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## The treatment of advanced tuberculosis by pneumothorax and phrenicotomy

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(Advanced)

THE TREATMENT OF PULMONARY TUBERCULOSIS

BY

PNEUMOTHORAX AND PHRENICOTOMY

---James C. Soderstrom  
1931  
Senior Thesis

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## FOREWORD

This treatise on the therapy of pulmonary tuberculosis by pneumothorax and phrenicotomy represents a subject comparatively new, but which has enjoyed rapid progress and endorsement by tuberculosis therapists both in this country and abroad.

An attempt has been made to correlate and organize the views and results obtained by prominent authorities now at work on this phase of tuberculous therapy. Reference has been limited to English literature with only occasional reference to foreign works.

This work does not represent an obscure specialty to be performed only by skilled surgeons. On the contrary, an attempt has been made to show how the general physician may profit by a more complete understanding of the subject.

## INTRODUCTION AND HISTORY

The therapy of pulmonary tuberculosis dates back to our earliest record of man. Each era and each generation has seen some change or some new method that has offered hope--only to be found wanting and cast aside. Some few fragments of usefulness have still been retained from the multitude of theories and experiments performed, and together they furnish a base upon which modern therapy rests. It is startling that when these "extracts of millions of minds" are analyzed they are found to approximate very closely the ways that nature attempts her healing. Those that diverge from nature have proven the most useless, those that assist her the most useful. Thus it seems that unraveling the secrets of nature is our way of solving the problem of therapy, and it is along these lines that modern therapy is progressing.

At present we are not ready to, and can not cast aside the accepted and proven worth of treatment by rest, immobilization, fresh air, clean, pleasant surroundings, good vitalizing foods, protection, and nursing. These are nature's means of healing and are to remain. But, we can further improve upon these in various ways, whether it be chemical, physical or mechanical. The problem today is to find and select these ways. Many have been advanced, too many to be of any use, and a general weeding would be an endeavor worth while. The chemical phase is in its infancy and has, as yet, offered but possibilities. So also is the mechanical, but it seems as though this phase offers more for the immediate future.

If we observe the process of healing in pulmonary tuberculosis, even in advanced stages, we can not help but notice nature's various ways of

checking, and preventing the spread of the disease. What does this fundamentally consist of? An attempt to put the diseased part at rest and limit mobility! There is a decreased amount of thoracic movement, the production of fibrosis, and adhesions to limit the constant movement, and an altered chemical condition rendering the individual unfit to carry on strenuous exercise. 16, 9

Why not help nature's efforts and complete her attempts whenever it is possible? This is exactly what the mechanical phase of modern therapy aims to do. Simply to put the diseased part at rest as an adjunct to the generally accepted methods of treatment. 42, 20a 9 Various methods have been devised in relatively late years in order to do this, some very complex and major, others relatively simple and minor, but all with the same purpose, (i.e.), to put the affected lung at rest, or in other words to collapse or partially collapse the diseased lung. This idea is not new as the principle was suggested in the works of Hippocrates, and others of ancient times have made casual comments on the possibilities of surgery of the thorax. Nothing along this line was ever attempted, or if attempted was never put into practical use until what we would call "modern times". No doubt due to failures in attempts at surgery of the thorax when tuberculosis was the pathology the opinion that any mechanical interference of tuberculosis was considered ill-advised and meddling. 21a 42 Not until the late eighteenth century was this popular opinion overthrown, and even today many believe that by so doing, is to invite complications.

Compression therapy in the treatment of pulmonary tuberculosis can therefore be said to be a modern procedure, both along surgical lines and in the treatment of selective cases of pulmonary tuberculosis.

To James Carson of Liverpool should be given full credit for having laid the entire foundation upon which the entire structure of modern pulmonary

compression therapy is built. He urged the production of Artificial pneumothorax as early as 1821 and pointed out the theories and reasons for doing so.

Forlanini of Pavia 1882 also proposed the use of artificial pneumothorax and made its use practical.

De Cereville, 1885 of Lausanne, was the first to undertake the relaxation of the lung by a thoracoplasty operation upon the overlying bony cage. His work was based upon empyema studies in which he noted that in these cases and in pleural effusions the tuberculous lesions in the lung were limited presumably by the compression that the fluid exerted upon the diseased lung.

Other men of later date have added their experience and results along the same line and thus made the field more stable. Among the most notable are Freund 1858, Quinke 1888, J. P. Murphy 1898 of Chicago, Ill., Brauer of Hamburg 1907, Stuertz 1911 who first proposed and practiced phrenicotomy, Alvarez of Oviedo, Spain, 1913, and Jacobaeus of Stockholm 1913. Each of these men were pioneers in the field of thoracic surgery and each brought forth some new phase and put it into practical use.

Today many notable men have been added to this list, proving that the foundations are secured and that there is a decided usefulness.

#### The Meaning of Pulmonary Collapse

Pulmonary collapse as the word suggests is a deflation of a lung, either partial or complete, by mechanical intention in order to prevent movement and activity of that part, with the hopes of arresting or curing lesions therein. Many means to accomplish this are now in use, the explanations of each will be given in brief.

1. Artificial Pneumothorax means the collapsing of a lung either partially or totally by the introduction of air or gas within the thoracic cage, thus changing the intrapleural negative pressure to a positive pressure or to that equal to the pressure within the bronchi.
2. Thoracoplasty is the resection of portions of the ribs on the affected usually para-vertebral and including the upper ten ribs with from 3.5 cm. to 13 cm. resection of each from above downward. This operation allows the scapula to fall inward upon the diseased lung, thus compressing it. Wilms uses the parasternal ribs and costal cartilages for resection in selective cases.
3. Phrenicotomy is the intentional production of diaphragmatic paralysis on the affected side by cutting and extracting a portion of the phrenic nerve where it lies over the scalenus anticus muscle in the neck. This operation allows the diaphragm to ascend on the affected side and thus compress the lung on its base.
4. Pulmonary Resection is the actual cutting out of portions of the diseased lung by open operation. This operation has been performed by Tieffier and Jessen several times but it is not generally accepted by other surgeons.
5. Direct Cavity Drainage is the aspiration of tuberculous cavities directly through the thoracic wall. This procedure is not popular however.
6. Intra Pulmonary Pneumolysis is the direct cutting of pleural adhesions by instrument through the thoracic cage so that other means of producing collapse might be successful. This operation has been perfected by Jacobaeus of Stockholm and is often referred to as Jacobaeus' operation.
7. Ligation of Pulmonary Artery combined with phrenicotomy is the ligation of the lobe branches of the pulmonary artery in order to produce shrinkage of the part affected. Phrenicotomy further aids in the compression.



8. Intercostalectomy is the resection of the intercostal nerves of one side in order to prevent thoracic breathing. It is usually combined with phrenicotomy.

These are the chief surgical procedures to collapse the diseased lung as practiced today. Not all of them have been accepted as worthy and sound in principle, and time will, no doubt eliminate a few. There are three, however, that in their short existence have proven their worth and are to remain as a valuable addition to the therapy of pulmonary tuberculosis. These three are; thoracoplasty, pneumothorax and phrenicotomy. Thoracoplasty is now generally accepted as the treatment par-excellence for late and apparently hopeless cases <sup>10</sup> and very little argument is needed as far as it itself is concerned. Its indications and results have been established relatively satisfactory to all. Artificial pneumothorax has also established itself and there is no question but what it is to remain as one of the chief, if not the chief, procedure in tuberculous therapy. There are many men who advocate its use in preference to thoracoplasty, <sup>42, 33a</sup> although it is generally conceded to have a place in selective cases only. <sup>42, 45, 32</sup>

But, satisfactory as these two are, they are not without their shortcomings in certain particular group of cases. Due to this fact paralysis of the diaphragm by phrenicotomy has been in recent years pushed to the front with the idea of overcoming these faults. So many satisfactory results have been reported from its use that today there is a question in many prominent men's minds as to whether it is not a better procedure than artificial pneumothorax. Certainly it has its place along with pneumothorax and thoracoplasty, that fact has been established, but when it should be used, and in what types of cases it should be used, is the controversy of today.

This paper can not deal with the whole subject of thoracic surgery in the treatment of pulmonary tuberculosis as the field is too large and too complicated by various methods and opinions of authorities. It is necessary then to limit, or choose some part of it which presents a problem to the surgeon, therapist and patient.

The question of the procedures of artificial pneumothorax and phrenicotomy furnishes a subject applicable to discussion. The remainder of this paper will therefore be devoted to these two methods, their comparative worth, and their beneficial results and failures will be presented according to the opinions of authorities who are at work today on these problems.

## ARTIFICIAL PNEUMOTHORAX

Artificial pneumothorax has won for itself an accepted place in the treatment of pulmonary tuberculosis. In the past decade it has enjoyed widespread popularity and its literature has accumulated rapidly to vast proportions. There has arisen on the one hand a feeling of pessimism as to its essential usefulness and on the other, a tendency to constantly extend the accepted indications for its employment. <sup>30,9,33a,51</sup> Being a new procedure, there is a diversity of opinion concerning all phases of the subject, but today these have become of minor details rather than of the subject at large and artificial pneumothorax is gradually becoming fitted into its proper place along with other methods of like nature.

Technique: In defining artificial pneumothorax it was said that it was a deliberate introduction of either air or gas within the pleural cavity in order to bring about a collapse of the diseased lung. Since 1898 when the procedure was introduced into this country by J. B. Murphy of Chicago <sup>49</sup> the technique has gone through several changes. Murphy made a small slit through the skin and subcutaneous fascia and then inserted a trocar and cannula until the rib was struck, at which time the stilette was withdrawn, the gas turned on and the trocar plunged through the pleura. The amount of gas ranged from 50 to 200 cubic inches depending on the reaction of the patient. He kept the lung compressed to its full degree for from three to six months, making fresh insertions every six to ten weeks. He practiced high pressure collapse in all patients and did not attempt an accurate measurement of intrapleural pressure.

Various modifications have been suggested. <sup>43,36,13</sup> The following is the accepted method of today: <sup>51</sup>

It is useless to describe the apparatus and its mechanism in detail as there are many varieties in use at different institutions. All the apparatus in use employ a system of fluid displacement between two communicating glass vessels or jars for the admission, egress, and measurement of the air or gas. Connected between the jars and the needle is a manometer which registers the amount of pressure in the pleural cavity, thereby indicating the degree of collapse that is desirable. Finally a hollow needle or cannula is attached suitable for insertion between the pulmonary and parietal pleura. Bottles and manometer are graduated so that all readings of the amount of gas introduced and the pressure produced are direct. Either pure nitrogen or pure air may be used. It was originally thought <sup>49</sup> that nitrogen was superior because of its inertness and theoretical advantages of slower absorption. Rist and Strohl <sup>50</sup> in 1920 made a complete study of pleural gases and their behavior and came to the conclusion that air was as satisfactory as nitrogen and that in selected cases oxygen itself proved efficient, especially with pleural effusions. <sup>51</sup>

The patient is prepared in the same way as any entering an operating room for minor surgery. The thorax is washed and antiseptics applied. Five tenths to one per cent procaine solution with adrenalin is used as a local anesthesia. <sup>51</sup> The ascertain when the needle has entered the pleural cavity, the plunger of the needle is observed; when it suddenly moves toward the lung, the pleural space has been entered. The reason for this is that the negative pressure within the cavity exerts a suction action on the plunger. The manometer will further indicate that the needle has entered the pleura.

The amount of air to introduce depends on several factors. (1) The freedom of the pleural space from adhesions; (2) the capacity of the chest; (3) the condition of the opposite lung; (4) the character of the disease and its associated symptoms. <sup>51</sup>

Full compression of the lung with high positive pressure is not practical today. <sup>11</sup> The more scientific studies <sup>x</sup> have proven that it is dangerous both to the patient at the time and to the course of the disease. <sup>x 42,16,30,40</sup> From the above conditions it is therefore impossible to state a rule for the amount of air introduced. The administrator must use his judgement and knowledge in each case. <sup>42</sup> However, in most cases when pneumothorax is at all indicated, 250 to 450 cc. of air may be given. <sup>51</sup> The latter statement is not supported by some who advocate the introduction of small amounts of air over the site of the lesion only, terming this procedure "selective collapse." <sup>7,13,27,14</sup> By this method enough air is introduced to collapse the lesion and to produce a 40 per cent collapse of the healthy part, leaving a negative pressure of 0 or -1 after each inflation. The advantage they claim is that it (1) minimizes respiratory disturbances, prevents circulatory distress, throws less work on the other lung, and can be used bilaterally. <sup>13</sup> This procedure is not accepted by all and is criticized by many, <sup>11,16,42</sup> who have studied the physiology of the thorax and compressed lung. <sup>1,51,33a</sup> Its very recent use prevents a gathering of statistics to make any comparison. It no doubt, has its place in certain select cases but the concensus of opinion is that it can not supplant the complete collapse. <sup>16,1,3,42,11</sup>

The length of time that collapse should be maintained varies with the pathology of the lung. <sup>21,51 p 384</sup> Ringer, <sup>42 a</sup> in his experience divides his cases into three groups: (1) cases with total collapse; (2) cases with partial collapse; (3) cases collapsed for hemoptysis. Collapse in the first group should be maintained at least two years as there is no definite way of telling

when healing is complete. The second group should be refilled indefinitely as complete healing is never assured. In the third group it should be continued only as long as bleeding is definitely arrested. <sup>42 a</sup>

It is now generally agreed that collapse should extend over a period of years, depending on the severity and type of lesion. Long standing active cases with extensive cavitation should be treated for at least 2 years and then terminated only when the fluoroscope and symptoms show that arrest has taken place. Some men advocate treatment for life in these cases, <sup>40,39,51</sup> saying that discontinuance causes rapid retrogression and if fibrosis has taken place there is a constant pull on old cavities tending to open them again. The less advanced lesions may be terminated sooner, governed always by symptoms and the fluoroscope. <sup>x 16</sup>

The number and amount of refills vary with almost every case as the activity of the individual, his thoracic capacity and rate of absorption vary. <sup>8 a</sup> Also the kind of pulmonary collapse makes a difference in the number and interval. Therefore the patient should be watched each day and treated accordingly. Generally speaking, however, it may be said that the treatment should be given on alternate days for the first two or three injections and then the interval gradually increased by a day or two up to one week. The seven day interval is usually maintained for two or three weeks; then a ten day interval working up to intervals of two weeks which is maintained from then on. <sup>51</sup> It should be rarely necessary to give more than 500 cc. at one time.

The proper method is to watch the patient and keep the lung collapsed as the progress indicates, with frequent use of the fluoroscope. <sup>16</sup>

#### Anatomical and Physiological Effects

Intra Pulmonary Tissue Changes: As is well known, tuberculosis in any part of the lung heals by fibrous encapsulation. In bringing this about

individual resistance plays the greatest part, next and equally important is the functional rest of the diseased part. <sup>21</sup> Rest is the keystone of successful treatment of tuberculosis of any organ and the more complete the better the result. <sup>1</sup>

Compression therapy by artificial pneumothorax causes partial or complete rest of the diseased lung, not only grossly but histologically which is the ultimate of expectation. Normally the lung is an organ that is in constant motion, the reason of which is to better ~~dr~~<sup>e</sup>riate the blood and promote circulation into the general system. <sup>53</sup> This activity tends to rid the lung of all contamination either by way of the circulation, lymph, or bronchi. Therefore any disease process and its toxins are dissiminated through the general circulation to ultimately be overcome by bodily resistance, or to gain a foothold when this resistance has been overpowered.

By compressing the lung the blood supply and lymph drainage is curtailed, <sup>1,51,21,42</sup> therefore the toxic products of a tuberculous lesion are less liable to enter the body and can become localized where the resistance is better able to promote healing. It has not been definitely determined whether this stasis of blood and lymph is primarily responsible for the production of the most desired histological change, i.e., fibrosis. Gardner <sup>21</sup> says that fibrosis is perhaps the result of pressure or the action of retained metabolic products which afford a toxic irritant to the areolar tissues. At any rate blood and lymph stasis and fibrosis are present in the collapsed lung, each phenomena acting favorably toward the healing of the lesion. Caseous foci become encapsulated and pneumonic processes tend to become organized. The co-adaptation of cavity walls, if maintained for a sufficient length of time, may insure effective healing. <sup>32</sup> About uncollapsed cavities is thrown a more or less thick fibrous envelope, which

acts as an effective barrier against further extension of the destructive process. This process continues until the lesion is healed, at which time scar tissue and fibrosis becomes partially absorbed. <sup>21,51</sup>

Like all rules, these have their exceptions and in some cases healing does not take place. Especially, where there is adhesions to the parietal pleura, the cavities may be held open by a mechanical pull that prohibits coadaptation. <sup>33a</sup>

Gross Changes The gross lung presents a small contracted mass, semi-solid, confined to the hilum of the lung. Fibrous tissue is seen in great abundance around the old tuberculous lesions and cavities, next to the bronchi and in radiating strands from the thickened pleura. The spongy alveolar tissue is absent. Tortuous bronchi and blood vessels with thick walls transverse the specimen; the bronchi are often dilated and filled with caseous matter or semi-fluid exudate; the arteries are often thrombosed and narrowed by endarterites. <sup>21,1</sup> The tubercles are dry and seen to be firmly encapsulated by fibrous tissue which either just surrounds them or grows through and through them.

Adhesions to the parietal pleura alter this picture in which case the lung is not fully collapsed and strands of adhesions extend irregularly from the chest wall to lung mass. <sup>33a</sup>

#### Effects on Heart and Mediastinum

In consequence of the positive pressure or a pressure equal to the atmosphere on the compressed side there exists some changes in the heart and mediastinum. The lung on the opposite side still has its negative pressure, therefore a positive pressure on one side of the mediastinum and a negative pressure on the other produces opposing forces exerted on the central structures which is the heart and mediastinum. When the latter is not fixed by adhesions it is displaced toward the affected side. During inspiration the negative



pressure in the unoperated side expends itself in sucking the mediastinum and heart toward that side. On expiration these structures are pushed back to the other side. We have produced, then, a pendulum motion which is termed "mediastinal flutter." With high pressure and a thin mediastinum the displacement may be extensive producing an embarrassment to the contained vessels, heart, and the good lung. Symptoms such as dyspnea, possibly cyanosis, tachycardia, low blood pressure, and occasionally cardiac pain may occur. 55,29,51 With atmospheric pressure these symptoms are not observed and the mediastinal displacement produces no untoward effects either at the time of injection or in the healing process. 19

The opposite lung: It has been stated, <sup>51</sup>(Sauerbruch) that the uncompressed lung enlarges as a result of emphysematous and hyperplastic changes, as much in some cases as one third normal size, due to a compensatory hypertrophy. Also the uncompressed lung moves more than it did before, <sup>1, 51</sup> and therefore lymph and blood flow are increased in the good lung.

#### Effects of Respiratory Gas Exchange

With pneumothorax there is a marked reduction of respiratory surface as one lung has been practically rendered functionless. One would expect that the tension of oxygen in mixed arterial blood to be proportionately diminished. This has been proven not to be the case except when there is too great positive pressure on the diseased side or when the pneumothorax is open. 53

From experiments and clinical studies it has been proven that while at rest with a unilateral pneumothorax the factors of gaseous exchange, alveolar carbon dioxide tension, respiration and total ventilation of the lungs were normal; also that the reaction to inspired carbon dioxide was normal up to the point at which the respiration is trebled or sometimes quadrupled, but beyond that point the limit is reached where dyspnea becomes evident. 51,37a

It is recognized then that a patient with induced pneumothorax suffers no discomfort as long as he remains within moderate limits of activity. Just why there is not more embarrassment is explained simply by the fact that the human body was endowed with about eight times as much lung tissue as it needs for ordinary purposes, the remainder serving as a reserve in times of great exertion. <sup>51,53,37a</sup> Also the compensatory hypertrophy of the good lung with its increased blood supply aids in the ventilation.

#### Indications for Artificial Pneumothorax

As has been before stated, artificial pneumothorax should never be assumed to be a substitute for routine hygienic treatment. It is only after general treatment has apparently failed that the procedure is resorted to and then only after a careful observation of the patients condition, the type of pathology present, the age of the disease, complications present, and the condition of the opposite or good lung. All of these factors must be considered and weighed by men who have had experience and judgement born from that experience. <sup>42</sup>

When J. P. Murphy <sup>49</sup> did his work on thoracic surgery he selected only those cases of apical lesions or those having monolobar lesions, the opposite lung being free from disease. He did not consider late and chronic cases to be worth the effort as so many failures resulted. No doubt he had not obtained the keen judgement necessary in these cases, for today the chronic and advanced cases are considered the most logical for pneumothorax. In his time with the limited experience along the line of thoracic surgery, general statements could easily be made as to the type of cases suitable for collapse. Today it is not so easy nor desirable for it has become recognized that each case is a problem in itself and all factors must be considered.

Just how long a trial should be given routine treatment in a given case depends on the clinical judgement of the physician.<sup>16</sup> However, if at the end of two to six months, if there is evidence from physical or x-ray examination, of advancing infiltration with caseation and softening, a more drastic scheme of treatment is to be considered.<sup>43</sup> If the progress is rapid or if its advance is not checked by absolute rest, and if the comparatively good lung remains in statu quo, pneumothorax should be definitely considered.<sup>51</sup>

In one group of cases it has become accepted by all that the indications for pneumothorax are perfectly clear.<sup>5</sup> Symptoms are so severe and the involvement of one lung so extensive that it appears perfectly obvious that a collapse of the lung is the only measure likely to forestall an early and fatal issue.<sup>5, 51</sup> This group has been termed the last resort group.

It is not with this group that we are particularly concerned, however. It is those mid-way between the early and very late that requires the most careful consideration.<sup>51, 43</sup>

As in all branches of surgery there is a diversity of opinion regarding the choice of these cases, and there should be, as every case presents a different problem and should be handled accordingly.<sup>43,16</sup>

Some of the most accepted standards will be given, however, along with possible exceptions.

In reviewing the literature and the opinions of various authorities, it can be set down as a general principle that the chief indication for treatment by pneumothorax is unilateral disease that is progressive in spite of hygienic rest treatment.<sup>12,51,43</sup> Burns and Peters<sup>51</sup> classify the pathology as follows:

1. Acute bronchopneumonic or pneumonic, where the disease is confined to one lung, and progressive in spite of attempted hygienic routine.

2. Chronic Phthisis, the lesions being chronically infiltrative, with or without cavitation. Depending upon the amount of scar tissue that has been laid down there are subdivisions often referred to as fibroid, fibrocaseous, fibrocavernous. Pneumothorax is indicated here if these lesions are progressing and all other conditions are satisfactory.

They class one type of case as an indication even though it is not progressive, or even though adhesions are present. This type is the long standing case of fibrocaseous-cavernous phthisis, with the other lung competent. Here the patient is incapacitated because of cough, sputum, fever, and loss of resistance.

3. Chronic Bronchopneumonic Tuberculosis. This type is usually infiltrative, caseating and ulcerating, and experience has shown that if allowed to go on will doom the patient to invalidism.

4. Cavitation, thin walled. This is the type that spreads through the lung tissue without the fairly marked surrounding infiltration and caseation, and the type that yields very satisfactorily to compression as the thin walls approximate easily. All authorities agree that this type of pathology is a certain indication.

5. Chronic Pulmonic Tuberculosis Chronic caseous pneumonia may become converted into massive fibrosis or it may soften and cavitate with varying rapidity.

The progress in this type is slow as the consolidation resists compression. Repair takes place by a gradual resolution and fibrous replacement of the pneumonic process.

6. Basal Tuberculosis Indications here as in other lesions but results not so satisfactory because of diaphragmatic adhesions.

7. Hemorrhage. In cases of repeated hemorrhages that resist control by ordinary methods. Also acute hemorrhages with symptoms of exsanguination.

The great majority of men today accept this classification<sup>1,43,12,42</sup> but it is the time when to perform the operation in these cases that the opinions stand divided. At present there is a plea to perform early operations in such cases before complications such as adhesions, pleurisy, tuberculous empyema, etc. develop.<sup>5,43,53,12</sup> Of course this is the ideal way but the patient does not always present himself so early, nor has ordinary rest treatment proved itself a failure until the moderately advanced stage has set in. All agree that to wait until there is no hope or to wait until so many complications have set in that operation is doubtful, is the height of folly, but all do agree that the patient should have hygienic treatment first and pneumothorax when this fails. All in all it requires keen judgment in every case and a thorough knowledge of the pathology in every case to be able to say just when is the time to operate.

There are some<sup>33a,17</sup> who advocate the late treatment and combine pneumothorax with intrapleural pneumolysis (severing of adhesions) as practiced by Jacobaeus but this operation is complicated and as yet little understood. It does offer, however, a solution to those cases that can not be collapsed by pneumothorax because of adhesions.

These indications as given are general but fairly well decided upon. Exceptions are as often as the rule and each case must be the governing factor.

#### Contraindications

As with the question of pneumothorax, indications, the problem of when not to produce a lung collapse in a given case depends very largely on the judgement of the physician. Contraindications for one type of patient may not, and often does not, hold true for all types with similar conditions. Therefore, it appears that no set of rules can be set to govern the selection of all cases that are not without a great many exceptions.<sup>42</sup> However, some

working guide is desirable and a few contraindications have come to be established and generally accepted.

First, it must be emphatically stated that pneumothorax is reserved for cases that have not responded to ordinary treatment.<sup>43,42</sup> This implies then that it is contraindicated before other means have been tried.

Acute Stages: The acute miliary form is unfit, because the disease has advanced to both lungs and the collapse of one would lessen the breathing surface and respiratory exchange to such a degree that by so doing would only invite an earlier exitus. For the same reason an acute broncho pneumonic spreading to the opposite lung would be contraindicated.<sup>51</sup> In short all very acute progressive disease involving both lungs make pneumothorax a contra-indication.

The opposite lung: One may notice the frequency of the statement that pneumothorax is indicated in certain forms, "provided the opposite lung is free from disease". This involvement of the opposite, or "good lung" in early days was considered a distinct contraindication for the production of artificial pneumothorax,<sup>49</sup> and even today there are many who stand by this belief. It is granted by all, however, that in acute progressive cases the involvement of the second lung is a contraindication. However, it is becoming more and more realized that disease of the good lung in most cases where pneumothorax would otherwise be indicated is a factor of small importance. It can not be disregarded, however, and in some cases is a contraindication, when other factors accompany it.

A great difference of opinion exists regarding this subject. Most authors use conservatism when pathology exists,<sup>42</sup> but a few all but disregard it. Emerson,<sup>19</sup> states; "that on the contrary, pneumothorax applied to the most involved lung in extensive bilateral tuberculosis is frequently

of great benefit. Davies<sup>16,17</sup> says that activity in the opposite lung is not a bar, but must be latent. He also adds that a cavity or scattered foci are contraindications. Peters and Burns<sup>51,40</sup> disregard old hilum changes such as calcification, likewise, if physical signs are negative, they pay no attention to accentuation, prolongation and discrete beading of the pulmonary trunks as they appear in the x-ray. The only point of actual significance is the demonstration of actual parenchymal lesions progressive with symptoms of toxemia. In last resort cases they disregard doubtful lesions and give the pneumothorax.

Most authors<sup>1,51,16</sup> etc. agree that cavitation in the opposite lung is a bar to lung collapse on the worse side. Emerson<sup>19</sup> disregards this idea and his results equal those of the average thoracic surgeon of today.

It has been advanced<sup>1,51,19,21,32a</sup> that by collapsing the worse lung in a bilateral involvement the lesion in the "good lung" tends to heal spontaneously because of the increased resistance produced by removing the worst source of infection.

The trend of opinion is at least progressing toward the thought that pneumothorax is becoming more indicated in bilateral lesions provided there is enough intact respiratory exchange. This latter determining factor has been put into practical use of late by experimenters,<sup>37a</sup> by estimating the vital capacity of both or of the better lung before operation thereby making it possible to foretell the degree of lung surface remaining after collapse and whether it is sufficient to carry on ordinary gaseous exchange.<sup>32a,37a</sup> They maintain that the vital capacity should not be below 50 per cent of the normal in order to be on the safe side. They also advocate vital capacity reading at intervals during collapse in order to estimate

any progress that a lesion in the good lung may be making. Barlow and Krammer<sup>7</sup>, Cutler<sup>13</sup>, Hennell and Stivelman<sup>27</sup> advocate a procedure termed "selective collapse" in cases of bilateral involvement whereby lesions in both lungs are partially compressed, leaving the remaining healthy tissue to carry on respiration.

Both of these procedures, the estimation of vital capacity, and selective collapse may do much in solving the problem of the opposite lung.

There the opposite lung is diseased and its function reduced by other lesions such as bronchitis, bronchiectasis, asthma, empyema, abscess, etc., contraindication to compression in the good lung is established. All authors recognize this.

It must appear from the above that no definite rule of procedure can be established covering the selection of ordinary cases. In each instance one must balance one set of factors against another and then render judgement.

#### Influence of Tuberculous Complications

It is accepted as a general principle that any measure tending to improve the general resistance will indirectly tend to exert a beneficial effect on tuberculous complications elsewhere.<sup>51</sup> Therefore in most instances pneumothorax exerts a favorable influence instead of being an exciter of complications.<sup>51</sup>

As a general rule tuberculosis elsewhere is not a contraindication unless it is in some way functionally incapacitating the patient.<sup>51,16</sup> Davies<sup>16</sup> and Ringer<sup>42</sup> in a review of the subject state that laryngeal tuberculosis is not a contraindication, but that intestinal tuberculosis is. They further imply that these must be weighed by the practitioner before passing final judgement.

Other Contraindications: Besides tuberculous lesions and their complicating factors, the presence of other types of disease must also be



considered. Davies<sup>16</sup> considers albuminuria, Glycosuria, intestinal stasis, and a poor temperament as bad risks. He points out that treatment will be a failure in those who refuse to cooperate or neglect having refills when they are due.

All of these factors must be considered in order to give a good prognosis or to make the treatment worthy of the reputation that it has established for itself.

#### The Advantages of Artificial Pneumothorax Treatment

In order to discuss the advantages of any treatment an understanding of those procedures to which it is being compared is desirable. However, it is not within the scope of this paper to discuss the mechanisms, etc., of every surgical form of therapy. Consequently, let the conclusions of present day workers suffice.

Beside phrenicotomy and pneumothorax, all thoracic surgical procedures are deforming, and when once accomplished their results on the human frame are permanent and beyond recall. (1)

"Artificial pneumothorax in contradistinction is painless, non-deforming and non-shocking.<sup>55,42</sup> As compression is produced gradually at many settings, it avoids the dangers of acute circulatory and respiratory upsets.<sup>x</sup> Also, as accumulated toxins are only gradually squeezed out of the lungs into the general circulation, and as the operation of pneumothorax, per se, does not lower general resistance, there is less danger of "lighting up" tuberculous foci in the contralateral lung and elsewhere. Lung compression is greater in pneumothorax and what small respiratory movements occur are normal and not paradoxical." (1)

Pneumothorax can be released when the lung is healed, therefore, respiratory function is not permanently lost. This is important in case

pneumonia, pleurisy or any other disease of the opposite lung should occur. All that is necessary in these cases is to withdraw a part of the air from the treated side temporarily in order to create more lung surface and thereby increase the vital capacity.

Another advantage is that pneumothorax can be performed quickly in an emergency, and can be done in the home provided the physician in charge has been sufficiently trained to administer it.

These advantages have led to the adoption of almost all clinics of a working rule that thoracoplasty or other more major and deforming operations should never be employed when satisfactory pneumothorax is obtainable, or until after pneumothorax has been tried.<sup>x 55</sup>

#### The Disadvantages of Artificial Pneumothorax

As in every type of therapy that has its fine points and a favorable record in the majority of instances, pneumothorax has likewise its disadvantages which must be considered as possibilities in every case before treatment is undertaken. There are numerous accidents that can occur in the course of treatment, and there are also numerous complications that may arise at any time. Consequently, one disadvantage, in some opinions, is that the patient must be constantly watched over his year or years of treatment by trained physicians in order to prevent or correct such accidents and complications.

There are many patients who dislike being the object of many operations over a period of years and consequently a few, instead of reporting for their refills every two to three, or five to six weeks (1) may skip several or fail to present themselves again until fresh symptoms arise. Then, if he returns, most likely the lung has re-expanded and become firmly adherent to the chest wall making further collapse impossible. Or, the physician may have voluntarily terminated treatment thinking the disease checked, to have the patient return later with a "lighting up" of an old lesion.

It is never possible to predict when tuberculosis is cured and is a very trying question to the physician to tell when to terminate the treatment. (1)

In some cases great discomfort is complained of after termination of treatment which is often the result of incomplete re-expansion of the lung. When a lesion heals, scar tissue forms and later shrinks. As the chest cavity is larger than the shrunken lung that is expected to fill it, various changes occur in an attempt to compensate. The hemithorax flattens, the ribs crowd together and the diaphragm rises, the heart and mediastinum shift toward the affected side and the relative normal portions of both lungs become emphysematous. A partial pneumothorax will continue to exist, and as the absorption of air persists an abnormal negative pressure will be created. The result is dyspnea and pain and cardiac embarrassment. Also, by the constant tug on lung tissue old cavities or lesions may be reopened and the infection started anew. (1) (55)

#### Serous and Purulent Effusions

With the exceptions of pleural adhesions pleural exudates are by far the commonest and troublesome of the complications that may arise. <sup>51,5a</sup> Not all types are of significance and have been discovered only by fluoroscopy. <sup>31a,51 p404</sup> Some surgeons report as high as 70 per cent <sup>5a 40</sup> of cases while others have met with it less frequently. <sup>14</sup> Boonshaft reports 47 per cent.

Various reasons are given for this complication. Some believe it due to infection during operation, but effusions occur, nevertheless, when strict asepsis has been carried out. Without going into the discussion of etiology at great length, it may be said that the possible avenues of infection, or discharging the bacilli into the pleura are:

1. Direct extension of a tuberculous focus from lung to the visceral pleura, with or without caseation.

2. Rupture of an adhesion at its attachment to such a focus.
3. Retrograde lymphatic extension.
4. Hematogenous infection.

Lilienthal<sup>51</sup> believes the first to be the more common method of infection. Fagenoli<sup>5a</sup> considers the nitrogen a foreign body which irritates the pleura, causing an inflammatory reaction.

Bullock and Twichell<sup>5a</sup> state that when the pleural surfaces are together the exudates are normally absorbed, but when they are apart the exudates accumulate and the absorptive power of the pleura at the same time becomes less, thereby producing an effusion. Bettman<sup>8a</sup> has demonstrated this in laboratory with India ink injections.

Effusions, by depositing adhesion-forming fibrin, cause the lung to gradually expand and adhere to the chest wall in spite of attempts to maintain compression with increasingly high air pressure.<sup>55</sup> Pleural effusions are in themselves toxic to the patient and sometimes rupture into the lung and spread infection there.<sup>55</sup> The secondary adhesions that result render the lung unfit for further collapse and then more drastic surgical means must interfere. All forms of effusions may occur, simple pleurisy, pleurisy with effusion, pleurisy with infection, and tuberculous empyema.

With the improvement in technique and better selection of cases less complications are being seen.<sup>43,14</sup> Morriss<sup>30</sup> reports only 18.9 per cent with effusion, Cole<sup>14</sup> only 15 per cent, Singer<sup>43</sup> in his conclusion on complications says that; "fortunately serious complications are relatively rare; most of them being of no importance."

#### Adhesions

One great disadvantage in the treatment by artificial pneumothorax is that the presence of adhesions makes collapse almost impossible in those cases which need it the most. "Pleural adhesions are the rule in chronic

pulmonary tuberculosis and are practically always present at the time that the pulmonary lesion has reached the moderately advanced stage." <sup>51</sup> The moderately advanced stage is the stage where pneumothorax is most indicated.

Matson <sup>et al</sup> <sup>303</sup> conclude that forty per cent of failures with pneumothorax treatment are due to pleural adhesions.

What should be done in these cases where collapse is otherwise indicated? Attempts at forcefully breaking them loose by high air pressures has been done, but with disastrous results in some cases and failures in most. Barlow and Kramer <sup>7</sup> suggest partial or selective collapse under these conditions, but others point out that adhesions are over the lesions, and thereby the diseased part is not collapsed.

In 1913 Jacobaeus of Stockholm devised an ingenious technique to sever adhesions using a thoroscope, a cystoscope-like arrangement through which he divided adhesions by a galvano-cautery. Since then others have done likewise. <sup>1,31,40</sup> Matson <sup>31a</sup> being the leader in the field today has made the operation practical, but it requires skill and training and keen judgment. The procedure offers a solution to this problem of pneumothorax treatment, but must be worked out better as yet.

Phrenicotomy has been proposed by <sup>x</sup>many <sup>x</sup> <sup>40</sup> either in conjunction with or separate from pneumothorax. Many good results have been obtained in this way, and will be spoken of later.

When neither of these methods are successful thoracoplasty must be resorted to. <sup>40</sup>

#### Operative Accidents

Besides the disadvantages of complications arising in a few cases accidents during treatment do occur and may be serious or fatal.

Gas embolism may occur accidentally by introducing air into a vessel,

by the use of very high pressure, especially where there have been thick adhesions containing new vessels which have become opened by the high pressure.<sup>55 p361</sup> Or high pressures, or even moderate pressures, may in rare cases collapse the lung and loosen a blood clot which forms an embolism. Matson<sup>33a</sup> reports 4 cases, 2 of them fatal, among 12,000 inflations; also 15 cases of pleural shock. Cole<sup>14</sup> reports "several" in his experience. The warning here is to beware of haste, high pressures, pleural adhesions, and practice carefulness.

Pleural shock is another accident resembling gas embolism the cause of which is speculative, but occurs more often in apprehensive types of individuals. It may be due to pleural reflex acting on the vagus nerve.

Other accidents that have happened, but rarely, are puncture of the lung, puncture of the heart, hemothorax, puncture of the peritoneum, surgical emphysema.

These accidents and untoward occurrences are to be feared and guarded against, but their occurrences are relatively rare and can not outweigh the indications for pneumothorax.<sup>40</sup>

We may apply here the words of Woodcock: "There are dangers in connection with the production of artificial pneumothorax, but the greatest-- and about this let there be no mistake-- is the neglect in which it is held."

#### Clinical Results

Immediate: The mechanism of favorable effects has already been touched upon, a summary of which would include, the formation of fibrosis, a collapse of cavity walls reducing exudation, a decreased blood and lymph circulation reducing toxemia, and most important, a total rest of the diseased organ.

A gain of weight and strength is the rule. Among Matson's<sup>33a</sup>

235 satisfactory collapse cases, 87 per cent gained weight during the treatment.

Usually there is a corresponding improvement in subjective symptoms as well. The sense of lassitude and fatigue lessens, the appetite and energy return.<sup>42</sup> A decrease in cough and expectoration may be noted immediately if the collapse is complete. Of 235 cases reported by Matson the sputum, previously positive, became negative in 70 per cent during treatment.

In a small percentage of cases, cough, vague pains in the chest due to chronic pleurisy, continuance of temperature may persist, but only in a very small group are these symptoms, if not banished, made less severe.  
42 33a

These favorable results are the rule in the ideal case, the percentage being reduced in those questionable cases and those which a complete collapse is prevented by adhesions.

Matson<sup>33a</sup> in his report of 600 cases exemplifies this statement, as can be readily seen from his figures: Fever, of 235 cases comprising the satisfactory collapse group, 77 per cent became afebrile. Of 245 cases of partial collapse, only 34 per cent became afebrile. In the no-free-space group, (adhesions present), of 120 cases 30 per cent became afebrile. Sputum, of 235 satisfactory cases 70 per cent became negative of tubercle bacillus. Of the 245 partial collapse cases, 25 per cent became negative. Of the 120 no-free-space cases, only 15 per cent became negative. Weight, Of the 235 satisfactory cases 87 per cent gained weight, among the 245 partial collapse cases 75 per cent gained. And of the 120 no-free-space only 69 per cent gained weight.

Remarks made by other authorities indicate that they also have experienced like results. 5,30,42,1

It is clear, therefore, that the most brilliant results occur in those selected cases where complete collapse is made possible.

#### Later Clinical Results

The collection of statistics and reports of final results in cases treated by pneumothorax alone is quite difficult and unsatisfactory.

55 The reasons being that; each individual case presents a separate problem; that some are early, others late; that complications were present in some, not in others; some were left alone, others interfered with by other methods, and the the pre- and post-operative care at each sanatorium differs.

Recognizing this fact I shall, however, mention the results reported within the last decade which may give one an insight into the value of the procedure as it is practiced today.

Matson <sup>33a</sup> in 1924 reported quite extensively a series of 600 cases mostly of the advanced type, covering a period of twelve years, at the end of which time he reported: "Of 600 cases comprising this study, 480 recieved actual pneumothorax treatment. Of these, 235 were satisfactory-collapse cases and 48 per cent are clinically well, 18 per cent are arrested, and 22 per cent are dead. Of the 245 recieving only a partial collapse, 11 per cent are clinically well, 12 per cent are arrested and 58 per cent are dead."

He reported his most favorable results in the chronic fibrocaceous type. He also had favorable results in the actively advancing, caseous pneumonic and caseous broncho-pneumonic types provided a satisfactory collapse was obtained. Progression of disease took place in 4 per cent of satisfactory collapse cases and 9 per cent in partial collapse. Gas embolism occurred 19 times and was fatal in 2 cases.

Spontaneous pneumothorax occurred in 3 per cent and 3 were fatal.

Tuberculous empyema occurred in 12 per cent of 480 collapsed cases.



Adhesions were almost invariably present in those cases demanding a pneumothorax.

His best results were in those cases where adhesions had not yet formed.

Blanchet<sup>5</sup> 1925, reports 200 cases treated during the years 1911 to 1922.

	In 100 moderately advanced cases.	In 100 advanced cases.
Dead	24	97
Failing	6	1
Improved	23	1
Arrested	18	1
Working	<u>29</u>	<u>0</u>
	100	100

He lists his causes of failure:

	Moderately advanced, 24 deaths, 6 failing	Advanced, 97 deaths
Ineffectual collapse	14	40
Rupture of Lung	4	20
Purulent effusion	7	18
Hemoptysis	2	6
Intercurrent disease	2	4
Disease in good lung	<u>1</u>	<u>9</u>
	30	97

The most common cause of failure is seen to be the result of adhesions preventing total collapse.

Morriss <sup>30</sup> in 1923 reports two series of cases. The first comprises thirty seven, 6 far advanced, 30 moderately advanced, with the following ultimate results:

Improved	2.7 per cent
Cured	5.4 per cent
Died	81 per cent
No record	10.8 per cent

The second series of 25 cases were of a later date, composed of 7 far advanced, 18 moderately advanced, with the following results.

Improved (treated)	52 per cent
Treatment discontinued	48 per cent
Died	12 per cent
Improved	24 per cent
Arrested	8 per cent
Unimproved	4 per cent

Adhesions in this series were quoted to head of list as the chief cause of failure.

Farrel and Moore <sup>20</sup> report 109 cases. Of these 45 improved, 42 unimproved, and 22 died in the sanatorium.

Peters <sup>40</sup> 1929, reports results of 700 cases grouped into two series.

First series, 273 cases

Clinically well	31 per cent
Dead	44 per cent
No free space	30 per cent

Second series, 427 cases

Clinically well	34 per cent
Dead	42 per cent
No free space	28 per cent

The second series were taken at a later date, showing improvement with added experience.

He also makes comparison between complete collapse and partial collapse, showing that with the complete there was 53 per cent well and only 24 per cent dead, while in the partial collapse 25 per cent were well and 44 per cent were dead.

Singer<sup>43</sup> reports some interesting results. He divides his cases into various stages.

Incipient cases:

Apparently well	80 per cent
Not improved	20 per cent
Deaths	--

Moderately advanced:

Apparently well	58 per cent
Improved	25 per cent
Not improved	16 per cent
Deaths	--

Advanced:

Apparently well	16 per cent
Not improved	22 per cent
Deaths	61 per cent

These results would indicate that pneumothorax is more beneficial in the earlier stages, yet he states some startling cures are obtained in the far advanced. "At least," he says, "the most hopeless sufferers are often placed in the position of enjoying, in a way, the few remaining months or years."

### Conclusions

In general, it can be seen that the results of each authority are as a whole, quite similar, each has practically the same relative percentage and the same complications to deal with. All agree that results are better with the earlier cases free from adhesions. Reports from foreign authorities are very much like these given above, being better in some cases, not as good in others.

The foregoing certainly affords convincing evidence that the treatment of advanced tuberculosis by artificial pneumothorax is worthwhile. The percentage of cures and improvements in otherwise doomed invalids is too high to argue on the contrary.

There is one great regret, however, in looking over the case reports and that is that the percentage of cures are too low in the far advanced stages. These cases are the ones who need the benefit of a promising cure most of all. And, it is not the type of lesion present that makes results discouraging, it is the inability to collapse the lung for reasons that adhesions have formed, preventing that procedure.

It is agreed that if collapse could be complete in every case, the percentage of cures would rise twenty per cent. <sup>32a</sup> Is there then no way to fully collapse the lung in spite of the presence of adhesions? Of course thoracoplasty has proven itself valuable in these cases, but not for the patient who can not afford to have it done, or to obtain a specialist who has had experience to undertake such an operation.

Matson <sup>32a</sup> and Davies <sup>17</sup> and others <sup>23,42</sup> advise the cauterization of adhesions and then collapse the lung totally by pneumothorax. Good results have been obtained by these men trained in this specialized technique. Matson reports a 74 per cent successful operation in a series of 100 cases, with no complications following. However, he makes a statement that he would not

encourage those without experience to undertake such an operation, as it is not without risks. His cases where only a few long slender adhesions were present were to most successful.

It remains to be seen, therefore, that the far advanced case with dense pleural adhesions is still unsatisfactory for pneumothorax collapse.

Since Stuertz in 1911 introduced phrenicotomy, this procedure has been advanced as a valuable aid to pneumothorax in these far advanced cases, or as a procedure in itself without collapse by air. Results are promising and much work is being done along this line. A discussion of this phase, both as an independent procedure, and as an aid to pneumothorax in the treatment of advanced pulmonary tuberculosis.

## PHRENICOTOMY

Phrenicotomy was first proposed by Steurtz in 1911 to paralyze the diaphragm on one side for severe unilateral tuberculosis.

He used the operation in cases where the lower lobe was diseased and resisted collapse by pneumothorax because of pleural adhesions.

Sauerbruch in 1913 also proposed the operation independent of Steurtz.<sup>55</sup>

### Anatomy

The following account of the anatomy of the phrenic nerve is taken principally from the descriptions of Aycock<sup>4</sup>, Martin<sup>30a</sup>, and Matson<sup>53</sup>.

The phrenic nerve has its origin in the third, fourth, and fifth cervical roots and occasionally some fibers come off the sixth, seventh and eighth, and first thoracic roots. Its course in the neck is obliquely downward and medially over the scalenus anticus muscle under cover of the sterno-mastoid, then beneath the subclavian vein into the thoracic cavity where it passes along the external surface of the pericardium to the diaphragm.

Aycock<sup>4</sup> in a series of 130 dissections showed that 65 per cent of phrenic nerves showed anomalies, or received accessory fibers below the usual site of operative.

Felix<sup>55</sup> (quote) found that the phrenic nerve supplies the entire motor innervation of the diaphragm, except for a few fibers that arise from the twelfth intercostal nerves.

### Physiological Effects

Radical section of the phrenic nerve and accessory nerves cause complete paralysis of the diaphragm on one side.<sup>20a</sup> If not bound down by

adhesions this part soon rises reducing the volume of the thoracic cavity on the operated side, according to some authors, by from one-fifth to one-fourth. <sup>15,5,35</sup> Aycokk <sup>5</sup> says that there is a decrease of 400 to 800 cc. of lung volume in the average case.

Frank and Miller <sup>46</sup> say there is a 10 per cent decrease of lung volume.

The average rise of the diaphragm is 4 cm. <sup>15</sup> but may be as high as 7 or 8 cm. if all accessory nerve fibers have been removed. <sup>15,55,35</sup> This rise may ensue immediately or only after weeks or months with the atrophy of the muscle. If the nerve resection is not complete the muscle retains its tonus and rises only slightly. <sup>15</sup> After a total radical phrenicotomy including section of the accessory nerves the tone is never again regained and function is not restored. <sup>20a 35</sup>

Small excursions simulating small respiratory movements of the paralyzed diaphragm may take place due to the tugging on the mediastinum by the excursion of the normal side. <sup>15</sup> Also paradoxical movements, (Kienboch's phenomenon) in which the relaxed and atrophied diaphragm is sucked upward by inspiratory effort occurs. <sup>15</sup>

Paralysis of half the diaphragm eliminates its piston-like action with each respiratory cycle. The lung is thus at rest and its work is diminished. Absorption from the pleura is less, and the cough reflex is less sensitive. <sup>25</sup>

The positive pressure of the abdominal contents help elevate the flacid diaphragm and thus compress the lung. Compression of lung tissue is more complete at its base, but apical compression and rest occurs likewise, if adhesions do not interfere. <sup>45,4,47</sup>

Due to the compression on the diseased side the capacity and work of the opposite lung is increased. <sup>25</sup>

### Clinical Effects

The apparent and immediate effects following phrenicotomy have been most gratifying both to the patient and physician. Particularly to the former because his outlook on life assumes a brighter aspect. In most cases he ceases to be tortured by the manifestations of the disease. He becomes less of a social outcast and new hope arises within him. All of which tends to combat the disease with which he is afflicted.

Within a week or ten days the temperature, pulse, cough, and sputum amount and general condition are often markedly improved. <sup>55 p183</sup> The reduction in sputum is sometimes striking, 150 cc. to 200 cc. often being reduced as low as 5 cc. <sup>20a</sup> O'Brian <sup>38</sup> reports that in 500 cases those with positive sputum became negative in 52.2 per cent of the cases. The great majority of patients say that expectoration is made easier, none say that it is worse. <sup>46</sup> Distressing cough is relieved in most instances, due to relaxation of adhesions to the diaphragm, and also to the fact that the abdominal muscles function more completely in collapsing the lung. <sup>15,55</sup>

Control of hemostasis has been very successful even in the presence of adhesions. <sup>48</sup>

Remarkably few cases have been reported where unfavorable or distressing symptoms resulted, sometimes there are gastric complaints at first but according to Aycock <sup>4</sup> these are mild and disappear in time. Dyspnea appears in a few cases at the time of phrenic resection but passes away quickly. No circulatory or cardiac symptoms have been reported.

Complications are practically nil; Moore <sup>35</sup>, Cole <sup>14</sup> and others report none. O'Brien <sup>38</sup> in a series of 500 cases reports 5 made worse by the operation.

Sauerbruch (51 quote) maintains that phrenicotomy tends to diminish the tendency to effusion after a pneumothorax has been performed.



It can be concluded then that the clinical effects are quite one-sided and all to the favor of the patient.

We can not say so much for pneumothorax or thoracoplasty.

The end results are the most vital, however, and here it is that Phrenicotomy often falls short of expectations, keeping the question of whether to do phrenicotomy, pneumothorax, thoracoplasty, still patent.

#### The Operation

The original operation was a simple section of the phrenic nerve in the neck under a local anesthesia.<sup>55</sup>

While this technique resulted in diaphragmatic paralysis in most cases, many time no rise occurred, or, if it did occur, function was resumed in the course of four to six months.<sup>4,48</sup> In 1921 radical phrenicotomy was proposed<sup>4,55</sup> and established by Felix and Geotze.<sup>55</sup> (quote) They maintained that the accessory phrenic nerve assumed the function of the cut main trunk. Today all surgeons perform the radical operation or the "phrenic exairesis" of Felix<sup>55</sup> which extracts the accessory as well as the main trunk, thus insuring complete paralysis.

Under local anesthesia, incision is made about one inch above the clavicle and parallel to it, just posterior to the sterno-mastoid muscle. The nerve is anesthetized, dissected free from the scalenus anticus and severed. The distal end is wrapped slowly around a pair of forceps, and gentle traction exerted until the nerve breaks. At least 8 cm. of nerve should come away in order to get the accessory nerve.<sup>4,48,46,31</sup>

The small wound opening is closed by primary union.

Some men use simple section as a temporary procedure in doubtful cases and where the opposite lung is diseased.<sup>48</sup> Others crush the nerve for the same reason.<sup>48,33</sup>

### Operative Dangers

Matson<sup>33</sup> and Bettman<sup>8</sup> list the complications as (1) damage to vascular structures, (2) damage to important nerve structures, (3) and severing the thoracic duct. Very few accidents have been reported, however, and practically no deaths. In 300 cases Matson had none. Most authors report the same result.<sup>30,46,48</sup>

### Indications

When to do a phrenicotomy and in what type of case, is still somewhat of a debatable question among specialists in the field.

It was originally proposed for only lower lobe lesions, but today it is becoming to be used in a wide variety of cases of pulmonary tuberculosis, apical as well as basal. It is also used alone, and in conjunction with pneumothorax or thoracoplasty.

The variety of indications as listed by different authors who report favorable results, point just to one conclusion and that is that each case is a problem in itself and that a few sets of rules can not govern. As in pneumothorax, judgement must be practiced in every case and the indication of phrenicotomy decided upon with the details of the patient's condition clearly in mind.

There is some controversy regarding the preference of pneumothorax and phrenicotomy. The consensus of opinion is that phrenicotomy can not replace pneumothorax,<sup>35</sup> particularly is this so in America. However, foreign workers are more and more advocating the independent use of phrenicotomy, Goetze,<sup>56</sup> in particular, saying that it gives just as good results and is free from the complications and accidents of pneumothorax.

Alexander<sup>55</sup> in his work has divided the indications into its independent use and its use with pneumothorax and thoracoplasty. This outline is in general followed by most surgeons in America today, especially Moore.<sup>35</sup>

As An Independent Procedure:

1. In acute, highly fibrile, progressive, predominately caseous types of tuberculosis, even though there is actively in the opposite lung and when adhesions prevent a pneumothorax.

2. For chronic types of disease, in which adhesions prevent a pneumothorax and in which thoracoplasty is feared because the patient's general condition is too poor, or because the better lung is too much diseased.

3. For those moderately or far advanced cases in which there is no contraindication to artificial pneumothorax or thoracoplasty, but in which phrenicotomy might be expected to effect good results without the prolonged treatment and complicating dangers of the one, and the hazards of the other.

This use is becoming more and more to be used by many thoracic surgeons.<sup>35</sup>

4. For those cases of early unilateral tuberculosis which do not respond to a continuation of sanatorium treatment.

Alexander<sup>1</sup> advocates this use highly, pointing out that the "curing time" is shortened, and that distressing symptoms are relieved. This idea is supported by Moore<sup>35</sup>, Aycock<sup>4</sup>, Bridges<sup>48</sup>, and Welles<sup>47</sup>.

These four indications are generally accepted, but today more has been added and the good results obtained in all types of cases seem to warrant a more inclusive use. Welles<sup>47</sup> and others have found that good results are obtained in upper lobe lesions more often than when cavities are at the base. In a series of 271 cases he had beneficial results in two-thirds, with no complications or deaths.

Bilateral disease is receiving more treatment by this means than formerly. 46,47,48,38.

Used Supplementary to Pneumothorax or Thoracoplasty:

This use of phrenicotomy is warmly supported by many specialists, Davies<sup>16</sup>, O'Brian<sup>38</sup>, Alexander<sup>1</sup>, and others, who report excellent results and cures where failure would have resulted had pneumothorax been carried out alone. They use it in cases where pneumothorax is failing because of adhesions, hemoptysis, effusion and other complications, and especially where there are basal lesions. Also, they use it supplementary to a complete and satisfactory pneumothorax in many cases. Archibald<sup>2,3</sup>, says there is less complications, and that after expansion the shrunken lung better accommodates itself to the altered thoracic cavity. Other advantages of the combination are that refill intervals are made shorter,<sup>38,20a</sup> adhesions are relaxed, complications are fewer,<sup>4</sup> and if the patient should discontinue his air injections the partial collapse by phrenicotomy remains.

By using the combination the advanced and unsatisfactory collapse cases, receive nearly as much collapse as those early and satisfactory cases free from adhesions. The radical thoracoplasty operation is made unnecessary in the majority of cases and therefore the far advanced case is no longer a subject of shock and the hazards that accompany thoracoplasty.

In order to receive and better judge the indications of phrenicotomy some actual results reported by specialists of today would be in order, both from the standpoint of an independent procedure, and as an aid to pneumothorax.

Final Results of Phrenicotomy

Until very recent years the estimation of final results of phrenicotomy operations has been quite unsatisfactory, due to the fact that treatment by this means alone was not considered sufficient and therefore interfered with by additional therapy. Recently, however, it has become more recognized as an independent procedure and as an aid to unsatisfactory pneumothorax cases,

therefore several series of case reports have appeared. The largest series is reported by O'Brian<sup>38</sup> who has performed the operation on 500 patients, not select, but routine. His statistics are as follows:

Of the series reported 378 were operated on for cavitation. In 191 of these, or 50.5 per cent, the cavities closed. In 31.2 per cent, they became smaller. Therefore 82 per cent of cavities were closed or became smaller.

In 102 patients, on whom operation was performed preliminary to thoracoplasty, the cavities in 8 closed, making thoracoplasty unnecessary.

His results with cavities located at the base and apex were; 80 per cent closed at base and 46.6 per cent closed in apical cavities.

The combination of phrenicotomy and pneumothorax proved effective.

In these patients, 70 per cent of the cavities closed, making otherwise failures by pneumothorax satisfactory in 50 per cent of cases.

The table which follows shows these results:

<u>Results of Phrenicotomy Alone and Combined with Pneumothorax</u>		
	Total No.	Closed, per cent
Patients with cavities---phrenicotomy alone	102	62.7 " "
Patients with cavities---{and pneumothorax not possible	131	19.8 " "
Patients with cavities---{in which pneumothorax and phrenicotomy were combined	145	70.8 " "

As for the contra lateral lung:

In 120 patients the good lung was clear.

In 288 patients the better lung was diseased.

(a) In 26 per cent the disease in the contralateral lung healed.

(b) In 52.7 per cent the contralateral side was improved.

Therefore a total of 78 per cent were benefited. In only 10 per cent was there an increase of disease in the better lung.

Sympathetic nerves were injured four times, one patient died of pneumonia, but other than this no complications or deaths were reported. Two hundred and eleven patients are at this time arrested.

Welles<sup>47</sup> reports 3000 cases in which the operation was used in all types of conditions.

His final results were:

Out of 271 where phrenicotomy was used alone, 173 or 64 per cent were improved and 98 or 36 per cent were not benefited. This includes all degrees of improvement and all risks and types of failures.

He adds that if all the hopeless cases were excluded, the number of good results would be over two-thirds of the total.

Of the 300 patients 5 were made worse. To him the apical lesions healed as well if not better than the basal. The cases in which phrenicotomy was used with pneumothorax proved satisfactory, although the theoretical expectations were not fulfilled.

Moore<sup>35</sup> in an extensive report of 63 cases treated by phrenicotomy says that in selected cases one can expect improvement from phrenicotomy alone in 80 per cent.

Of 63 cases, 43 or 68,3 per cent, the expectations were fulfilled.

Bridges and Bly<sup>48</sup> report 60 cases dating back to 1925 which do not include those cases done preliminary to thoracoplasty.

In 20 cases the disease was unilateral.

In 40 cases the disease was bilateral.

15 of the unilateral are improved, or 75 per cent.

22 of the bilateral are improved, or 55 per cent.

To date 8 or 20 per cent are dead.

Frank and Miller<sup>46</sup> report 100 cases treated since 1926. 90 per cent of these were far advanced. 40 per cent showed improvement; in 8 the sputum

became negative, and in 8 the cavities disappeared.

Used with pneumothorax 44 per cent showed a better collapse out of the 54 that pneumothorax was used without success.

Better results were obtained in basal lesions than apical, although fair results were obtained here also.

These authors concluded that phrenicotomy will pass through the experience accorded pneumothorax.

Cole and Johns<sup>14</sup> report 18 cases which have all improved. These were all select. No complications and accidents occurred, and none were made worse by the operation.

Many more such reports might be listed from the literature, especially from foreign authorities; Goetze, Fischer, Prihan, Hauke, etc., but the above is sufficient to throw light on the subject and the results that are being obtained today. Nowhere is there any unfavorable reports, and practically no reports of the disease being made worse by phrenicotomy.

#### Conclusion

Phrenicotomy is a relatively recent newcomer to the list of surgical treatment of pulmonary tuberculosis, but during its short life it has and is proving itself to be a valuable aid in pulmonary rest and collapse therapy. It is simply performed, free from danger and complications, and effective both when used alone and in conjunction with other operations and mode of therapy.

By its use in this latter way, new hope may be offered to those suffers who, even though treated by pneumothorax, are at a standstill and agonized by the manifestations of the disease.

From the foregoing results it may be comprehended how well the expectations are being fulfilled in these cases, rendering a partially and

unsatisfactory mode of therapy complete and satisfactory in the majority of cases, with all benefits to the patient.

Thus many cures and many cases are arrested, where otherwise their lives would have been shortened and the last days stormy.

Used alone in select cases the bothersome refills by pneumothorax are abolished as well as the complications and hazards of the latter.

Used in connection with pneumothorax the ultimate of collapse is obtained in nearly every case regardless of adhesions, making the dangerous and deforming thoacoplasty unnecessary.

Its more extensive use therefore seems to be well indicated. 4,46,47  
19,16,31.



## GENERAL CONCLUSIONS

The foregoing account of the treatment of pulmonary tuberculosis by pneumothorax and phrenicotomy presents a distinct advancement in the therapy of that disease. An advancement not only to the medical profession in controlling the ravishes of tuberculosis, but also to the patient, himself, in offering him new hope, a fresh outlook on life, and a possible cure of his affliction that not many years ago was deemed hopeless and left to the will of nature to either heighten his suffering or cause a prompt exitus.

That this mode of therapy is a specialized one, and but a part of general treatment is granted, but not so specialized that the average well equipped physician can not perform it when he has attained a sound fundamental knowledge of the science of tuberculosis, its manifestations and prognosis.

In the literature these two forms of therapy (pneumothorax and phrenicotomy) have been spoken of as "operative procedures", implying that great skill and precise technique are essential in order to carry them out. While these characteristics are of course, desirable in every physician, he does not have to be a highly specialized surgeon in order to make use of and perform these two modes of therapy when the disease so indicates their use. Rather, must he be a man of judgement, and a student of tuberculosis, and when the disease indicates a pneumothorax or phrenicotomy, have it done, or learn to do it through experience as every other therapeutic procedure is learned in the general practice of medicine.

On the other hand a word of warning must be sounded as regards their over-use. There would be some to plunge directly into the use of a pneumothorax, without weighing the case first, and failing there, refer the case to a specialist for a final thoracoplasty. Neither form of therapy is without

its dangers when not properly indicated.

Collapse therapy is an aid to recovery from pulmonary tuberculosis and should never replace general treatment by rest, fresh air, food, and time.

A nicety of judgement, therefore, is the prime essential in the use of both procedures.

Pneumothorax is admitted by all <sup>16,35</sup> to be the procedure of choice when collapse is indicated. Some advocate its early use, others use it only in late cases, while still others use it only to partially collapse the lung. With each method good results were obtained because to these experienced men the individual case seemed to warrant the method used. This is as it should be, for every case is a special problem to be treated as the pathology and stage of the disease demands.

There are some authorities who use pneumothorax and phrenicotomy together in every case that requires collapse and their reasons for so doing seem logical in all ways. Certainly it is not as drastic a procedure as a thoracoplasty and the degree of collapse is even greater. This combination promises to be used more in the future and possibly supplant thoracoplasty, making the treatment of tuberculosis more satisfactory in the hands of the "everyday" physician.

Phrenicotomy used alone promises much, as can be seen from the foregoing account. There are a few who concede it the place pneumothorax now holds. However, at present it is mainly used as an adjuvant to other operations, reinforcing them, so-to-speak. Even with this use, it is most certainly valuable when by its application an unsatisfactory collapse can be made complete, and thus a relatively hopeless case converted into one with a favorable prognosis.

We might also add that by these two methods the patient can "afford to get well" whereas if he were subjected to thoracoplasty or allied major operations the "cost of getting well" would never offer him any stimulus to get back on his feet and "buck" the world.

It is interesting to speculate on the changes that will come in the handling of tuberculosis of the Lungs. A time will no doubt come when the public will expect that the surgical methods which are proving so triumphant shall be available for poor and rich alike. The two subjects here-in presented offer more toward this goal than any other, while at the same time are as effective when the underlying pathology are understood.

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