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Collapse therapy in the treatment of pulmonary tuberculosis with special reference of artificial pneumothorax

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INTRODUCTION

In the treatment of pulmonary tuberculosis, one of the most valuable forms of therapy which has been developed in the last century, has been collapse of the lung. Many patients, who in the past have been "lost" by the regular sanatorium regime, have been saved by this means. It must always be borne in mind, however, that tuberculosis is a general disease and foci may exist outside of the lungs. It stands to reason though, that if the field of greatest involvement is arrested, manifestations elsewhere can be expected to improve. Nature's method is still by far the best, being the safest and the more permanent. Experience, down through the years of trial and error methods, has taught that rest, fresh air, and nutrition in addition to collapse therapy will arrest the disease and keep the patient well. Preliminary and continued use of hygienic treatment is often necessary before compression of the lung can be brought about; thus increasing the resistance of the patient and also preparing the opposite lung for a greater degree of function than normal while the diseased one is healing under compression therapy.

Surgery, as practiced in the cure of pulmonary tuberculosis, is not applied in the same sense as it was formerly used. Generally, the diseased part is not removed by the operative process in the strict sense of the word. Instead, the diseased portion of the lung is placed at rest through the operative procedure which attempts to aid nature's method of spontaneous healing. Therefore, surgical treatment is not advocated as a replacement for nature's methods, but as a sup-

plement or a course of action when palliative measures have failed or their maximum benefit has been reached without an arrestment of the disease process. Lately, in this "rush" period of modern civilization, due to economic reasons, the time factor is an important phase of the treatment. Here again, collapse therapy is of value in that it may hasten the period of recovery and so return the individual to his occupation and his place in the world in a much shorter length of time.

In all, surgery or collapse therapy has a useful field in the modern treatment of pulmonary tuberculosis, not to be underestimated. If surgery should be refused by many of the medical profession as a means too radical, in adjunction to the more conservative methods of rest, fresh air and nutrition, many of the more advanced cases would not be getting every opportunity for recovery. If it is possible by collapse therapy to save only a small portion of the more advanced cases, the procedure is well worth while and the efforts have not been in vain.

GENERAL HISTORY OF THE TREATMENT OF PULMONARY TUBERCULOSIS

The present day treatment of pulmonary tuberculosis, may be said to have started when Brehmer in 1849 opened the first tuberculosis sanatorium at Garbersdorf, Silesia. He believed in fresh air and enforced feeding, but paid little if any attention to rest.

Later, Dettweiler, one of Brehmer's pupils, founded a sanatorium at Falkenstein, Germany, and for the first time applied rest in addition to fresh air and a careful sanatorium regime. He also was the first to use graduated exercise during convalescence. (10) (13)

In this country, Trudeau developed the same idea, and demonstrated to the medical profession the value of rest in the open air under sanatorium supervision.

Very little of importance has since been added to the treatment of tuberculosis except tuberculin, heliotherapy, and collapse therapy (phrenicectomy, thoracoplasty, artificial pneumothorax, oleothorax, pneumolysis, etc.).

Robert Koch made the discovery of tuberculin in the year 1890.

Artificial pneumothorax treatment was developed by Forlanini in 1888, and in this country by Murphy in 1894. (13) (21) (33)

Rollier did the pioneer work in heliotherapy, opening the first clinic at Leysin in 1903.

Friedrich, Brauer, Spengler, and Sauerbruch perfected thoracoplasty between the years 1907 and 1913.

Phrenicectomy was suggested by Stuertz in the year 1911 for the treatment of basal tuberculosis and bronchiectasis, but it was not un-

til it was discovered by Felix in the year 1921 that failure of the operation was due to the presence of accessory phrenic nerves below the operative field and exeresis of the nerve was advocated that success came. (13) (38)

It is an established fact that a tuberculous lung when placed at rest has a much better chance to heal. Rest in bed affords increased rest, especially to the upper parts of the lung. Coughing exercises the lungs and should be controlled. Various methods have been devised for keeping the lungs quiet; such as postural or lying on the involved side, strapping the chest, Sewall's chest belt, sand or shot bags on the affected side, resection of the phrenic nerve, artificial pneumothorax, and thoracoplasty. (15) (25) It is the purpose of this paper to discuss these latter means of resting the lungs, or what is now termed "Collapse Therapy".

ARTIFICIAL PNEUMOTHORAX

HISTORICAL:

Artificial pneumothorax was first suggested as a means of treating pulmonary tuberculosis by James Carson in the year 1833. At this time he published a study on the "Physiology of Respiration" in which he suggested the most rational treatment of phthisis would be the collapse of the affected lung. Carson attempted to establish an artificial collapse in two cases, but both were failures due to the presence of adhesions. (35)

In the year 1837, William Stokes observed that the symptoms of pulmonary tuberculosis were often modified by pneumothorax after the first violent symptoms had subsided. In all probability, though no mention is made in the references, the cases he reported were of spontaneous origin. (13)

Walter Hayle Walsh, about this same time, observed that the symptoms of phthisis underwent improvement when there were signs of hydropneumothorax. He thought this observation was rare and so no warranty for the treatment of phthisis by artificial pneumothorax. (9) (13)

Pierre Carl Edouard Potain of Paris was the first to use artificial pneumothorax therapy successfully. He treated three cases in the year 1885; two of which were successful. (35)

However, artificial pneumothorax was not definitely established as a therapeutic measure until about the year 1890. At this time, an Italian physician, Carlo Forlanini of Pavia, and John B. Murphy, of Chicago, began experiments in artificial pneumothorax treatment almost

simultaneously. There is record of Forlanini treating three cases altogether; one in 1888, one in 1894 and one in 1895. A. E. Lemke, Murphy's assistant, reported 53 cases so treated in the year 1899. (35)

Murphy's and Lemke's work was not followed up in this country. However, in Europe, Forlanini's ideas were adopted by Brauer and L. Spengler and mention is made of their work in Germany in the year 1905. From this time on, the use of pneumothorax became rather widespread and reports were made from many parts of the world. (13)

Brauer changed the original technique by making an incision down to the parietal pleura before using the puncture needle. In 1907, Saugman introduced the use of the water manometer which lessened the danger, especially when Forlanini's puncture method was employed. This is almost the procedure used at the present time.

Although artificial pneumothorax has so been known for many years, its use has been gradually increasing from year to year. The apparatus has been perfected and the technique of air insufflation has been greatly improved. Also, many conditions formerly considered as contraindications for the use of artificial pneumothorax are no longer considered as such. (13) (35)

There is scarcely any field of modern therapy in which so much scientific work has been expended as in artificial pneumothorax. The development of the X-Rays has been a decided advancement in the use of this form of therapy. At the present, artificial pneumothorax is the most extensively used, as well as the most successful form of compression therapy in the treatment of pulmonary tuberculosis. (9)

TYPES OF PNEUMOTHORACES:

Artificial pneumothorax, as a means of therapy, necessitates certain changes in the thoracic organs and circulation. There are three distinct types of pneumothoraces; the expansile, the static and the compression types. (5)

In an expansile pneumothorax, the intrapleural pressure remains negative at the close of the introduction of air. The lung being slightly compressed by virtue of its own elasticity, is still able to expand to a certain degree upon inspiration. It is for this reason that this type of pneumothorax is often called selective collapse; the area of compression being greatest over the tuberculous involvement due to the lessened amount of elasticity, while the relatively uninvolved portion of the lung functions quite normally during respiration. The same is true when reexpansion is permitted. That is, the diseased portion of the lung, or where the selective collapse has been established, remains compressed long after the uninvolved area has reexpanded.

If more air is introduced, the expansile property of the uninvolved portion is gradually diminished and a phase is reached where the intrapleural equals the atmospheric pressure. At this point the contractile and expansile forces of the lung are neutralized and the lung is at complete rest. When this has occurred, it is known as static pneumothorax. This compression stage is only transitory or of a temporary nature. As the air is absorbed by the pleura, the state of equilibrium is upset and the compression gradually approaches the expansile type; or as air is added, the static compression approaches the follow-

ing and last type of pneumothoraces.

When the intrapleural pressure exceeds that of the intrapulmonary or atmospheric pressure, the negative factor is completely lost and it becomes positive. The expansile property of the lung is overcome and pressure has been added in addition which causes the lung to squeeze up at its root. This is known as compression pneumothorax. This type of compression is to be avoided for not only is the intrathoracic equilibrium disturbed to an unwarranted degree, but the lung remains in a state of permanent contraction and decided changes occur in its structure and functions. (2)

Artificial pneumothorax therapy is only of a temporary character, and when completed, an almost normal lung should result. Therefore, the more expansile character of the compression, the better the end results will be when reexpansion is permitted at the termination of the therapy. (37)

THERAPEUTIC PRINCIPLES:

It has been repeatedly shown at autopsy and observed clinically, that tuberculous lesions in lungs compressed by artificial pneumothorax heal with unusual rapidity. The healing, in general, is by absorption of the smaller tubercules and the fibrosis of the larger areas. Extension and new tubercule formation in the compressed lung rarely occurs. When it does, it is usually of bronchogenic origin. (20) (31)

The rapid healing of the diseased process in the compressed lung has been explained in many ways. Probably all of which are important

factors in the healing process. Rest is the basic principle of treatment in any disease, and in artificial pneumothorax the lung is at partial rest in the expansile type and at complete rest in the compression type. Anatomical and physiological studies of the changes brought about by compression of the lung are not in accordance in the hands of many authorities. Some say that an ischaemia is the underlying principle, while others believe it is a hyperemia or congestion of the lung, which is the important factor. (4) It is entirely possible that both observations are correct and that the ischaemia or hyperemia depends upon the degree and duration of the compression. Especially is this probable at the very beginning of the compression therapy, for the lung is rendered atelectatic in direct proportion to the degree of pressure exerted upon it. The alveolar capillaries are collapsed, and the veins compressed more than the arteries so that a congestion must result.

All authorities upon this subject agree that a stasis occurs in the lymphatics, that the aeration of the blood is interfered with, and that the carbon dioxide content of the collapsed lung is increased. To some this is the principle factor in the healing of the lung.

Microscopically, the compressed lung shows marked fibrosis in and around the tuberculous lesions, an increase in the peribronchial and perivascular tissues, and a fibrosis of the pleura. The production of fibrosis by collapse therapy has been demonstrated by the fact that it results when the pulmonary artery or vein is ligated or the diaphragm is paralyzed. All of these procedures being similar in action and bring-

ing about the same end result. (4)

In the treatment of pulmonary tuberculosis, the primary aim is to keep the disease localized and prevent its spread. Ideal conditions for the dissemination of the tubercule bacilli and their products exist in the normal lung because of the constant respiratory movements and the rich network of blood vessels, lymphatics and air passages. The favorable therapeutic action of artificial pneumothorax rests upon the fact that it combats these factors for spread and makes the conditions as unfavorable as possible for dissemination by placing the lung at rest, closing some of the air passages, and slowing up the blood and lymph streams; thus causing a blocking of the lung, an increase in the amount of fibrosis, and an increase in the carbon dioxide content of the blood.

Compression of the lung will cause a complete obliteration of pulmonary cavities if not prevented by pleural adhesions or by thick fibrous walls in consolidated and inelastic fibrotic lung tissue. In these cases, other means of collapse must be considered. (14)

The contralateral or opposite lung from that being compressed is also affected by the pneumothorax. (32) A compensatory emphysema occurs and the mediastinum is often displaced to a marked degree depending upon the intrapleural pressure, the depth and rigidity of the mediastimum, and the presence or absence of pleural adhesions. If the displacement is to a marked degree, the expansion, aeration and circulation of the lung may be interfered with and grave embarrassment be noted. (4) The more moveable the mediastimum, the greater disadvantage to pneumothorax therapy for it gives less rest to both lungs and prevents the use of compression

pneumothorax in stretching adhesions, closing cavities, or arresting hemorrhages. After discontinuation of the compression and reexpansion of the lung, the mediastinum gradually returns to its normal position. (37)

The effect of artificial pneumothorax therapy with respect to the lungs is of great importance, but it also has a very important bearing with regard to the heart. The heart is required to perform extra work because of an increased resistance in the pulmonary circulation and altered conditions of intrathoracic pressure causing displacement of the mediastinum. The same quantity of blood must pass through the lesser as through the greater circulation to prevent an accumulation or congestion of the blood in the lungs or in the systemic vessels. By compression, the blood vessels in that lung are shut off and the blood flow is diverted to the opposite lung which has less resistance, but must allow a greater volume of blood to pass in the same unit of time as normal for both lungs. Thus an increased strain is thrown upon the right ventricle and if the myocardium is able to compensate, an adjustment is made and no harm is done for the right ventricle hypertrophies and a compensatory emphysema or dilatation of the vessels in the contralateral lung occurs. However, if the myocardium is weak or if the mediastinum is so displaced so as to present mechanical difficulties to the heart action and also to the compensatory changes in the opposite lung, cardiac decompensation occurs with dilatation of the right ventricle and congestion in the pulmonary and systemic circulation. (23)

The pleura is also affected by the pneumothorax. The parietal and

visceral layers are separated and any adhesions which may be present, are either broken or stretched depending upon their degree of firmness. The normal relationship of the blood and lymph circulation is interrupted and a fibrosis results as within the lung substance. Often subpleural foci are ruptured and cause a tuberculous empyema which is difficult to treat and lessens the chance of complete pulmonary reexpansion. Not infrequently, a spontaneous pneumothorax or bronchial fistula is brought about by this same means. (7)

INDICATIONS FOR:

The principle indication for the use of pneumothorax therapy in the presence of pulmonary tuberculosis, is for preventing of the spread and the facilitating of healing the tuberculous lesions; including the compression and obliteration of cavities. In young individuals with acute cases of unilateral distribution or for the most part in one lung, in infraclavicular or nonapical lesions of a broncho-pneumonic character, collapse therapy should be instituted at once. In older patients, with similar lesions, collapse therapy may or may not be started immediately; it often being best to wait and observe the effects of rest and hygienic treatment first. In chronic cases of large involvement with cavitation, or in cases of only moderate involvement which have not shown any progress in healing after pursuing the rest cure faithfully for a year or so, collapse therapy is more or less indicated. Cases with basal involvement, especially with cavitation, or with fibrous tuberculosis in an upper lobe and recent extension to the lower part of a lung, would indicate collapse therapy. Bilateral cases should

always have the most involved lung collapsed. Often under this regime, the contralateral or noncompressed lung will show remarkable progress in healing. Also an expansile type of pneumothorax may be induced on the more severely involved side, permitting it to heal and reexpand, then performing the same therapy on the opposite side. In severe bilateral cases of pulmonary tuberculosis, bilateral or simultaneous pneumothorax may be instituted. The more involved lung is collapsed first and after the pneumothorax has been well established so that refills are a week apart, an initial is then induced on the other side making refills on alternate weeks. Such cases do well if the mediastinum is more or less fixed, if the lower lobes are little if any involved, and if a low intrapleural or selective compression is employed. (12)

Artificial pneumothorax therapy is also indicated as an emergency treatment in severe and uncontrollable hemorrhage and in cases which are constantly bleeding or hemorrhaging upon the slightest provocation. Control of hemoptysis by this means is not entirely safe, for usually when the hemorrhage has been severe, blood has been aspirated into the bronchial tree of both lungs. This frequently results in a pneumonitis; dyspnea and cyanosis become prominent; and there is cardiac embarrassment which may lead to acute failure. Again, it is not always easy to definitely determine which lung is hemorrhaging. If cavitation is limited to one lung, it is fairly reliable to assume that the hemorrhage is from this one. Physical signs are not reliable and an X-Ray plate should always be had before inducing pneumothorax. If there is any doubt, artificial pneumothorax should not be attempted. (24)

In certain cases, pneumothorax therapy is indicated as a preliminary step to thoracoplasty to gradually adjust the intrathoracic viscera or to splint the lower portion of the lung and so prevent an aspiration pneumonia during an upper stage operation. (9) In all, the character of the patient, the extent and nature of the involvement, the progress, if any, of the disease and the necessity for a shorter time of treatment have to be considered in all cases before artificial pneumothorax can be decided upon.

CONTRAINDICATIONS:

Few conditions may be considered as absolute contraindications to the introduction of artificial pneumothorax therapy. All have become less absolute as the principle of expansile and selective compression has been developed. Especially is this true since there is much less cardiovascular disturbance. With the development of a finer technique, every resultant step from therapy can be demonstrated by means of the X-ray.

Severe bilateral renal tuberculosis, chronic parenchymatous nephritis, severe decompensating heart disease, severe asthma, or marked emphysema, are considered as definite contraindications to the introduction of artificial pneumothorax. Likewise, artificial pneumothorax is contraindicated in severe bilateral cases of pulmonary tuberculosis in which all lobes are actively involved. In other races having a low resistance to tuberculosis, especially the Indians and Negroes, collapse therapy is not contraindicated but the results are somewhat discouraging. (24)

Childhood, old age, diabetes, pregnancy, moderate diseases of the cardio-renal-vascular system, tuberculous laryngitis and enteritis are no longer considered contraindications. It has been proven that extra pulmonary tuberculous conditions or complications improve when the pulmonary condition is controlled by means of collapse therapy. (12)

APPARATUS:

The type of apparatus used today is that of Brauer, of which two modifications are generally employed; one by Floyd Robinson and the other by Pilling. Both are very similar and employ the same principles though there are minor differences. (1)

The apparatus consists of two graduated bottles of 2000 c.c. capacity; connected by elastic tubing. For inducing air, the left hand bottle is stationary and contains the air to be injected. The right hand bottle is elevated and contains fluid. Then by a siphon action, the fluid runs from the right hand bottle into the left, forcing out a corresponding quantity of air into the intrapleural space by means of the elastic connecting tube to which is attached the pneumothorax needle. Refilling of the right hand bottle, or withdrawing air from the pleural space, is accomplished by reversing the positions of the two bottles; that is, elevating the left and lowering the right. A three way stop-cock controls the flow of air into the chest or enables a manometer reading to be taken. There are many other types and modifications of pneumothorax apparatus, but these two are simple and practical enough for all purposes.

Two types of needles are used in giving pneumothorax, an initial and

a refill. The initial ones are large blunt needles with an obturator, known as a trocar and cannula, to prevent the admission of outside air. For refills, smaller calibre and sharper needles are used with or without an adjustable stop. The Fisher needle, gauge 16, is very practical for initials or partial collapses which make the location of the lung margin uncertain. It consists of a cannula with a hollow blunt stylet, containing the opening near the end laterally. (15) (26)

TECHNIQUE:

In both initial and refill pneumothoraces, strict asepis is required. The hands are scrubbed and a sterile gown and gloves are used. The patient is placed on the table, affected side up, with the head lowered and facing away from the operator. The arm is elevated with the hand upon the head and the elbow thrown back. This tends to widen the intercostal spaces and facilitates thoracentesis. Further widening of the intercostal spaces is accomplished by placing a pillow beneath the opposite side, thus flaring apart the ribs. The skin of the area selected for puncture is swabbed with tincture of iodine and cleansed with 95% alcohol. Then a sterile open center pneumothorax sheet is arranged in position over the prepared site. The tract of the needle puncture, usually in the anterior axillary line and in the fifth interspace for reasons to be given later, is anaesthetized by infiltrating the skin, fascia and intercostal muscles down to the pleura with a 1% solution of novocain. The fifth intercostal space at the anterior axillary line is generally the most suitable; as at this point there is only a small layer of lung tissue and there is also little risk of striking any of the larger pulmonary

vessels. However, other sites may be selected if circumstances make them more preferable. (15)

After infiltration, the special cannula is inserted in a small stab wound and pressed slowly inward until the parietal pleura has been pierced. When the cannula has entered the intrapleural space, there is a connection made between the negative pressure of the space and the outside atmospheric pressure. The difference in pressure causes an audible aspiration of air into the intrapleural space which reduces the negative pressure and causes some pulmonary compression. This aspiration of air is regarded as an excellent prognostic sign for it shows that the cannula is not in the lung tissue and also that the pleura is relatively free of adhesions which is very important in obtaining a satisfactory collapse. Following this, the trocar may be introduced without danger of lung puncture as there is now a definite pleural space. A minus reading obtained on the manometer should show a rather wide range as to respiratory fluctuation. Failure to obtain a satisfactory negative reading with definite wide fluctuations during respiration indicates a pocket of pneumothorax rather than a free pleural space. Fluctuations which are to an equal degree negative and positive, usually indicate an intrapulmonary reading, and the trocar and cannula must be withdrawn till a satisfactory reading is obtained. (6)

The administration of air should be slow and after each 100 cc of air, manometer and blood pressure readings should be taken. The initial fill should not exceed 300 to 400 cc, and should be concluded without a positive pressure manometer reading. This reduces the danger of air

embolism and prevents any severe cardio-vascular or respiratory disturbance. Also, undue intrapleural pressures may cause the rupture of adhesions with the formation of a superimposed spontaneous pneumothorax. (2)

After the introduction of air has been completed, the trocar and cannula are withdrawn and a gauze dressing is applied over the puncture wound with a three inch strip of adhesive tape reaching from the sternum to the spine. This method of dressing usually controls subcutaneous emphysema which is not as dangerous a complication as many others but is still a disturbing and uncomfortable condition for the patient. (33) Fluoroscopic or preferably X-Ray plates are taken after the initial fill to determine the amount of collapse, the position of the heart and the mediastinum, and the presence or absence of adhesions. Refills are given in the same manner except that a sharp refill needle is used instead of the cannula and trocar and no dressings are applied.

The optimum degree of collapse for each individual case must be settled empirically after a number of refills. The rigidity of the mediastinum, the presence or absence of adhesions, the presence of cavities, and the condition of the contralateral lung must all be taken into consideration. The intervals between injections are so planned so as to provide a stable degree of collapse. The absorption power of the pleura is at first very active but as the continued treatment produces a more or less inflammatory thickening, the pleura becomes less permeable and the intervals of refills may be lengthened without increasing the amount of the refill. (15) (29)

DURATION AND REEXPANSION:

Artificial pneumothorax therapy in pulmonary tuberculosis, should be, in the average case, continued for a minimum of two years. No period of treatment can be adhered to as a hard and fast rule for it is necessary to determine any form of therapy as an individual problem. It may be necessary to continue treatment for an indefinite period of time if large cavities exist and cannot be completely compressed. This brings into consideration the various aids and substitutes to artificial pneumothorax therapy, such as the electro-cauterization of adhesions preventing collapse of a cavity (Jacobaeus Method), resection of the phrenic nerve, and various forms of thoracoplasty. (27) Phrenico-exeresis frequently gives an increased collapse, especially in the presence of a moveable mediastinum, with less air pressure necessary, and is almost always necessary in basal cavitation with diaphragmatic adhesions. Thoracoplasty in its various forms are the final steps and is necessary when artificial pneumothorax and phrenico-exeresis have failed. (9)

Reexpansion or discontinuation of compression treatment is a very important phase and requires careful supervision. Refills are given at wider intervals and of lessened amount so as to allow the lung to expand gradually. During this time, repeated and careful physical, X-Ray and sputum examinations are made to confirm the opinion that the condition of the lung warrants reexpansion. Depending on the observations and findings, the lung may be permitted to reexpand till artificial pneumothorax therapy is completely discontinued, or it may be recompressed. Reexpansion results in the majority of patients in partial or complete pleural symphysis so

that the reinduction or establishment of air compression is impossible. (35)

The aim of compression therapy is to cause an arrestment of the disease process, and to maintain this arrest a sufficient length of time so that upon pulmonary reexpansion a reactivation of the tuberculous lesions will not result. The accurate status of the condition should be estimated or determined by all the clinical data such as symptons, physical findings, serial X-Ray films, laboratory data, a partial test reexpansion with accurate observations at frequent intervals, and finally the effects of complete reexpansion with discontinuation of compression therapy.

RESULTS:

The immediate results of artificial pneumothorax therapy, where satisfactory collapse has been obtained, is often very striking. The majority of the symptoms disappear entirely, and if not, at least are improved to a noticeable degree. The temperature becomes normal, cough and expectoration decrease or cease, tubercule bacilli are no longer found in the sputum, pleuritic pains and night sweats disappear, body weight increases; all of which may be summed up as a marked improvement in the individual's general condition.

The pathological picture within the lung tissue likewise shows marked changes. The exudative lesions resolve like an ordinary pneumonia; caseous lesions become permeated and surrounded by fibrosis; productive lesions, if small, may disappear entirely, but the larger ones fibrose; cavities which can be completely obliterated by compression, permanently heal. (20)

The permanent results of artificial pneumothorax therapy in the treat-

ment of pulmonary tuberculosis compare very favorably with any other form of therapy; bearing in mind that it is often instituted when other measures have failed or have reached their maximum of benefit. Saugman, in 1921, reported his results in 310 cases of pneumothorax between the years 1907 and 1918 which he had been able to follow up. In 218 cases, the pneumothorax therapy could be carried out; in 92 cases, for various reasons, this was impossible and had to be given up. Of the 218 successful pneumothoraces, 74 or 33.9% were able to work, 7 or 3.2% were unable to work due directly to tuberculosis, 1 or 0.5% was unable to work on account of other causes, 130 or 59.3% died of tuberculosis, and 6 or 2.8% died of other causes. Of the 92 unsuccessful cases, 10 or 10.9% were able to work, 1 or 1.1% was unable to work because of tuberculosis, 79 or 85.9% died of tuberculosis, and 2 or 2.2% died of other causes. (20) Fishberg reported 25% of his cases at the Montfiere Home were able to return to a gainful occupation. (13) The Matson Brothers reported the end result of 600 cases, 480 of which received artificial pneumothorax therapy, as follows: Of the 235 cases with a satisfactory collapse, 48% were clinically well, 18% were arrested, and 22% were dead. Of the 245 cases with a partial collapse, 11% were clinically well, 12% were arrested, and 58% were dead. (31) Various other authorities report recoveries ranging from 15% to 35%. (20) (3) Any type of statistics is unsatisfactory for the various types of cases are not differentiated. If only cases were included in which a satisfactory collapse had been obtained, the percentage of clinical recoveries would no doubt be higher. However, it is readily apparent, considering all cases whether a success or a failure, that artificial pneumo-

thorax therapy in pulmonary tuberculosis has a very high percentage of clinical recoveries in comparison with other forms of treatment. (31)

COMPLICATIONS:

(a) Pleural Adhesions: Pleural adhesions are the most common cause for an unsatisfactory collapse in artificial pneumothorax therapy. Just as they prevent a complete collapse, they also prevent the introduction of a suitable selective collapse for the obliteration of cavities. Adhesions are usually over the involved portion of the lung and so the longer the individual has had clinical tuberculosis, the denser the adhesions and the less chance of obtaining a satisfactory artificial pneumothorax. Instead, a pocket or partial pneumothorax forms over the uninvolved portion. Pneumothoraces of this type, though unsatisfactory as far as obliteration of cavities is concerned, are of definite value. (5) They serve to gradually accustom and test out the contralateral lung for its increased work when a thoracoplasty is to be performed. Partial collapse also prevents aspiration tuberculosis in the uninvolved lower portion of the lung during the upper stage of a thoracoplasty. Pleural adhesions, if not too dense or rigid, may be stretched and separated by means of positive pressure or a compression pneumothorax, if respiratory or cardiac embarrassment isn't of a too severe degree. Adhesions, if few and definite, may be severed by thoracoscopy and electro-cauterization. The open method or intrapleural pneumolysis, is a dangerous procedure because of mediastinal flutter, and it is best not attempted when there are other means of obtaining a collapse. If a sufficiently free pleura cannot be found or obtained by the methods mentioned above, it is necessary in order to ob-

tain a satisfactory collapse, so that large cavities may be obliterated, to perform phrenicectomy and thoracoplasty and thus accomplish the desired results. (15) (27)

(b) Air Embolism: Air embolism is a very serious complication, but fortunately is a relatively rare occurrence. It is usually brought about by the injection of air into a pulmonary vein, either during an initial or a refill. (39) Pleural adhesions are again of danger in that veins within the adhesions may form an anastomosis between those of the chest wall and the lung; and air, even though injected into a systemic vein, may be carried to the left heart. Air from or in a systemic vein, otherwise enters the right heart and is filtered out in the lung capillaries without any ill effects. However, air in a pulmonary vein, either directly or through a systemic anastomosis, goes directly to the left heart and any reaching the coronary or cerebral vessels, causes severe and alarming symptoms, often with death as a result. Air emboli may develop without air being injected directly into a pulmonary vein. The pneumothorax needle may penetrate the lung and open up a communication between a pulmonary vein and an alveolus or bronchiole; or by the needle puncturing a vein in the pleura or chest wall; or adhesions, so that the communication is made between the air in the pneumothorax space and the vein punctured. As mentioned before, air embolism is more frequent during the initial induction but may occur at any time. Statistics show about a 35% mortality in all proven cases of air embolism. (8)

The symptoms of air embolism are tonic and clonic convulsions, usually unilateral. The convulsions are usually limited to a

group of muscles corresponding to the area of the brain involved. Coma, passive manic depressive excitation state, and retrograde amnesia may also occur. Sometimes the air emboli lodge in the retinal arteries, which can be demonstrated upon eye ground examination, and cause blindness. The characteristic picture of "red marbling" in air embolism is due to local stasis of the blood stream in the peripheral circulation. Some quick deaths, resembling heart failure, are caused by air emboli in the coronary arteries. (8) (39)

There is no adequate treatment for air embolism. It is mainly one of prevention. The main factors in prevention are: the use of blunt needles for initials or refills where there is doubt about the degree of compression; obtaining satisfactory manometer readings before introducing air at any time; and keeping the head lower than the rest of the body as an air embolus follows the law of gravity. If air embolism should occur in spite of these precautionary measures, prompt treatment is necessary. The head should be lowered further, heart stimulants such as atropine hypodermically and adrenalin intravenously should be given, and last, but not least, oxygen inhalations to support both the respiratory and cardiac mechanisms. Artificial respiration should never be employed. (8) (39)

(c) Emphysema: Emphysema, or air in the tissues, causes some soreness and pain, but it is not serious and absorbs in a few days. It is inconvenient as it makes the patient very uncomfortable and also makes it necessary to postpone refills until the condition subsides. Too great a degree of intrapleural pressure may cause the air to burrow around through

adhesions and enter the mediastinum. True mediastinal emphysema is caused by the air being introduced directly into the lung and then forcing its way along the lung septa into the mediastinum. Air under positive pressure within the pleural space may escape into the fascia between the thoracic muscles and the parietal pleura. From here it may work up into the deep fascia of the neck, or spread subcutaneously to any part of the body. (33)

(d) Pulmonary Hemorrhage: Pulmonary hemorrhage is one of the most serious complications that may develop during pneumothorax therapy. It is, of course, more common in cases of cavitation and where there is an unsatisfactory collapse. It is immediately necessary to determine which lung is hemorrhaging, as the course of treatment depends largely on the origin of the hemorrhage. This information is gained from the physical signs and X-ray findings. If the hemorrhage is from the contralateral lung, which must be assumed if the other lung is completely collapsed and lesions are present in the uncollapsed lung, removal of some air from the collapsed lung may be advisable to decrease the load on the contralateral and hemorrhaging lung. If the treated lung is not completely collapsed, the compression should be increased. In addition to the compression aspect, general treatment should be instituted. The patient should be on absolute bed rest until five days after streaking has disappeared. A semi-dorsal position is advisable as it seems to bring about greater ease in raising the accumulated blood. All unproductive cough should be controlled, using codeine sulphate, one eighth grain, by mouth, if necessary. Cracked ice by mouth is often of value, but fluids, in general, should be restrict-

ed so as not to increase the volume of blood. Amyl nitrite, three minim capsules as inhalants, or nitroglycerine, one-fortieth or one-sixtieth grain, hypodermically may be used to lower the pressure further. Sodium bromide or sodium chloride, fifteen grains orally, may be given every one-half hour if necessary, or five to ten cc of 10% sterile sodium chloride solution may be administered intravenously. Morphine, horse serum, thromboplastin, pro-thrombin, and hemoplastin may be of value. Calcium lactate, fifteen grains t.i.d., is often administered during and after the symptoms of pulmonary hermorrhage have subsided. (13) (14)

(e) Spontaneous Pneumothorax: (40) (6) Spontaneous pneumothorax following the induction of artificial pneumothorax is not an uncommon occurrence, being one of the most serious and fatal complications to pneumothorax therapy. However, there is only a relatively small percentage of complete spontaneous pneumothoraces as adhesions in the majority of cases prevent a complete collapse. Fatality is due to shock, immediate heart failure, pyopneumothorax developing, or bronchogenic spread to the contralateral lung. Often, after a spontaneous, especially of the incomplete type, the lung may expand without serious results. Everything depending upon the degree of the collapse.

Spontaneous collapse may be due to needling the lung tissue with a subsequent fistual formation, to the rupture of a cavity near the pleura, to perforation of a subpleural caseous focus, to the tearing loose of an adhesion, or to the bursting of an emphysematous bleb.

Most fistulae are of the ball or check valve type; that is, letting air into the pleural space but allowing none to flow back; thus in-

creasing the pressure with every breath. Sometimes the fistula may close upon collapse of the lung and seal over permanently with fibrin. However, this is not the usual end result. As mentioned before, the air in the pleural space increases with each respiratory effort or cough, thereby increasing the pressure with a corresponding displacement of the diaphragm and mediastinum, and thus interferring with the work of the contralateral lung and the heart. The patient has an almost characteristic picture, feeble pulse, cold perspiration, anxious expression, cyanosis, and is almost in extremis. Immediate and efficient treatment often brings about surprising recoveries.

Treatment consists of two parts; first, to relieve the distressing symptoms, and second, to prevent pyopneumothorax. Morphine or codeine is given for the relief of pain and to control the cough; digitalis for the heart; and oxygen for the cyanosis. The air pressure in the intrapleural space is then decreased by withdrawing air by means of reversing the pneumomachine or by continuous evacuation by means of a stationary needle in the chest wall connected to a tube with the opposite end in a bottle of water; thus permitting air to be forced out but none to be taken in.

If a pyopneumothorax develops and the patient's condition will permit, an immediate thoracoplastic collapse is indicated; the principle being that a small pyopneumothorax cavity is less serious than a large one, for tuberculous patients in the first place do not stand empyema well, and in the second place, a large pyopneumothorax cavity leads to amyloidosis with a prognosis of about three years. After such a thoracoplasty, corrective or plastic operations may be necessary to obliterate the empyema

and to close the bronchial fistula. If the patient's condition will not permit an immediate thoracoplasty, tubing and dakinization may bring about good results or improve the patient's condition until a thoracoplastic collapse can be performed. If the condition is not a severe one, aspiration as indicated by symptoms and X-ray findings, plus irrigation with a 1-5,000 solution of sterile gentian violet in the mixed pyopneumothoraces and a 10% solution of sterile gomenol for the tuberculous processes, often brings about surprising good results. (35)

(f) Pleural Effusions: Pleural effusions are the most frequent but not the most serious complication of artificial pneumothorax therapy. The incidence being given as from 40% to 80%. (21)

The causes of pleural effusions are many, not all of which can be ascribed to infection during the induction of air. The irritation of the air upon the pleural surfaces, the tearing of adhesions, the difference between intrapleural and intrapulmonary pressures, the rupture of subpleural tuberculous foci into the pleural space, or tuberculous pleurisy may all cause effusion. Most authorities have found that the incidence of pleural effusion is much lower under low intrapleural pressures. (21) (2)

The fluid may be sterile and cause no trouble except for pressure symptoms when in great amount, or the effusion may be tuberculous, being positive for the tubercule bacilli. As mentioned, if a spontaneous has occurred, the exudate will be of a mixed type and the symptoms rather severe. (33) (35)

Sterile exudates need not be removed except when pressure symptoms are too severe, for a hydrothorax causes compression the same as a pneumothorax. However, they must be closely watched for the effusion may absorb

rapidly and the lung expand and adhere to the chest wall, thus losing the collapse before an artificial air pneumothorax can be instituted. Non-sterile effusions should be aspirated and irrigated with a 1-5,000 solution of sterile gentian violet in the mixed type and a 10% solution of sterile gomenol in the tuberculous type. (35)

THORACOPLASTY

HISTORICAL: (26)

The first recorded plastic operation for the treatment of pulmonary tuberculosis was by Quincke in 1880. Soon afterwards, several operations were performed by Karl Spengler around the year 1890. (38)

At the beginning of the twentieth century, Landerer (1902) made further operative experiments in the surgical field of phthisis. Brauer and Friedrich in 1907 began the present operative procedure although it has been modified to a marked degree. Through their extensive work in the treatment of pulmonary tuberculosis, Brauer and Friedrich decided that a more extensive operation was necessary than had previously been advocated. Briefly their technique was as follows: a long horseshoe shaped incision was made from the sternal end of the clavicle anteriorly to the spine of the scapula posteriorly, doing a radical removal of the arches of all the ribs so uncovered. This operation had a high mortality in that it left the entire lateral side of the chest unsupported and so caused paradoxical movements of the lung, thus causing serious physiological disturbances of respiration. Also, the final result of the operation was often unsuccessful, in that the collapse was not complete. Although the arches of the ribs were removed, the stiffer posterior portions were left which caused a continued expansion of the larger posterior half of the thorax. Wilms, in 1911, published a modification of Brauer's and Friedrich's thoracoplasty, especially valuable for less advanced cases of phthisis.

The type of thoracoplasty in use at the present time is known as the posterior operation as devised by Sauerbruch. The operation consists of

an extrapleural paravertebral resection of the upper ten or eleven ribs. He recommended a less wide resection of the ribs and brought out the necessity of removing the ribs up to the lateral processes of the spine.

Brauer later devised a modification of Sauerbruch's operation in which he made a wide resection of the upper ribs and used the scapula as a support to the upper chest. Both Brauer and Sauerbruch in their operative technique made the rib resections from below upward. In the United States, most chest surgeons operate from above downward; the theory being that this procedure provides the collapse at the very beginning when it is most necessary, also that the extent and character of the resection can be better fitted for each individual's need. After all, the success of thoracoplastic surgery depends largely upon the proper selection of cases. It is a major operation and is accompanied by all the usual dangers; often times being a failure with regard to the complete obliteration of cavities and so necessitating further surgery. (22) (26)

GENERAL:

Various types or combinations of anaesthesia may be used in performing a thoracoplasty. Local anaesthesia may be used by blocking the intercostal nerves near their exist from the vertebrae. Nitrous oxide, light ether general, or a combination of local and gas oxygen may be used. Combinations of ether, nitrous oxide and oxygen, avertin and nitrous oxide, have been used with very satisfactory results. (35)

A complete thoracoplasty is usually divided into two stages, although this is not a set rule for conditions vary so that more than two stages may be necessary. In the multiple stage method, the resection of the

upper five ribs is performed first, (the upper stage); and then in two weeks the remaining ribs are resected, (the lower stage). If the upper or lower part of a lung is all that is involved with cavitation that cannot be obliterated, and it is not considered desirable to sacrifice the entire lung, an upper or lower stage may be all that is indicated. In performing the complete operation, the condition of the patient after the resection of the first three ribs determines the extent of the upper stage. The upper ribs are cut in the order of three, two, one and if the patient's condition permits, the fourth and fifth ribs are resected at the same time; thus requiring only two operations for the complete thoracoplasty. The remainder of the ribs to be resected for the second stage may be performed with no serious danger. Wide sections of the second to fifth ribs should be removed as the scapula acts as a support to the chest in this region and not below. It is of primary importance in securing a good collapse that wide resection of the lower ribs up to the lateral process of the spine be made. If this is not done, there will be a gap between the cut end of the ribs due to the scapular support of the upper chest, with the result that sufficient support to the lower lateral thorax will not be given and paradoxical breathing results with dyspnea and heart embarrassment. Some men advocate, in cases with large cavities in the apex, that the first and second ribs be removed in their entirety.

Anterior as well as posterior thoracoplasty is necessary in cases with large cavities or an empyema to bring about a complete obliteration. Shock, due to the degree of manipulation necessary in performing the operation, is a very dangerous condition always present. To combat this condi-

tion as far as possible, the patient should be digitalized prior to the operation. In addition, various laboratory tests, such as a basal metabolic rate, vital capacity, blood chemistry, complete blood counts, electrocardiograms, and blood typing for immediate transfusion if necessary, should be performed. Thoracoplasties are primarily for the purpose of saving life; thus it is a grave operation and all emergencies should be met promptly.

With few exceptions, thoracoplasties should be preceded by a phrenicoexeresis to test out the integrity of the opposite lung and to gradually adjust it and the heart to the demand for increased function; also to prevent spread by aspiration during and immediately after operation. (25) (10)

INDICATIONS:

Thoracoplasty is indicated in tuberculous pyopneumothorax, especially if there is a bronchial fistula and a mixed infection present. Rib resection should always be contemplated in cases with large unilateral lesions after all other forms of treatment, including a careful sanatorium regime and attempted artificial pneumothorax, have failed. Also in cases with large unilateral cavitation in which pneumothorax is only partially successful because of incomplete compression due to adhesions. Some authorities advise thoracoplasty in all cases of multiple cavitation without trying other forms of therapy, the decision of course depending upon their interpretation of the degree of emergency which exists. After all is said, thoracoplasty is largely for the purpose of healing cavities and, therefore, a life saving means. (21)

Statistics collected by H. L. and L. R. P. Barnes (3) covering 1454

cases with cavitation show that the average duration of life for these patients was around one year. Eighty per cent (80%) or 1163 of these patients died within one year while only fifteen percent (15%) or 218 patients survived for three years. This high mortality can be traced directly to cavitation for it is through this means that hemorrhages, extensions, and overwhelming toxiemas occur. Therefore, any means of obliterating this continuous menace is indicated after careful consideration of the case; bearing in mind that other forms of treatment have failed.

Involvement of the contralateral lung is not a contraindication if there is sufficient normal lung parenchyma present to carry on the respiratory function. The involvement may be scattered and no-dose in type or even cavitation may be present. Usually the most severely involved lung is contracted, excavated and bound down by adhesions, while the relatively good side has already compensated by hypertrophy and will carry the extra demands thrown upon it without embarrassment. Often the contralateral lung will be benefited and show improvement. (32)

When the most severely involved lung is completely compressed by thoracoplasty, the cavities are obliterated and a source of toxemia is eliminated; thus the bodily resistance is improved. As there is an improvement in the pulmonary pathology, lesions elsewhere may be expected to improve also.

X-ray studies make the final decision as to whether a thoracoplasty should be attempted. The extent and character of the involvement can be estimated quite accurately by this means and has been one of the most important factors in the development of collapse therapy. Roentgenograms

show definitely the amount of fibrosis and the degree of hypertrophy of the opposite lung, which is very important when a thoracoplasty is contemplated. Fibrosis, in general, means resistance, while hypertrophy of the contralateral lung indicates that a compensatory reaction has taken place because of its increased work. Thoracoplasty should be performed rather early and at a favorable time instead of waiting until it is a last resort and the patient is a poor operative risk. This is one of the main factors in the high mortality of the procedure, but as all indications are a matter of degree and their interpretation may be widely disputed, it is remarkable that the final results are as a whole so satisfactory. (9)

CONTRAINDICATIONS:

One of the most important contraindications to thoracoplasty is a poor general condition on the part of the patient, that is, a poor operative risk. Extensive and active involvement of the contralateral lung forbids operation as does emphysema or multiple adhesions which prevents it from compensating. Severe myocarditis which will not respond to digitalization is an absolute contraindication for the patient would never last through the operation. Advanced diseases such as amyloidosis, diabetes, severe nephritis, hepatic cirrhosis, or any other disease which lowers body resistance and makes death a matter of time, are contraindications to the operation. Patients of races, such as the Negro and Indian, which have a low immunity to tuberculosis are poor operative risks in general, but this is not an absolute contraindication. Tuberculosis in other parts of the body, such as the larynx, bowel, genito-urinary tract, and joints, is not a contra-

indication for just as under artificial pneumothorax these secondary foci of infection usually improve after riddance of the primary foci in the lungs by thoracoplasty. (9)

Before surgical collapse of the chest is performed, care should be taken that there are no nontuberculous infections present such as tonsilitis, sinusitis, cholecystitis, etc. All such conditions should be erradicated before the thoracoplasty so as to have the patient in the best general condition possible and not a poor operative risk.

OPERATIVE AND POST OPERATIVE TECHNIQUE: (9) (29) (35)

As in all operations, strict surgical asepsis is necessary. The position of the patient is of a semirecumbent type; the operative side up and inclined anteriorly so that there is a good posterior view. The incision is made from the posterior axillary line along the tenth rib, upward between the posterior border of the scapula and the spinal column, to a point slightly above the spine of the scapula. The incision is then carried down to the ribs; cutting the muscle layers well out over the costal angles so as to avoid the thick paraspinal muscles which are retracted inward instead of being cut. All bleeding vessels are caught with hemostats but not tied. However, little bleeding usually occurs. When the ribs are resected, the bleeding is controlled by means of hot packs. All ribs to be resected are first cleaned of periosteum and then cut at one time. By this procedure, the time to which the patient is exposed to chest flutter and paradoxical breathing is reduced. Some men believe this is the procedure of choice for the lower ribs but that the upper three should be cleared of periosteum and resected separately.

As mentioned, the ribs are resected as close to the transverse processes of the vertebrae as possible, extending the resection outward depending upon the rib resected and the amount of collapse desired. Usually from one to one and a half inches is resected from the first rib and gradually increasing the amount of rib removed until from four to four and a half inches of rib is removed from the lower ones. The wound is then sutured in layers after the insertion of a drainage tube in the highest and deepest portion of the incision. Adhesive plaster is then applied over the dressings, tight enough to support the chest until the wound has healed by first intention.

Fast surgical technique lessens shock but careful operative skill is much more important. Undue traumatism predisposes to infection and post operative toxemia. Shock post operatively is combatted by warm enemas and hypodermoclysis of 500 to 1000 cc of normal physiological saline solution. Codein, one-half grain hypodermically, is given for pain instead of morphine because it is less of a depressant. Small amounts of water are allowed the first day; a liquid diet the second; and a soft diet on the third. Hypodermoclysis of the same amount as before may be repeated if necessary. Digitalis is continued as long as indicated. Amytal or veronal and codein are given for restlessness and insomnia. On the third day, the drainage tube is removed. Dressings and restrapping are usually changed every third day depending on the condition of the wound. Sutures are removed from ten to fourteen days, but strapping is continued for about six weeks. Physiotherapy is of value in developing the shoulder muscles and preventing spinal deformity. Corrective operations may be necessary in

cases of very large cavitation or pyopneumothorax to obtain the best results from the thoracoplasty. All physiotherapy measures and corrective exercises should be properly and early applied before muscular retraction occurs and thus reduce the post operative deformities to an inconspicuous degree.

THE COMPLICATIONS AND DANGERS:

1. One of the most important and common complications of thoracoplasty is shock. Shock depends on two factors; the condition of the patient before operation and the operative procedure itself. Hemorrhage during the operation should be minimized as bleeding increases shock in a direct relationship. Forceful and extensive manipulation of the shoulder blade over that normally required to perform the operation is another important factor. Especially is this true of muscular and well developed patients. An operation of long duration favors mediastinal flutter and paradoxical breathing which, in turn, causes shock. Careful and thorough preoperative preparations plus accurate and rapid surgical technique during the rib resections reduces this factor to a great extent. As soon as the wound is sutured, dressings applied, and the chest strapped, the chest flutter is decreased to a very great extent and usually causes no further trouble in the average case. It is very necessary that the strapping, which is an important factor in controlling mediastinal flutter and paradoxical breathing, is not too tightly applied, being only supportive in nature for it may also cause further shock if otherwise. (9) (35)

2. Probably the most common and serious complications are cardiac

decompensation and toxemia. These two conditions are not immediate in their appearance but usually occur during the first post-operative week. Cardiac decompensation is due to a degenerative myocarditis which cannot always be foretold but becomes apparent when the heart is placed under a great strain. Digitalization may bring about complete compensation before operation, but if some complication occurs, the heart falters and no means will restore it. A decompensated digitalized heart has no remedy. Oxygen is of great value in the presence of cardiac stress, especially when dyspnea exists, but has no great effect upon marked decompensation.

There are a number of post-operative causes of decompensation. Secondary hemorrhage may occur into the wound but this is not common and rarely serious if it does occur. Pulmonary hemorrhage is quite a different problem. As a rule, the patient is unable to clear the bronchi fast enough and death is caused by suffocation in a short time. Secondary infection into the surgical wound should not be a complication if strict surgical asepsis is carried out during and after the operation. However, if it occurs and is discovered and treated early, it is not serious. As infection interferes with the healing of the wound and makes tight strapping impossible, it may lead to more serious complications such as mediastinal flutter, paradoxical breathing, and an incomplete collapse. Displacement of the mediastinum with a resultant cardiac embarrassment and decompensation may occur. Especially is this true when thoracoplasties are performed on artificial pneumothorax cases which are incomplete because of pleural adhesions which prevent obliteration of cavities, and on pyo-

pneumothoraces when it is attempted for the purpose of reducing the empyema space. A spontaneous pneumothorax may develop and so increase the intrapleural pressure so that the heart and mediastinum are displaced. Thus the heart is weakened and as it is using its entire reserve to compensate from the operative effects, this new complication cannot be met and the heart fails. Aspiration tuberculosis and pneumonia are not uncommon following operation. Often the heart can compensate for this extra load and the pneumonia will resolve and the tuberculosis remain localized. Many times though, especially if there were cardiac symptoms preoperatively, decompensation and death is the final result. (14) (40)

3. Toxemia is another common cause of fatality in thoracoplasty. Symptoms usually appear during the first twenty-four hours post-operatively and lead to a fatal termination sometime during the first week following operation. Various etiological factors have been brought forward to explain this condition. Many think that it is due to compression forcing the toxic products of the tubercule into the lymph channels. Some believe that the secreations of the cavities and diseased bronchi are prevented from draining by the collapse and are so absorbed. Still others say that the condition is from a toxic absorption from the wound due to coagulation necrosis or gangrene of traumatized tissures. It is also conceivable that the retention of suptum can cause toxemia for patients are unable to raise it because coughing is painful and the operative side is weak. Whatever the cause, it has been observed repeatedly that a toxemia causes an increase activity of the quiescent lesions in the opposite lung and so lessens the individual's chance for a good prognosis. (9) (35)

PROGNOSIS:

1. As to life:

All authorities admit that thoracoplasty has a high mortality. The advantages of doing an early thoracoplasty have been discussed fully in the earlier portion of this paper, but for many years yet to come, the operation is still going to be considered as a last resort, a life saving measure when all other means have failed. As this is the general consensus of opinion at the present time, the high mortality should thus be evaluated and the procedure not condemned absolutely as a therapeutic aid in the treatment of pulmonary tuberculosis.

Alexander (1), in anlayzing 1159 cases appearing in the various medical literature, brought forward the following statistics on thoracoplasty: 24.8% were apparently cured, 12% were clinically cured, and improvement was noticed in 24.4%. Thus there was a total of 61.2% in which the operation was at least of value. He also estimated that 1.5% died directly as a result of the operation, 13% died within two months postoperatively for various reasons, and 19% died sometime later from a failure of the operation either to cure or to arrest the disease in the collapsed lung or to progression and spread of the disease in the contralateral lung.

Bruns and Casper (9) in a review of 120 cases with a total of 186 operations found that 38% of the cases died, 22% were cured, 19% were arrested, 18% were improved and only 4% were unimproved. Direct operative mortality was limited to about 8% and indirect operative mortality to around 12%, a total of 20% which were fatal. Causes of death in thoracoplastic cases were found as follows in the order of frequency: contralateral spread, general retrogression, cardiac failure, shock, spontaneous

pneumothorax, tuberculous meningitis, amyloidosis, toxemia, streptococcic infection of the wound, pneumonia,and hemorrhage.

Graveson (15) reported 109 cases as follows: able to work, 43.1%; unable to work, 13.8%; died of tuberculosis, including operative deaths, 40.4%; died of other causes, 1.8%; and no record on 0.9%.

Brunner reported on 700 cases operated in Sauerbruch's clinic with 4% operative deaths, 20% dead within two years, 10% unimproved, 30% cured, and 27% improved. Sauerbruch with statistics of over 3000 cases shows an operative mortality of around 1%. His low figure is attributed to a careful selection of cases and by the fact that he prefers thoracoplasty to pneumothorax, and so operates cases in an early stage when they are comparatively excellent operative risks. (3)

The Matson Brothers in 116 thoracoplasties on 70 cases, reported an operative mortality of 2.8%. (29)

The prognosis as to mortality of the operation may be summed up as follows: In 20 to 25% of thoracoplasty cases, the operation hastens a fatal termination in varying degrees; in 50% of the cases, the operation lengthens the life of the patients who would otherwise probably have died within a short time.

2. As to obliteration of cavities:

Thoracoplasty often requires supplementary operations before the cavities are completely healed. Practically all operations are performed on fibrous cases of phthisis and the cavities are almost invariably posterior, lying subpleurally in the paravertebral groove. This offers a great deal of protection and inhibits complete collapse by means of a

thoracoplasty, although it may be greatly reduced in size. Continued positive sputums, signs of toxemia and positive X-ray plates are good evidence of a continued cavity. To obliterate such cavities, a posterior pneumolysis and pack or wide unroofing as for a pulmonary abscess is necessary. (14)

Extrapleural thoracoplasty is a well established surgical procedure although further improvement and development will minimize its dangers greatly. The possibilities of such an operation are just beginning to be realized and as time goes on, it may become much more popular. In the past, extrapleural thoracoplasty has been very mutilating, but in the hands of a specialist, no great deformity results and the final result should be quite satisfactory, both from the standpoint of the patient's welfare and the surgeon's pride in his technique. This will be discussed further in the next section.

EXTRAPLEURAL PNEUMOLYSIS

DEFINITION:

Extrapleural pneumolysis or apicolysis is an operative procedure in which an extrapleural loosening of the lung is brought about and the space thus formed is packed by various means to bring about compression upon a lung.

INDICATIONS:

Extrapleural pneumolysis is indicated in cases of pulmonary tuberculosis with large apical cavitation in which artificial pneumothorax therapy cannot be employed because of massive pleural adhesions. It is also of value when thoracoplasty is contraindicated because of the patient's unfitness, or the involvement is of a massive bilateral character, or when it is considered unwise or unnecessary to sacrifice the entire lung by a more or less complete rib resection when only a small portion is involved by the tuberculous process. Sometimes apicolysis is used as a preliminary step toward thoracoplasty to obliterate large apical cavities and thus bring about sufficient improvement in the contralateral lung so that thoracoplasty may be performed with a much greater degree of safety. (18)

GENERAL:

Gauze, paraffin, or grafts of muscle or fat may be used to pack the space produced by the extrapleural loosening of the lung and so produce compression of the lung. Grafts of muscle or fat are unsatisfactory as a rule for large enough pieces of tissue to produce sufficient compression

cannot be maintained as they soon atrophy and lose their effect. Gauze packing maintains satisfactory compression but has its drawback in that the pack must be renewed daily and the dressings are very painful. Paraffin packing is more successful but as it acts as a foreign body, it may be expelled in part or in mass. Also infection spreading from the lung may occur around it. No matter which means of packing is employed, the extrapleural space sooner or later fills in with granulation tissue, which upon healing retracts and reopens the cavity to some degree. Thus as mentioned before, extrapleural pneumolysis has only a limited sphere of usefulness. (19) (22)

TECHNIQUE:

Lilienthal, in performing his version of this operation, resects subperiosteally one or two ribs in the axilla and then carefully loosens the parietal pleura from the chest wall. The extrapleural space thus obtained is filled with a crumpled rubber dam packed in under pressure. Gauze is then placed over the rubber dam and the entire pack held in place by means of suturing the skin over it with two or three heavy tie sutures. He claims that the rubber tissue expands and causes increased compression. As in other means of packing, the rubber dam must be removed and renewed every day or so until healing takes place. (26)

Baer uses paraffin for his packing. It is of a special composition containing one-half of 1% iodoform and ½% bismuth carbonate. His technique of obtaining an extrapleural space is the same as that of Lilienthal. (22)

RESULTS:

As mentioned previously, extrapleural pneumolysis has only a limited

sphere of usefulness and is very unsatisfactory as far as final results are concerned. It is mainly an attempt to better the patient's condition by any possible means when artificial pneumothorax or thoracoplasty cannot be carried out. (19)

INTRAPLEURAL PNEUMOLYSIS

GENERAL:

Intrapleural pneumolysis or the "Jacobeus Method of Closed Pneumolysis" was first introduced by Professor Jacobeus of Stockholm, Sweden. It consists of thoracoscopy with cauterization of stretched pleural adhesions. It is of value in only a small percentage of carefully selected artificial pneumothorax cases where a few cord like adhesions prevent a satisfactory collapse. However, where indicated, it is of great importance. (27)

INDICATIONS:

Intrapleural pneumolysis is indicated in occasional cases of pulmonary tuberculosis under artificial pneumothorax therapy. In these particular cases, after pneumothorax treatment has been begun and after it is thought that a sufficient number of refills have been given to secure a satisfactory collapse, it is sometimes noticed that the sputum remains positive and that all symptoms are not relieved. Upon making X-ray examination, it is found that cord like pleural adhesions are preventing collapse of the involved portion of the lung and obliteration of the cavity. In such cases, intrapleural pneumolysis should be considered. (28)

CONTRAINDICATIONS:

Often judgment of suitable conditions cannot be made until after the thoracoscope has been introduced into the pleural space. Wide band adhesions or massive adhesions are definite contraindications to this operation. If the artificial pneumothorax therapy is only a preliminary step to-

ward thoracoplasty, a general improvement and not a complete collapse is all that is desired; so, intrapleural pneumolysis is not indicated because of this procedure's rather frequent complications. (28)

TECHNIQUE:

General anesthesia is preferred, although this operative procedure has been performed under local. An incision is made through the skin and the thoracoscope is inserted down through the intercostal muscles of an intercostal space as near to the pleural adhesion as it is possible to approximate from X-ray studies. After surveying the pleural cavity and if cauterization of the adhesions present is decided upon, the cauterizer is inserted through a cannula in the anterior axillary line of another intercostal space either above or below that one through which the thoracoscope has been passed. The adhesions are then cauterized with the electrocautery as near the chest wall as possible to avoid any lung tissue which may be present in the adhesion. After a day or two, pneumothorax therapy, that is refills, is carried out in the usual manner.

COMPLICATIONS:

All such operations have a febrile reaction, pleuritis, and usually to varying degrees an exudate. The more serious dangers are hemorrhage, subcutaneous emphysema, spontaneous pneumothorax and massive effusions which may or may not be secondarily infected. All these complications increase proportionately with the difficulty of the operation and the length of time necessary for its completion. Hemorrhage to a marked degree may be

prevented to a great extent by inspecting all adhesions for large blood vessels and producing thrombosis of such vessels by slow fulgeration with the electrocautery before division of the adhesion is made. (28) Pleuritis is best prevented or at least minimized by performing the operation as quickly as possible. Subcutaneous emphysema, spontaneous pneumothorax and effusions are treated similar to that described under the complications of artificial pneumothorax therapy. (27) (28)

PHRENICO - EXERESIS

GENERAL:

Phrenico-exeresis or phrenicectomy was first thought of by Stuertz in 1911 and slightly later was advocated by Schepelman. It was Sauerbruch and his followers, however, who developed and improved on the operation. It was through their efforts that it was discovered that a more radical removal of the phrenic nerve was necessary than in the original operation to obtain a more lasting and satisfactory paralysis of the diaphragm. (18)

TECHNIQUE:

Phrenicectomy, as it is performed today, consists in exposing the phrenic nerve in the neck where it runs rather obliquely upon the anterior scalenus muscle and removing at least ten to twenty centimeters of its length. In late years, many surgeons clamp a hemostat upon the nerve and wind the nerve around until it breaks, thus removing the greater portion of the nerve. This is probably the more satisfactory procedure as it has been found that there are often accessory nerve innervations to the diaphragm through the phrenic nerve down lower in the chest. Thus "clipping" of the phrenic at the neck does not always bring about a satisfactory therapeutic effect. In cases where only a temporary collapse is desired, crushing of the nerve in the neck may be all that is necessary. Regeneration in this latter procedure is usually from six to eight months and during the time of paralysis, the therapeutic results may be obtained. Phrenic nerve crushing is of special value in cases of thoracoplasty, which

later develops cavitation on the contralateral side. (17) (34)

THERAPEUTIC PRINCIPLES:

Phrenicectomy is used in the treatment of active basal pulmonary tuberculosis or where cavities in the lower portion of the lung are held open by adhesions which prevent satisfactory artifical pneumothorax therapy. Paralysis of the diaphragm causes the diaphragm to be elevated and fixed in a position of rest on the side operated. This places the lower half of the lung on that side at rest and also causes compression at its base. "Fixing" of the diaphragm decreases cough and enables the patient to raise sputum more easily. Interference with respiration is not as great as one would expect for the loss of the movement of the diaphgram in breathing is compensated for by the use of the accessory muscles of respiration. Often, after several years have elapsed after the phrenicoexeresis, examination of the patient shows the diaphragm on the operative side in a normal position and again functioning. The reason for this regeneration is not clear but it is known to happen in a small percentage of cases. (23) (16)

THERAPEUTIC RESULTS:

Wirth and Jaske, with experience in over 600 phrenicectomies, believe that it should be given preference over pneumothorax, for upon the failure of the artifical pneumothorax there is very little that can be done except thoracoplasty. Their reasoning is in brief as follows: "Phrenicoexeresis may mean a short cure, while pneumothorax therapy requires years and interferes too much with the individual's occupation; phrenic nerve

resection has fewer complications and is less dangerous than other forms of collapse therapy; it is especially suitable in bilateral cases when pneumothorax and thoracoplasty are contraindicated; it should always be preliminary to thoracoplasty to allow the contralateral lung to compensate; it may be used in connection with artificial pneumothorax in which basal adhesions prevent a satisfactory collapse with air alone." Wirth and Jaske reported the following results on 162 cases of phrenic nerve resection of one to five years duration: improved 51%, unchanged 12%, and worse 29%. (36)

Cooper's statistics on 103 cases of phrenico-exeresis showed forty-four or 42% improved; fifty-nine or 57% as unchanged; sixty-five or 63% with a slight rise of the diaphragm; and thirty-eight or 37% with no effect whatsoever. Fifty-two of these cases had cavitation on the operative side, twenty-eight of which were apical; and of these, eight were decreased in size and twenty showed no change; fourteen were either basal or midlung and of these, six cavities were decreased in size and eight were uneffected; and of ten generalized multiple cavities, six decreased and four showed no change. (11)

In all, phrenico-exeresis is a very satisfactory operative procedure in certain selected cases of pulmonary tuberculosis. It is not only a complete means of therapy in these cases, but is of great value to assist other forms of collapse therapy such as artificial pneumothorax and thoracoplasty. Some authorities go as far as to say that all cases of artificial pneumothorax should have a phrenicectomy before reexpansion.

COMPLICATIONS:

Phrenico-exeresis has fewer complications than any of the other forms

of collapse therapy. The operation is not difficult or dangerous, and aside from some occasional neuritis due to traumatism of the brachial pleura during operation, it has no complications of any importance. (30)

SUMMARY

In this paper I have attempted to give a brief resume of the various forms of Collapse Therapy in the Treatment of Pulmonary Tuberculosis.

Artificial pneumothorax therapy, where indicated, is in my opinion the outstanding means at the present time of overcoming the tuberculous process in the lungs. It is, of course, only an adjunct to nature's method of rest but in many instances shortens the duration of treatment and brings about a complete resolution of the pathological area. This is especially praiseworthy in relatively young individuals with an active involvement in which the tuberculous process is one of infiltration or small cavitation and the pleura is free of adhesions. In old chronic cases of pulmonary tuberculosis with pleural adhesions and well walled off cavitation, artificial pneumothorax does not bring about such astounding results but is well worth a therapeutic trial.

Internal pneumolysis has only a relatively small field of usefulness as an aid to artificial pneumothorax therapy. In the great majority of patients, such a procedure is of too great risk, due to the density of the pleural adhesions and the procedure's frequent complications.

External pneumolysis is today a procedure which has fallen into the discard; namely, because such an incomplete resection rarely brought about the desired results and also because a thoracoplasty is a much better operation, both from the patient's and physician's point of view.

Phrenico-exeresis is of greatest value in cases of basal involvement. It is an important adjunct to artificial pneumothorax therapy, especially upon the discontinuation of the latter. For reasons as given, phreni-

cectomy should always precede a thoracoplastic operation.

Thoracoplasty is one of the most extensive operations in major surgery. It is classified as a life saving measure at the present time and is usually attempted only when other forms of therapy have failed. This opinion may, of course, be a matter of debate but it will undoubtedly be many years to come before the majority of the patients will consent to undergo such a procedure. Remarkable results have been accomplished in some cases of pulmonary tuberculosis by such a rib resection, but many times it is questionable as to whether it would not have been better if the patient had not survived the operation.

In closing, I wish to state that this thesis is not an original piece of work but is merely a composition of many articles written in the past years on the various phases of therapy in pulmonary tuberculosis.

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REFERENCES

1. Alexander, John: Surgery of Pulmonary Tuberculosis. 17 - 324; Lea and Febiger. Philadelphia and New York. 1925.

2. Aycock, G. F.: Artificial Pneumothorax with Collapse under Low Intrapleural Pressures. American Review of Tuberculosis. 12; 95 - 106 (Oct. '25).

3. Barnes, H. L., and Barnes, L. R. P.: The Duration of Life in Pulmonary Tuberculosis with Cavities. American Review of Tuberculosis. 18; 412 - 424 (Oct. '28).

4. Bendove, R. A.: The Circulatory Changes in Artificial Pneumothorax. American Review of Tuberculosis. 12; 107 - 115 (Oct. '25).

5. Bendove, R. A.: The Classification of Artificial Pneumothorax and the Clinical Value of the Several Types. American Review of Tuberculosis. 10; 540 - 561 (Jan. '25).

6. Bronfin, I. D.: Spontaneous Pneumothorax During the Course of Artificial Pneumothorax. American Review of Tuberculosis. 9; 350 - 355 (June '24).

7. Bronfin, I. D., Nelson, E., Zarit, J.: Artificial Pneumothorax. American Review of Tuberculosis. 12; 197 - 208 (Oct. '25).

8. Bruns, E. H.: Air Embolism as a Complication in Artificial Pneumothorax. Colorado State Medical Journal, May '31.

9. Bruns, E. H., Casper, Joseph: Thoracoplasty in the Treatment of Chronic Pulmonary Tuberculosis. American Review of Tuberculosis. 22; 739 - 756 (Dec. '30).

10. Bushnell, G. E.: The Treatment of Tuberculosis. Medical Record. 27 - 52 (May '18).

11. Cooper, A. T.: Phrenico-exeresis in Pulmonary Tuberculosis. American Review of Tuberculosis. 22; 769 - 779 (Dec. '30).

12. Cooper, A. T.: Pneumothorax Treatment in Pulmonary Tuberculosis. International Clinics. 4; Series 39, 1930.

13. Fishberg, Maurice: Pulmonary Tuberculosis. 2; 436 - 555 (1932). 4th Edition; Lea and Febiger, Philadelphia.

14. Gekler, W. A., Lovelace, W. R., Rankin, H. P., Weigel, B. J.: Tuberculous Cavitation of the Lung. Journal of the American Medical Association. 82; 457 - 463 (Feb. '24).

15. Gravesen, Johs.: Surgical Treatment of Pulmonary and Pleural Tuberculosis. 3 - 111 (1925). Wm. Wood & Co., New York.

16. Hansen, O. S., Maly, H. W.: Phrenic Nerve Interruption. American Review of Tuberculosis. 30; 527 - 534 (Nov. '34).

17. Hare, H. F., Davenport, L. F.: Phrenic Neurectomy. New England Journal of Medicine. 211; 762 - 767 (Oct. '34).

18. Hedblom, C. A.: Phrenico-exeresis and Extrapleural Thoracoplasty in the Treatment of Pulmonary Tuberculosis. Bulletin of the City of Chicago Municipal Tuberculosis Sanitorium. V-9 (Febr. '29)

19. Hedblom, C. A., Van Hazel, W.: Results of Extrapleural Thoracoplasty. Journal of Thoracic Surgery. 4; 55 - 72 (Oct. '34).

20. Kendall, W. B.: Artificial Pneumothorax - Results at the Muskoka Institute of the National Sanatarium Association. American Review of Tuberculosis. 10; 209 - 216 (Oct. '25).

21. Krause, A. K.: Tuberculosis. Nelson's Loose-Leaf Medicine. 1; 309 - 336. Thomas Nelson & Sons, New York. (1920).

22. Lambert, A. V. S., Berry, F. B.: Extrapleural Thoracoplasty During the Treatment of Pulmonary Tuberculosis. Annals of Surgery. 90; 57 - 64 (Jan. '30).

23. Lemon, W. S.: Efficiency of the Mechanical Factors of Respiration. A Study of Respiratory Reserve. American Journal of Medical Sciences. 173; 318 - 333 (1929).

24. Leslie, G. L.: Collapse Therapy. West Virginia Medical Journal. 30; 543 - 547 (Dec. '34).

25. Lilienthal, H.: The Surgical Treatment of Pulmonary Tuberculosis. United States Veterans Bureau Medical Bulletin. 5; 5 - 56 (June '29).

26. Lilienthal, H.: The Surgical Treatment of Pulmonary Tuberculosis. Thoracic Surgery. 2; 32 - 365. W. B. Sanders & Co. (1929).

27. Matson, R. C.: Cauterization of Adhesions in Artificial Pneumothorax by the Jacobaeus-Unvirricht Method of Closed Pneumolysis. American Review of Tuberculosis. 19; 233 - 305 (March '29).

28. Matson, R. C.: Electro-surgical Method of Closed Intrapleural Pneumolysis in Artificial Pneumothorax. Archives of Surgery. 19; 1175 - 1192 (Dec. '29).

29. Matson, R. C.: The Surgical Treatment of Pulmonary Tuberculosis. Trans. of the National Tuberculosis Association. (1927).

30. Matson, R. W.: Exeresis of the Phrenic Nerve in the Treatment of Pulmonary Tuberculosis. American Review of Tuberculosis. 22; 1 - 34 (July '30).

31. Matson, R. W., Matson, R. C., Bisaillon, M.: End Result of 600 Cases of Pulmonary Tuberculosis Treated by Artificial Pneumothorax. American Review of Tuberculosis. 9; 294 - 336 (June '24).

32. Matson, R. W., Matson, R. C., Bisaillon, M.: Observations Concerning the Contralateral Lung in Pulmonary Tuberculosis Treated by Artificial Pneumothorax. American Review of Tuberculosis. 10; 562 - 582 (Jan. '25).

33. Miller, J. A.: Tuberculosis and Complications. Nelson's Loose-Leaf Medicine. 1; 337 - 339. Thomas Nelson & Sons, New York (1920).

34. Moore, F. N.: Phrenic Nerve Evulsion. Texas State Journal of Medicine. 30; 379 - 381 (Oct. '34).

35. Pollock, W. C.: Collapse Therapy in Pulmonary Tuberculosis. American Review of Tuberculosis. 22; 780 - 792 (Dec. '30).

36. Schwatt, H.: Phrenico-exeresis. Journal of Thoracic Surgery. 3; 503 - 512 (June '34).

37. Sewall, H.: A Critique of Artificial Pneumothorax in Pulmonary Tuberculosis. American Review of Tuberculosis. 18; 117 - 201 (Aug. '28).

38. Turner, R. J.: A Tuberculosis Background for Advisors and Teachers. Bulletin 59. Federal Board for Vocational Education.

39. Van Allen, C. M., Hrdina, L. A., Clark, J.: Air Embolism from the Pulmonary Vein. Archives of Surgery. 19; 567 - 599 (Oct. '29).

40. Wilson, J. A.: Spontaneous Pneumothorax in Pulmonary Tuberculosis. American Review of Tuberculosis. 14; 567 - 585 (Nov. '26).