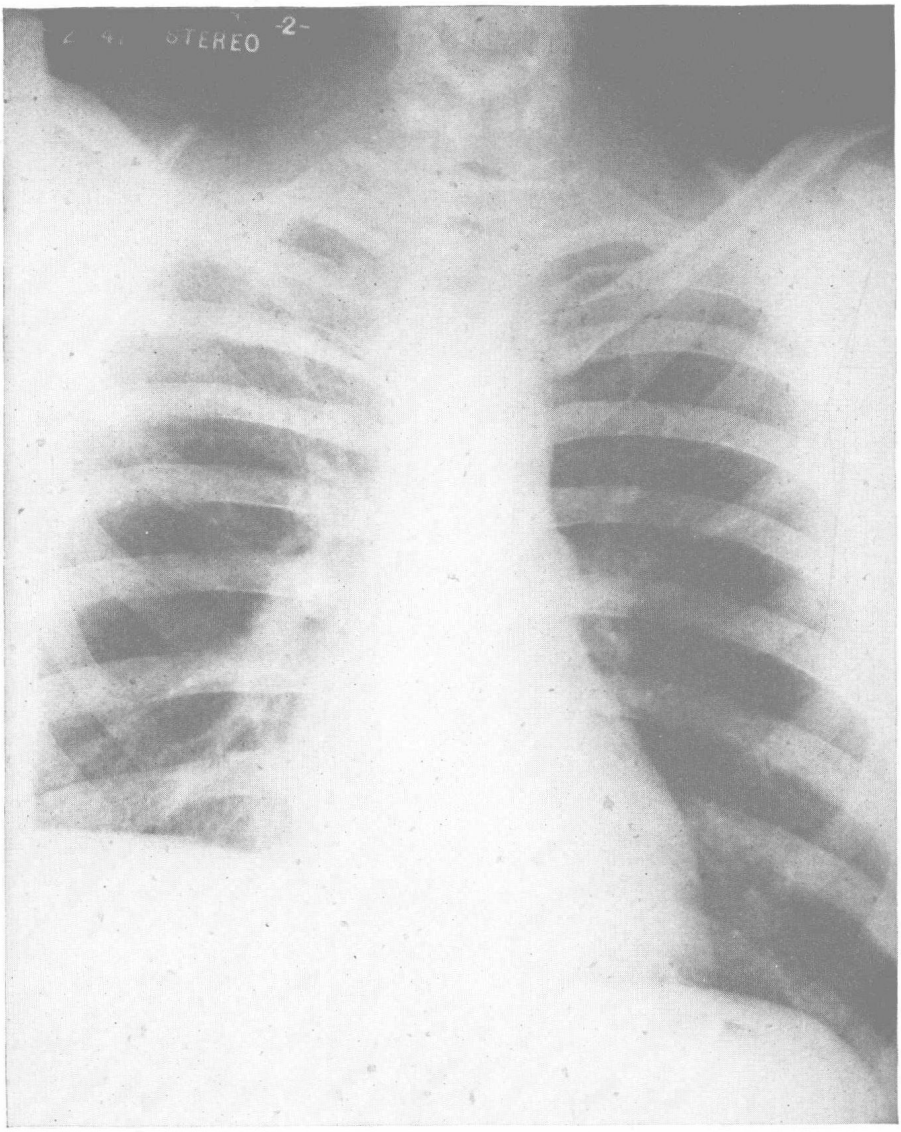

FIG. 1, B.—On the roentgenogram follow-up December 2, 1941, the right diaphragm was elevated, the cavity outlines had disappeared and there was increasing fibrosis in the right apex. The fluoroscopic examination showed paradoxical movement of the right hemidiaphragm. He was symptom-free and a small amount of sputum and gastric washings showed no tubercle bacilli. His disease has become quiescent.

Fluids by mouth may be given until two hours before the operative procedure. Radiographic films should be available in the operating room to enable the surgeon to positively identify the diseased side.

TECHNIC OF OPERATION.—The patient is placed on the operating table with a small pillow between the scapulae to permit the shoulders to drop back. The head is turned away from the involved side, and the skin is carefully prepared with a known reliable method and draped to expose only the operative field; the drape may be held from the patient's face by the attending nurse.

A point for the incision is then selected in the cutaneous crease about 2 cm. above the superior border of the clavicle, with its medial end at the posterior border of the sternocleidomastoid muscle. If the patient will attempt to raise his head when the operator's hand is placed against the draped temporal area, the posterior border of the sternocleidomastoid muscle can be palpated easily. After this point is accurately marked and the proper transverse skin crease selected, an intradermal wheal and subcutaneous injection of 1 per cent procaine solution are made. The incision then follows the selected skin crease for about 3 cm., and the underlying platysma muscle, subcutaneous tissue and superficial layer of the deep cervical fascia are divided. Bleeding points are carefully tied with the finest suture material as they are exposed. The external jugular vein may be exposed in the dissection and must be retracted anteriorly or, if this is not easily done, ligated and divided.

The edges of the wound must be carefully retracted and the fat pad lying in front of the scalenus anticus muscle divided. This should be done slowly with small scissors, and as each of the numerous vessels is exposed it should be carefully ligated and divided.

It is important that the operative field be kept entirely free from blood at all times. If the dissection causes pain, additional procaine solution (1 per cent) may be introduced into the fat pad. The dissection should take a posteromedial direction and can be guided by palpating the groove between the scalenus anticus and scalenus medius muscles; as this is approached the brachial plexus will be exposed. When the fat pad is completely divided, the deep cervical fascia is seen covering the scalenus anticus, scalenus medius and brachial plexus.

If the fascial layer is followed medially over the scalenus anticus muscle, the phrenic nerve can usually be palpated or seen as a definite small ridge lying beneath the fascia on the belly of the muscle. As the fascia is split to expose the belly of the muscle and the nerve, it is not uncommon for the nerve to be lifted with the fascia and to be concealed by the medial retractor. The direction of the nerve in its course toward the mediastinum is usually across the belly of the scalenus anticus muscle from the lateral to the medial border of the muscle. The course of the phrenic nerve is subject to great variation, and it may be found lateral or medial to the border of the scalenus anticus muscle, or even within the body of the muscle. By careful dissection and with a bloodless field, the main trunk can always be found. If there is doubt as to the structure exposed it can be followed upward to its origin from the cervical roots of the brachial plexus. If this is done it cannot be confused with the sympathetic chain or with the long thoracic nerve.

After the nerve is exposed it may be identified further by quickly pinching it with forceps. This usually causes pain referred to the shoulder, neck or arm and a quick contraction of the diaphragm which may be detected by a hand placed upon the anterior costal margin of the same side. Accessory branches of the phrenic nerve should then be sought. The most common accessory branches are found in conjunction with the nerve to the subclavius muscle arising from the fifth cervical root. As any accessory branch is exposed it is cut.

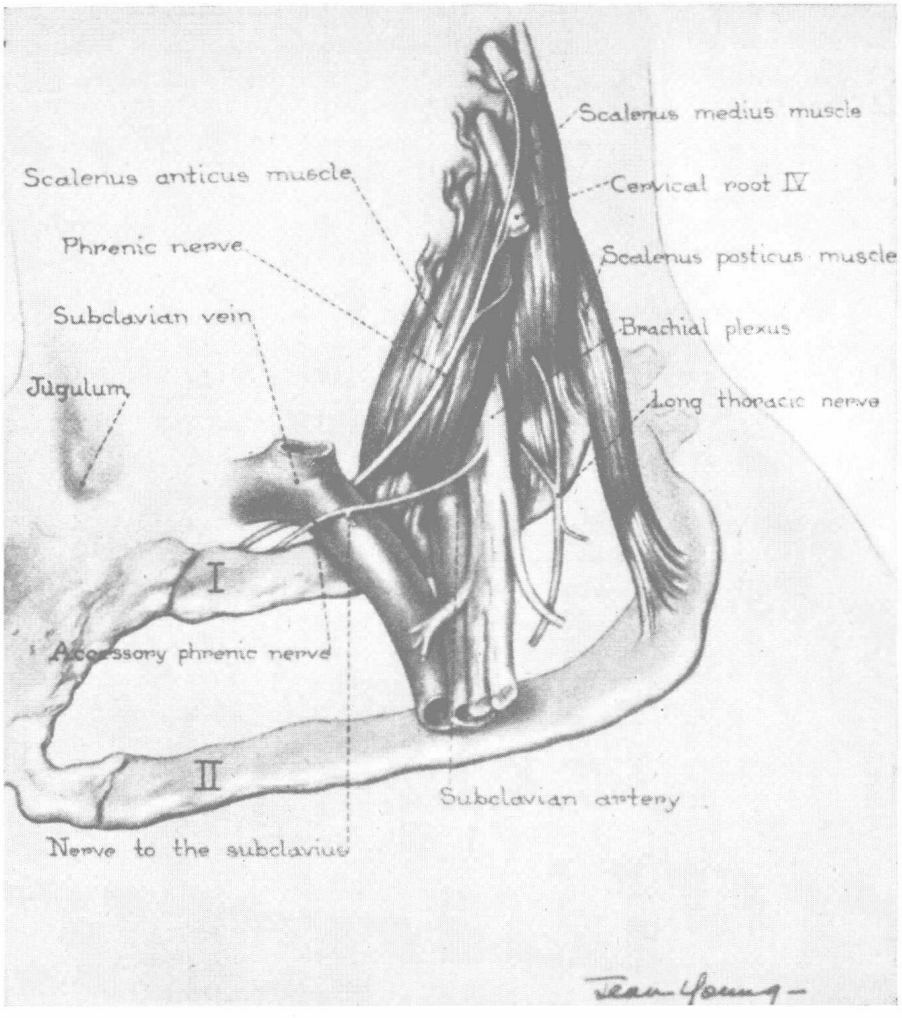

FIG. 2.—Important deep anatomic relationships of the three scalene muscles. Sibson's fascia and the pleura are not shown. (From Alexander's *The Collapse Therapy of Pulmonary Tuberculosis*. Courtesy of Charles C Thomas, Publisher.)

The phrenic nerve is anesthetized with an intraneural injection of 1 per cent procaine solution. The nerve is then thoroughly crushed with the tip of a mosquito hemostat by opening and closing the hemostat several times in exactly the same place. A section of the nerve only the width of the hemostat blade is crushed since multiple points of crushing are apt to cause either prolonged delay in regeneration of the nerve or permanent paralysis. It is essential that all accessory branches be found before completion of the operation if a complete paralysis of the diaphragm is to be obtained. (Fig. 2.)

After the nerve is crushed and the accessory nerves divided, the retractors are withdrawn and the fat pad falls together without sutures. The platysma is approximated with a few interrupted sutures of the finest suture material. The skin edges are then approximated with interrupted very fine silk or horsehair sutures, or a subcuticular horse-

hair may be used. A sterile dressing is placed over the wound and moderate pressure is made on the area by means of an elastic adhesive dressing. The skin suture should be removed within 48 hours after operation. A fine hairline scar will result.

After regeneration has occurred it may be necessary to again interrupt the phrenic nerve. This, as before, can be temporary or permanent. The old scar should be excised and the dissection carried out as in the original procedure. The exact location of the phrenic nerve should be evident from the operative note of the first operation.

Permanent Interruption.—Occasionally there are indications for permanent phrenic interruption. If the temporary interruption has been effective and it is still necessary to maintain rest and relaxation, permanent hemidiaphragmatic paralysis may be justified.

TECHNIC.—The exposure of the phrenic nerve is carried out just as in the exposure for temporary interruption. There are two methods in use for permanently interrupting the phrenic nerve. The first method is phrenic exeresis, in which the main phrenic nerve is isolated and slowly avulsed by dividing the nerve and pulling the distal fragment from the diaphragm and mediastinum by winding it around the blades of the hemostat with which it is held. As the avulsion proceeds, the nerve is repeatedly grasped below the hemostat about which it is being twisted, to prevent the distal fragment from retracting into the mediastinum in the event the nerve is torn by the tension. The greater the length avulsed, the more likely is a permanent paralysis to result. If the nerve is ruptured above the point of junction with an accessory branch, incomplete paralysis of the diaphragm will ensue.

There are certain dangers inherent in a procedure based upon blindly pulling a structure from the mediastinum. Serious damage may result in adjacent blood vessels followed by hemorrhage; adherent diseased tissue may be injured with unpredictable sequelae. The procedure itself is painful and the local anesthesia should be supplemented with general anesthesia while the actual extraction is being done. The blind extraction of the phrenic nerve must be regarded as dangerous and should not be used except in the occasional instance when the accessory phrenic nerve or nerves cannot be found and permanent paralysis is necessary.

The procedure of choice for permanent interruption of the phrenic nerve is dissection of the phrenic nerve and the accessory branches, with interruption of their continuity by the excision of segments of the nerve. After the phrenic nerve is exposed a segment 2 to 4 cm. long is excised. The deep cervical fascia overlying the fifth cervical root is incised to expose the root of the brachial plexus, and the accessory nerve or nerves are then exposed and segments are removed.

This operation entails slightly more dissection than phrenic exeresis but eliminates the dangers inherent in that procedure. The accessory phrenic can be exposed without difficulty in a bloodless field and with adequate lighting. The results of this operation are as satisfactory as those of exeresis, with less danger of serious complications.

Complications.—The dangers are those inherent in any operation close to large nerve trunks and large vessels. Injury to blood vessels can be avoided by slow and careful dissection in a bloodless field. It is extremely important to immediately ligate all bleeding points in order to keep the operative field clear of blood and instruments. Injury to nerve trunks can be avoided by following similar principles. Only gentle traction will be tolerated by the unanesthetized brachial plexus and, with care, injury to the brachial plexus can be easily avoided. The presence of other nerve trunks in this operative area makes the positive identification of the phrenic nerve necessary before interruption.

The thoracic duct or right lymphatic duct may occasionally be injured resulting in the escape of chyle. The greatest danger of this lies in the possibility of failure of recognition, for when found the point of leakage can be ligated without subsequent ill effects.

Operative complications occur in about 1.2 per cent of the cases and approximately half of these are fatal. Probably the incidence of complications is actually greater than this, due to the promiscuity of the operation and neglect to report complications. It is certainly less than this in experienced hands.

Postoperative complications not directly concerned with the operative procedure are infrequent but do occasionally occur. The continued spread of the disease must be distinguished from a precipitous spread that can be justifiably attributed to the operative procedure. The most likely cause for spread of the disease after phrenic nerve interruption is the stasis of secretions from inefficient coughing. This can be avoided by insistence upon frequent voluntary coughing postoperatively.

Gastro-intestinal symptoms may occur after phrenic nerve interruption. These are most common with left-sided nerve interruptions and usually persist for only a few days. The symptoms are those of gastric retention and can be relieved by gastric lavage and suction.

Thoracic pain may occur postoperatively due to the stretching of adhesions, but this is rare. Usually thoracic pain caused by tugging on the diaphragm by adhesions is relieved after diaphragmatic paralysis.

Severe postoperative dyspnea can be avoided by the proper selection of cases. Transitory dyspnea may occur and can be relieved by the use of oxygen inhalations postoperatively.

Results.—The carefully selected patients of Nehil and Alexander treated by unilateral phrenic paralysis showed that in unilateral lesions without cavity, 88 per cent were arrested or improved; unilateral with cavity, 84 per cent arrested or improved; bilateral without cavity, 84 per cent arrested or improved; bilateral with unilateral cavity, 55 per cent arrested or improved; bilateral cavities, with operation on the more diseased side, 34 per cent arrested or improved.

The excellent results obtained in carefully selected patients have led to the recommendation that almost all cases of minimal or moderately advanced tuberculosis should be treated by phrenic interruption, or pneumothorax, on the diseased side. Contrary to this, some consider that healing will result in the majority of patients with min-

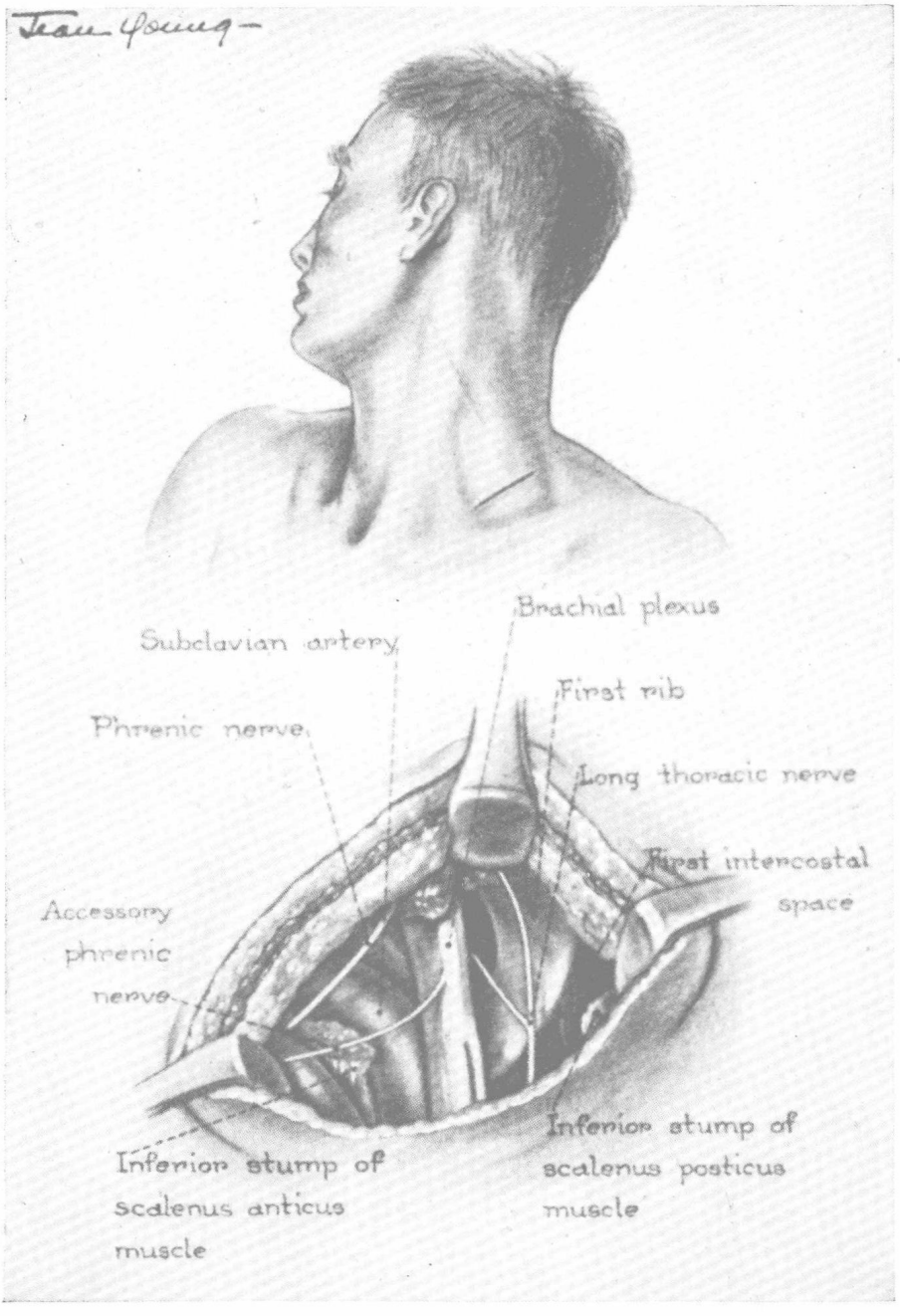

FIG. 3.—The upper drawing shows the position and length of the incision for scalenectomy or scaleniotomy. The lower drawing shows the appearance of the wound after partial resection of the three scalene muscles. All the deep structures appearing in the lower drawing cannot actually be seen at the same time through the cutaneous incision between the sternocleidomastoid and trapezius muscles; the incised skin and superficial tissues must be moved about by the retractors to expose the anterior or posterior limits of the field of operation. (From Alexander's *The Collapse Therapy of Pulmonary Tuberculosis*. Courtesy of Charles C Thomas, Publisher.)

imal and moderately advanced tuberculosis with rest in bed alone, and believe it is unwise to expose the patient unnecessarily to an operative procedure. The author believes that it should be used in those patients with minimal or moderately advanced tuberculosis who are not making satisfactory progress with a sanatorium regimen alone.

Scaleniotomy or Scalenectomy

The scalene muscles function as accessory muscles of respiration. During quiet respiration they act as supporting muscles for the upper ribs; in deep respiration they aid the rest of the muscles of the shoulder girdle and neck to lift the upper ribs. It has been found that releasing the upper ribs from their attachments permits them to descend slightly with a resultant decrease in the size of the upper thoracic cage and an immediate decrease in the size of apical parenchymal cavities. Fluoroscopically there is a decrease in the inspiratory rise of the ribs and a narrowing of the intercostal spaces. The collapse is not sufficient to produce a marked effect on the underlying apex of the lung, when used as an isolated procedure. When used in conjunction with hemidiaphragmatic paralysis in an attempt to close an apical cavity, it is logical to expect some additional collapse of the apex by the procedure. It is to be used, however, only as an accessory procedure with other forms of apical collapse therapy; alone it is useless.

The division of the muscles at their insertions into the ribs does produce an immediate effect. However, it is believed by some that subsequent formation of scar tissue bridges the gap between the divided muscles and ribs, and the muscles again become functional. For this reason it has been proposed that a portion of each of the scalene muscles be removed to make the effect definitely permanent. (Fig. 3.)

Technic of Operation.—The operative approach is similar to that for phrenic nerve interruption. Premedication, position for operation and anesthesia are the same. The incision must of necessity be longer to obtain adequate exposure. A 6 cm. incision is usually sufficient. The dissection down to the deep cervical fascia is carried out as in phrenic crush. It is essential to keep the field bloodless and free of instruments. The deep cervical fascia is then split to expose the phrenic nerve and the fifth cervical nerve root. The accessory portions of the phrenic nerve are located and divided, but the phrenic nerve itself is not crushed until after the division of the scalenus muscles has been carried out. This may avoid unintentional division of the crushed nerve.

The tendon of insertion of the scalenus anticus muscle is then palpated at the point of insertion into the first rib. It is carefully divided very slowly with small snips of scissors or a scalpel. The scalenus anticus is surrounded by a loose fascial sheath, and if this is not divided the adjacent structures will not be injured. The subclavian artery and thyrocervical trunk, the pleural dome, the vertebral artery and cervical nerve roots are all adjacent to the area of dissection and must be carefully protected from injury.