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Clinical discussion of artificial pneumothorax as a therapeutic adjunct in the management of pulmonary tuberculosis

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A CLINICAL DISCUSSION
OF
ARTIFICIAL PNEUMOTHORAX AS A THERAPEUTIC ADJUNCT
IN
THE MANAGEMENT OF PULMONARY TUBERCULOSIS

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INTRODUCTION

Artificial pneumothorax in the treatment of pulmonary tuberculosis is the commonest and most universally used method of collapse therapy in practice today. It is the most important addition to the treatment of pulmonary tuberculosis since the introduction of the sanatorium regime some 60 years ago. Since the World War it has gown by leaps and bounds until today it is a memb r of the armamentarium of every practicing physician.

In this paper a brief review of the evolution of artificial pneumothorax is first presented. Because of their value to one little acquainted with the procedure special emphasis is placed upon the selection of cases, complications, and duration of the treatment. Results have been stressed because they represent the accomplishments with this procedure as compared with those under a sanatorium regime. The technique, apparatus, and conduc tion of refills are stressed only lightly. The opinion in these instances varies with the will of each operator. Only a standard procedure is presented.

A relatively new type of artificial Pneumothorax has been included. Although falling into the realm of

surgery. Extrapleural pneumothorax fills a definite link in the types of collapse therapy. It can be used in cases where intrapleural pneumothorax is impossible and thoracoplasty contraindicated or too risky. The procedure has been tried by only a few. From their reports this material has been obtained. Since the method is recent and relatively untried the results are inadequate and at present u reliable.

HISTORY

Pneumothorax was first described by the Greek physician Hippocrates. He described the symptoms and treatment stating that it often comes on after a wound to the chest or following a drainage for empyema. (42) He also made reference to the therapeutic injection of air into the chest. (37)

Hippocrates' ideas were probably a result of his observations on soldiers with phthisis who recovered from the disease following wounds to the chest.

Pheracus, suffering with phthisis and feeling himself doomed, intentionally placed himself where he could easily be wounded. Following a spear thrust to the chest he recovered from the disease. (53)

DeBligny reports a case of phthisis in a Frenchman. In a duel he received a stab wound between the fourth and fifth ribs. Following this he completely recovered from the disease. (53) Beglieri in 1696 reported chance cures of tuberculous soldiers following penetrating wounds of the chest. (39) Thus,

from the 16th century on there are recorded chance cures from accidental collapse.

In 1821 James Carson, a Liverpool physician, realizing the hopelessness of treatment in pulmonary tuberculosis conceived the idea that the discharging ulcers or cavities were prevented from healing by the constant irritation of respiration. He applied the same principles here that are applied to any surface lesion which fails to heal because of irritation and lack of immobility. (34) Carson published an article on "The Physiology of Respiration" in which he decided that the only rational treatment of phthisis would be to immobilize the lung. (61) He proposed that this be realized by a surgical procedure in which a hole was made in the chest, thus collapsing the lung and making it quiescent. (34) Carson proposed this method from his results in animal experimentation. Although his ideas were well grounded they were not met with favor by his colleagues. (1)

In 1822 Carson attempted the procedure. He tried it on two cases with very far advanced tuberculosis. An incision was made between the sixth and seventh ribs but no collapse resulted. On post mortem

examination he found the pleural to the adherent. (34)

Although sound in principle Carson fell short of his goal. However, in the absence of any knowledge of antisepsis or asepsis it is probably better that his ideas were not put into practice. (62)

In 1837 William Stokes observed that the symptoms of tuberculosis were modified by spontaneous pneumothorax after the first violent symptoms had subsided. (25)

At about this same time Walsh observed that the symptoms of phthisis underwent improvement when there were signs of hydropneumothorax present. He thought that this observation was rare, hence, no warranty for collapse therapy. (61) (25)

In 1882 Carlo Farlanini of Pavia, Italy, published an article expressing his observations on many spontaneous pneumothoraces and on his own artificially induced pneumothoraces. Repeatedly he emphasized the primary principle of the procedure so often voiced by Carson, that is, healing following immobilization. (1)

Farlanini's results were much better than those of Carson. He had the good fortune of being able to use the antiseptic technique recently

brought out by Pasteur and Lister. (1)

Although he merely repeated much of Carson's work, Farlanini did bring to light the fundamentals of pneumothorax. For example, he presents the two major objections as:

1. Only a few with spontaneous pneumothorax improve.
2. Effusion following pneumothorax has a deleterius effect.

For a successful pneumothorax Farlanini stated that the opposite lung must be sufficient; the affected lung should be completely collapsed, but at the same time respiratory function not be impaired. He advised a pressure of 5-7 mm. over a long period of time as a means of reexpansion he presented absorption or aspiration. To prevent infection he suggested the use of antiseptic technique. Later, in 1894, he published a paper showing how adhesions could be destroyed by the persistent injection of air under pressure. Thus, Farlanini presented all of the basic principles of collapse except one, selective collapse. (1)

At this same time Pierre Carl Edoward Potain of

Paris was also using artificial pneumothorax. Pollacle (61) credits him with being the first one to use it successfully. In 1885 he treated three cases, two of which were successful.

Then, Cayley of London reported that hemoptysis in a consumptive could be stopped by the injection of air (62), and Potain reported the replacement of effusions with air to prevent too rapid an expansion of the lung. (1)

In 1898 J. B. Murphy of Chicago reported to the annual American Medical Association convention that pulmonary tuberculosis was at last readily yielding to artificial pneumothorax. Boldly he repeated the physiological principles set forth by Carson and Farlanini, proposed a cure consisting of one or two treatments over a period of three to six months with 30-50% collapse, and took the credit for the procedure. (53) (1) In 1899 Murphy's assistant, A. E. Leurke, reported 53 cases treated with artificial pneumothorax. (61)

The "Stormy Petrel" of American surgery did contribute to the evolution of the procedure. He suggested the use of x-ray to determine the location of disease processes and to determine the extent of

collapse following pneumothorax.

As suddently as he had become an enthusiast Murphy in turn dropped artificial pneumothorax, thus, delaying its acceptance in America by some ten years. (1)

In his hurricane of enthusiasm Murphy did stimulate work in Europe. Brauer and Spengler took up the work in Germany.(25) Brauer changed the original technique by making an incision down to the pleura before using the puncture needle.(61) (25) In 1904 Sangman introduced the use of the water monometer which lessened the danger especially when the puncture method was used. (62) (61) (25)

In 1912 Ascali urged the abandonment of complete or compression collapse. He suggested a partial or hypotensive collapse, one accompanied by low or negative monometer readings. (16) After experience with this type of collapse Barlow and Thompson brought forth selective collapse, a term first used by them in 1921. (16)

Thus, only a refinement of technique and wider experience were left to bring the procedure into its present day scope. (62)

Today the apparatus and technique have been

perfected. Conditions formerly considered contra-indications are no longer considered as such. Bilateral disease is a good example. (61) (25)

Artificial pneumothorax has kept stride with the volution of modern science. It has progressed through antisepsis, asepsis, and radiology until at present it is the most extensively used, as well as the most successful form of collapse therapy used in pulmonary tuberculosis. (10)

TYPES OF ARTIFICIAL PNEUMOTHORAX

Therapeutic artificial pneumothorax may be divided into the following clinical types:

1. Total (complete or compressive)
2. Incomplete (partial)
3. Selective (hypotensive)
4. Simultaneous bilateral
5. Alternating bilateral (24)

Total or complete pneumothorax was the first type used by Carlo Farlanini and his contemporaries. In this collapse the intrapleural pressure exceeds the intrapulmonic pressure. The expansile properties of the lung are overcome compressing it from all planes against the hilus. The entire function of the one lung is destroyed. Hence, it can be used only in unilateral collapse. Dyspnea, effusions, reactions, and discomfort are frequent with complete collapse. In addition permanent contraction and fibrotic changes take place in the good lung tissue as well as in the diseased tissue. Future re-expansion and function of the undiseased portion is fefinitely impaired. (16) (5)

Incomplete pneumothorax is a more or less transitory stage. It occurs when the intrapleural and intrapulmonic pressures are equal. The undiseased portion of the lung is relatively stationary being neither compressed nor under the influence of a negative pressure. Only a slight absorption of air is necessary to shift this type into the hypotensive collapse.

Selective collapse is based upon the presence and maintenance of a negative intrapleural pressure. Under this pressure the good lung tissue is able to expand and function normally while the inelastic diseased areas become compressed and contracted. Under this mechanism the symptoms and complications are greatly reduced. The individual has the use of the undiseased lung tissue. It is this mechanism that broadened the use of pneumothorax to include extensive bilateral disease. (16) (57) (1)

Simultaneous bilateral pneumothorax is that type in which both lungs are partially collapsed at the same time. This procedure is best fitted for bilateral upper lobe disease which is not too far advanced. It is useful in sanatarium patients when there has been a recent spread to the contralateral

lung. Each side is put under partial or selective collapse. There are no signs of discomfort, in fact, the patient may be ambulatory and even do work within certain limits. Refills are required more frequently. (16)

Alternating pneumothorax was brought out by Farlinini in 1911. It is indicated in patients who develop contra lateral disease during unilateral pneumothorax therapy, and in those who have bilateral disease when first seen. The most involved side is collapsed first, the opposite being watched closely for any extension. Often the untreated lung will improve along with the collapsed lung. However, a rapid extension in the better lung may require an alternate collapse of that side. The first side may be reexpanded or a bilateral collapse may be maintained. (16)

BASIC PRINCIPLES

Rest has always been the recognized treatment for tuberculosis. It was James Carson in 1821 who first applied the same principles to tuberculous lesions of the lung as were applied to a lesion anywhere on the body. Immobilization with absolute rest was the key. He suggested the local rest of the individual lesion by collapse. (34)

Artificial pneumothorax exerts both a mechanical and a physiological effect upon the lung. Mechanically the cavities are collapsed allowing the opposing walls to knit, thus, excluding the tuberculous process. The secretions are expressed from the lung preventing extension either by lymphatic channels or by way of the bronchiales. The tendency of the lung to shrink by the contraction of scar tissue in and about the lesion is augumented by collapse.

Physiologically, respiratory excursions are first diminished and then abolished. A condition of stasis and hyperemia then ensues. The circulation of lymph is diminished resulting in a limitation of

the infected areas and the proliferation of connective tissue.

Thus an exudative process is transformed into a proliferative process. (26)

Diseased areas in the lung are very different from normal lung tissue. They show a marked impairment of expansibility and elasticity over that of the normal tissue. Hence the tuberculous process tends to collapse more readily. (49) It cannot resist the pressure of the pneumothorax whether positive or less negative than the normal intrapleural pressure. Normal lung tissue does resist this pressure by virtue of its own elasticity. (16)

Through this mechanism a selective collapse may be induced. By a selective collapse is meant one in which only the diseased area of the lung is collapsed, the remaining normal lung being only partially collapsed. This is a natural process and takes place of its own accord. The diseased tissue having lost its expansibility is unable to resist the more positive intrapleural pressure. With each breath it expands less and less. Healthy lung tissue expands almost to the chest wall with each inspiration.

To make way for this expansion the intrapleural air is driven to the area of least resistance which is over the diseased area. By repeatedly compressing and forcing imprisoned air toward the diseased area with each respiration the diseased part finally becomes completely collapsed while the healthy tissue functions normally. (16)

Some believe in "Archimede's Principle of Buoyancy". In this principle it is implied that the intrapleural air is lighter than the air within the lung. The buoyant force of the dense air in the lung forms the lighter intrapleural air to the apex. If the lesion happens to be in that area collapse is successful. (22) This principle, although sound, is certainly found wanting. It does not explain selective collapse which we know by x-ray evidence does occur. Only the condition and quality of the diseased tissue could explain selective collapse.

Following collapse there is a fibrosis of the diseased areas and a tendency toward fibrous proliferation over the pleura. The bronchioles in this area tend to sclerose and atrophy while small blood vessels become shortened and narrowed. (26) The healing in general occurs through absorption of the

smaller tubercle and fibrosis of the larger areas. (35) (47)

SELECTION OF CASES

Artificial pneumothorax as compared with a sanatorium regime is a relatively new type of therapy in pulmonary tuberculosis. Like all new procedures it has taken the country by storm. It is being performed by all kinds of physicians on all types of pulmonary tuberculosis. In fact, it has been publicized so thoroughly among this class of patients that often on entering a sanatorium they often ask "to be given air". In this respect the laity have to look upon the procedure as a "quick cure."

In some sections the physicians regard it as a "cure all" irregardless of the type of infection or of what may be accomplished in that particular case. (30)

Every physician knows that in some cases the results from artificial pneumothorax are spectacular. In other cases he knows that the procedure is impossible to perform. Where should the limits for this procedure be placed? In just which cases should it be done? Should it be limited to the young or the

old; the male or the female; the colored or the white; the advanced or the minimal case; the toxic or the non-toxic patient. Above all, after the diagnosis has been made just when should the procedure be instigated?

Indications

Artificial pneumothorax can not always be performed, but it should be attempted in the following:

1. An active progressive disease of one lung which does not respond to bed rest of six to eight weeks. (39) (26)
2. In well established cases of cavitation. (39)
3. In patients with a stationary lesion but an unstable temperature and pulse, and evidence of toxemia. (26)
4. In cases of fibroid tuberculosis with a positive sputum and cavitation but no constitutional symptoms. Especially should it be done if the patient is uncooperative and living at home. These patients are the carriers. (39) (26)
5. In any patient with open disease who is

is uncooperative at home and cannot be treated in a sanatorium. (26)

6. In cases of advanced bilateral disease in which one-third of the remaining lung tissue is normal. (26) In these cases the lung showing the more extensive disease is collapsed first. The better lung may show marked improvement following this. (39)
7. In acute, spreading exudative processes immediate cautious pneumothorax may save the good lung. (39)
8. In children with the adult type of tuberculosis collapse should be done immediately. (39)
9. In pleurisy with effusion where the patient is running a more or less stormy course the fluid should be replaced with air. (39) (26) All pleural effusions should be considered tuberculous until proven otherwise. If allowed to absorb in tuberculous patients future pneumothorax will be impossible because of adhesions. The fluid should be aspirated and replaced with air. In the event of a pyogenic empyema diagnosis will

be made on aspiration. (1)

10. In negroes with little infection immediate collapse should be done because of their low resistance to the disease. (39)
11. Following spontaneous collapse in a tuberculous lung the collapse should be maintained. (39) (26) If allowed to expand future collapse will be impossible because of an obliterated pleural space. (1)
12. When complications such as tuberculous laryngitis, enteritis, or diabetes are present. (39) (26)
13. In the presence of co-existing pregnancy especially if the disease is unilateral. (39) (26)
14. To control hemorrhage if the causative side can be diagnosed. Usually it is the more involved side. (39) Hemoptysis may confirm a doubtful diagnosis of tuberculosis or indicate what was formerly thought to be a stationary lesion. In this respect it becomes a definite indication for collapse therapy. (1)

15. Bilateral collapse should be done in the ulcerative type with cavitations where there has been reactivation or extension of the infection in the good lung, or in processes that are equal in both lungs. (26)

16. Contralateral pneumothorax should be performed after the original pneumothorax has been established to control toxemia. (26)

17. Bilateral pneumothorax should be done in recurring hemorrhage of the good lung and unilateral cases with a displaced mediastium. (26)

In selecting pneumothorax cases there should be no differentiation as to sex. In children with the adult type of tuberculosis artificial pneumothorax is indicated and strongly advocated. This type of case does poorly on a sanatorium regime while those with the childhood type do very well. Pneumothorax should never be used in the latter. (27)

Should artificial pneumothorax be considered immediately following the diagnosis or should a regime

of sanatorium treatment be tried first and if the patient does not respond then instigate collapse?

It is true that many early cases can be arrested by a dietetic-hygienic regime. This therapy must be continued until the patient is completely arrested and not just better. If he does not progress artificial pneumothorax should be added to the sanatorium therapy. The patient should never be allowed to advance into the incurable stage. (11)

If it is unknown as to how the patient will respond should one take the chance of letting him progress any farther? Why should a period of several months be wasted in observation when pneumothorax could be done immediately? Jessel (33) and Wood (31) do favor early pneumothorax. Edwards (21) thinks that delay prediposes to adhesions and in general increases the risk.

These two viewpoints are based upon two schools of thought in regard to therapy. The conservative attitude regards the disease as one affecting the whole body; the radical attitude focuses its attention on the local lesion from which all trouble is thought to arise. (31)

Heaf considers every pneumothorax as a potential tuberculous empyema or effusion. From this an obliterative fibrosis with a distorted brenchiectasis may result. Therefore, he suggested that in approaching the patient one should ask himself, "Can this patient recover without pneumothorax?", rather than, "Can a pneumothorax be induced in this case?" (31)

In selecting collapse one must understand the response of the patient to the infection. This can be accomplished only by a period of observation. Up to a certain point the body is able to resist the toxemia. Above this it needs help by some artificial means. Preceding this point an artificial collapse might reduce the building up of immunity and resistance, thus hindering arrest and favoring recurrances. (31) (43)

Basing a selection upon x-ray findings alone is misleading. The activity of a lesion cannot be determined by x-ray or fluoroscopy. However, fluoroscopy will disclose two important pieces of information as to the condition of the lung:

(1) The type of chest movements during respiration, and, (2) the areation of opaque areas.

If the resistance of the body to infection and the condition of the lung are known it should become evident that there are cases in which artificial pneumothorax is unnecessary and sometimes harmful. These cases are:

1. The young adult with a negative sputum, a unilateral lesion, and no evidence of cavitation or evidence of small cavitation with no hemoptysis. Routine care here is sufficient.
2. The young adult with early infiltration, no cavitation, normal blood picture, abulatory, afabrile, and a positive sputum. If after three months of bed rest there is evidence of cavitation or the sputum remains positive pneumothorax should be done.
3. 45 years old, or over, with a fresh infiltration superimposed on an old fibroid condition. Collapse here is usually useless. It results in dyspnea, healthy lung tissue only becoming compressed.
4. Patients with a small lesion in the contralateral lung with a low resistance, a rapid

> sedimentation rate, or a poor blood picture - high monocyte and low lymphocyte count. Collapse here would produce an immediate extension of the small focus and result in extensive bilateral disease. (31)

In regard to waiting through a preliminary period of observation Burrell thinks that in early cases it is all right, however, in his estimation when temperature is present the case is no longer an early one. (11) Edwards (21) is opposed to waiting, and Harter (30) says the following: "Waiting in minimal cases to see how nature will take care of the disease is like setting course in the face of a threatening storm under full sail, hoping that the storm will not break. Suddenly the hurricane strikes and the ship is lost before the sails can be reefed." When the spread occurs and a cavity forms collapse is usually impossible because of adhesions. (30)

Approximately 40% of the patients with minimal tuberculosis show progression of the disease under the strictest sanatorium regime. In patients of the teen age this percentage is especially high.

Following artificial pneumothorax the number of arrested cases is greater than in any other treatment of minimal tuberculosis. In addition, complications in these patients are rare, hospitalization and morbidity are shortened, and there is little danger of further extension. (68) Touissant says that in cases with early infiltration artificial pneumothorax is the quickest and most practical therapeutic procedure. (67)

In selecting these cases one must consider the degree of activity of the disease. This factor is much more important than the extent of the disease. The importance of this consideration has been proved by the reduction of symptoms in one given up as hopeless anatomically. (46) Some phthisiologists go so far as to use artificial pneumothorax only in definite cavity formation and with no respect for the activity of the disease. (30)

Many contralateral lesions will heal after the original lesion is collapsed. This holds good only when the contralateral lesion is of recent origin. If the sputum remains positive after a unilateral collapse one may always suspect a contralateral lesion. Immediately a bilateral collapse

should be induced. Too frequently the lesion is allowed to progress too far before something is done. If diagnosed early a complete pneumothorax may be used on the original side with a partial collapse on the opposite side, or a partial collapse may be used on both sides depending on the case. (30)

It should be well realized that only the anatomical extent of tuberculosis can be determined by x-ray. One cannot determine the activity by this means. (31) Especially is this true of small diffuse lesions. (19)

The patients' reaction to the disease is not always a guide as to its activity, however, clinical findings will usually help in this determination. A slow, insidious onset with slight symptoms usually means an apical lesion. A sudden onset of more acute symptoms usually means a lesion lower in the chest and very much more in need of collapse than an apical lesion. (19)

These toxic symptoms do add strength to the indications for collapse. They are by no means absolute indications or contraindications. Mild pleural effusions may give profound toxic symptoms for a short time. On the other hand, the marked toxic

symptoms of emaciation, cyanosis, and dyspnea are found in far advanced cases. Here, collapse would be hopeless.

Local symptoms such as uncontrollable cough, large amounts of purulent sputum, and hemoptysis are important indicators of activity. The history of the individual may be a guide to his resistance; one who has led a life of leisure is normally less resistant than one who has abused his health by over work and strain. The former will need collapse while the latter case may do equally as well on bed rest alone. (1)

In addition to these factors the distribution of the disease is also important. Regardless of size or extent or location lesions may be completely and selectively collapsed. But, suppose the lungs are involved with a disseminate infection. It is apparent that both lungs cannot be totally collapsed. Alexander (1) says that at least two good functioning lobes or their equivalent must be left for sufficient breathing. If more than three lobes are involved one may do partial pneumothorax bilaterally. But, if the two best lobes contain lesions badly in need of rest the procedure is doomed to failure.

Induction should have been done before the disease progressed that far.

Lesions near the periphery are especially prone to form early adhesions. A lung with this type of disease should be collapsed as soon as possible. (1)

Fundamentally, pneumothorax is indicated for cavities and for progressive disease when these do not, or cannot, be expected to respond to bed rest or diaphragnotic collapse. It is indicated in progressive lesions regardless of size and in sluggish lesions to ward off chronic invalidism even though the disease would not materially shorten the life of the patient. (19)

Reviere quote Farlanini as saying, "Pneumothorax is indicated whenever life is threatened by the extension of a local lesion." (63)

Pneumothorax should be attempted first in every case upon which collapse therapy has been decided. Surprising as it may seem, the apparently most obstinate case will yield freely while the easiest in appearance will be most difficult. (1) An ineffective pneumothorax can be very beneficial in preparing patients for thoracoplasty. Even though the cavity closure may be unsuccessful the disease tends to

become more chronic thus making the patient a better thoracoplasty risk. When discovered that pneumothorax is not effective in collapsing the cavity thoracoplasty must not be deferred too long. Extension may occur in the contralateral lung increasing greatly the risk of thoracoplasty. (30)

Closing a cavity with pneumothorax and healing of that cavity are two entirely different things. Chronic fibroid apical cavities are hard to collapse. Usually there are adhesions. Even if collapse is sustained it takes a long while for the cavity to close and even then it may open again in reexpansion. In this type of case pneumothorax is indicated only as a pre-thoracoplasty procedure. (30)

Alexander (1) states the following in regard to indications:

1. Minimal lesions when extensive or rapid in progression with accompanying symptoms or many bacilli in the sputum should receive pneumothorax. Usually minimal lesions respond to bed rest.
2. Moderatly advanced lesions usually need collapse except for chronic, fibroid, stationary lesions without cavitation or symptoms,

and in recent, soft, bilateral lesions. In these two types it may be best to wait one month as an indicator of any progression or retrogression.

3. Far advanced lesions should have immediate collapse regardless of their extent. In many cases the attempt may be unsuccessful. In bilateral cases the collapse may be induced simultaneously or successively.

Contraindications

Contraindications for artificial pneumothorax are very indefinite and few in number. What seems to be a contraindication often turns out to be an obstacle or hindrance which prevents one from performing the procedure.

True contraindications are:

1. Cardiac failure - the benefit of collapse here would be doubtful even excluding the possibility of an immediate disaster from a change in intrapleural pressure. (26)
2. Emphysema - the procedure here may prove fatal. The degree of emphysema may be underestimated, thus somewhat masking the

the underlying tuberculous infection. (26)

3. Asthma - an acute attack of asthma following collapse could easily result in asphyxia. (26)
4. Extensive extrapulmonary disease - renal, laryngeal, intestinal, and skeletal tuberculosis usually have their origin from a pulmonary lesion. (1) If they are advanced they become a disease entity in themselves and treatment of the lung condition would be futile in their presence. (26) If these lesions can be controlled the pulmonary disease thus becomes the major issue, the extrapulmonary lesions no longer being a contraindication. (1)

Pneumothorax in the presence of pleural adhesions as evidenced by x-ray have been considered as contraindications. This is untrue. Packard showed in a series of cases that in the presence of seemingly massive adhesions the procedure was relatively simple. (58) Adhesions then do not fall in the realm of contraindications but under obstacles encountered.

Contralateral collapse in the presence of a

unilateral collapse is not contraindicated, but it should be undertaken with caution. Puncture of the one remaining lung might result in an immediate fatal collapse. (1)

Pharyngeal tuberculosis progresses with no relation to pulmonary tuberculosis. Therefore, in a strictly pharyngeal involvement pneumothorax should be out of the question. (1)

The severely cyanotic, emaciated, exhausted person in the far advanced stage should never have pneumothorax. However, one should not be misled. These symptoms may be stimulated by an irrevelant toxemia, pleurisy, or anemia - conditions readily ammendable to treatment. (24)

The acutely ill person with fever and toxemia of recent origin does poorly under either pneumothorax or bed rest. (35)

Pneumothorax is definitely contraindicated in cases in which the diagnosis might be mistaken, for example, lung absecess and effusion other than tuberculosis. (67)

Tubercle bacilli in the sputum should not be taken as the sole indication for collapse. A bronchoscopy should be done in an attempt to find a

bronchial or tracheal lesion. If, a strictly tracheo-bronchial lesion is found pnemothorax would be useless unless the lesion causes a complete obstruction of air and secretions. This type of lesion may cause an atelectasis simulating tuberculous pneumonia and hence be taken as an indication for pneumothorax. (71) (23)

It might be worthy of mention here that pneumothorax is not a contraindication for surgery under gas or spinal anesthesia. It is best to have the pneumothorax well established before hand. (36)

APPARATUS

A pneumothorax apparatus should be so designed that the measurement of air induced is exact. The operator should be able to stop the procedure at any time and withdraw air if necessary. In addition the taking of monametric readings should be accessable at any time.

Three types of apparatus are in use today. They are the gravity, gasometer, and aneroid-recording machines. The gravity type is most commonly used and in recent years many improvements have been made to simplify its operation. (1)

The gravity apparatus most commonly used is that originally introduced by Brauer of which the modifications most generally used were those of Floyd, Robinson, and Pilling. (2)

This consists of two graduated cylinders connected with rubber tubing and fixed upright being suspended on either end of a belt which passes through an overhead pulley. By turning this pulley with a key or lever one bottle is raised above the other at the operators choice.

One bottle is filled with water. As it is raised above the opposite bottle the water flows into the empty opposite bottle displacing the air by way of a flexible tube into the chest. By merely turning the lever so that the water surfaces in the two bottles are on a level the induction of air is stopped.

Attached by means of a three way valve to the induction line is the mercury monometer. By turning this valve at any time the induction of air ceases and the chest tube becomes connected with the monometer. Pressure readings can be taken almost immediately.

Withdrawing air may be accomplished by reversing the bottles from the position described under the induction process above.

There are many modifications of the apparatus but for all practical purposes this is sufficient. (1) (41) (59)

Two types of needles are used, an initial and a refill. The initial needle is large and blunt of the trocar type. The Fischer 16 gauge needle is very good for this purpose. The object of the blunt needle is to prevent injury to the lung on the initial inductions or on refills where the lung is partially

collapsed and close to the thoracic wall. It is easy to see that a sharp needle protruding at right angles against the visceral pleura could do severe damage during respiratory excursions of the lung.

For refills in which the lung surface is well away from the thoracic wall an ordinary 22 to 26 gauge needle may be used. They may be used with or without an adjustable stop to immediately shut off induction. (1) (41) (28)

TECHNIQUE

The patient should be placed on the table, affected side up, facing away from the operator. The arm on the affected side is abducted and externally rotated as far as possible. The forearm is flexed so that the palm of the patient's hand rests firmly over the ear on that side. This position extends the affected side widening the intercostal spaces. A pillow beneath the opposite side may increase the lateral extension and also add comfort.

Usually the anterior axillary line in the fifth interspace is chosen for insertion. At this point there is less danger of striking any of the large pulmonary vessels and the layer of lung tissue here is small. Any point may be chosen, depending upon the location of adhesions, location of the lesion, and the will of the operator.

The area is cleaned with 70% alcohol and painted with Tr. Merthiolate. An intracutaneous wheal is made by injecting 1% novocaine. The needle is then turned at right angles to the skin surface and inserted

to the parietal pleura. Usually a two inch needle is sufficient, the depth of the injection depending upon the thickness of the funiculus. Injection against the pleura should be made if possible to avoid the pain of the larger needle, introduced later. The entire area should be thoroughly infiltrated. (1) (41) (59) (28)

Throughout the procedure aseptic technique should be observed.

Before inserting the pneumothorax needle Gordon (26) prefers to make a small skin incision. This prevents plugging of the needle with integument and avoids carrying infection from the skin surface to the pleura. In fact, he does this before making the deep injection of anaesthesia. Dr. Fleischman (59) prefers to bore a small hole in the skin with the point of a scalpel. Both procedures do produce considerable scarring if repeated refills are done over a period of years. Dr. Allen (59) inserts the needle directly through the intact skin. In his experience infection is improbable and blocking of the needle infrequent and of little consequence. To the beginner, plugging of the needle may throw him off when he enters the pleural space producing serious complications. (1) (8)

Introducing the needle depends a great deal upon experience in the feel of the needle. On entering the pleural space a definite "giving away" sensation is experienced. There is little need to fear entering lung tissue. (26)

During the insertion the needle should be connected with the monometer. On entering the pleural space definite fluctuations of the monometer occur. They are predominantly negative fluctuations. (26) This occurs because there is usually a normal negative pressure of 9 mm. at the end of inspiration and 7.5 mm. at the end of the expiration. (26) The fluctuations should cover a large range. Small fluctuations may represent a pocket pneumothorax. Fluctuations of an equal degree positive and negative indicate usually an intrapulmonary reading. (8)

Braufin prefers to use the disconnected from the monometer. On entering the pleura there is a definite audible aspiration of air. This indicates that the needle is in the intrapleural space and not in lung tissue. It also indicates that the pleurae are free from adhesions and the lung is collapsing readily. Following this he continues with monometric readings. (8)

After determining definitely that the intrapleural space has been obtained 25 cc of air should be allowed to enter. Repeat the reading and if it continues negative allow 100 to 200 cc more of air to enter. Induction should be slow and the patient should be watched closely. It should be terminated immediately upon complaint of pain or dyspnea. (26) The procedure should be concluded without a positive monometer reading, the initial injection not exceeding 400 cc. Negative pressures tend to reduce air embolism and cardio-respiratory upsets. A positive, pressure might cause rupture of adhesions with resulting hemorrhage and spontaneous pneumothorax. (3)

Following induction the needle is withdrawn and the wound dressed either by applying collodian directly or with a cotton-collodian dressing. (59) A compression dressing using tape from sternum to spine may prevent subcutaneous emphysema. (52)

Fluoroscopic examination and x-ray plates should be taken as soon as possible to determine the extent of collapse and any shift of the heart or mediastinim. By turning the patient in different positions the presence of adhesions may be detected. (26)

The technique for refills is the same as for the initial induction except one need not fear puncturing the lung. If observed properly with the fluoroscope one should know the position of the lung at all times.

Obstacles to Collapse

1. Pleural adhesions - Adhesions are the most dreaded difficulties to overcome in obtaining a satisfactory collapse. They may cause complete symplysis of the pleura or they may occur in single folds or bounds. They form most readily over the diseased areas of the lung especially if they are located near the periphery of the lung. Selective collapse in these cases is impossible.

Adhesions may be so situated that a pneumothorax pocket will retain the air right over the diseased area of the lung. Although collapse is incomplete it may be worth retaining. In most situations this is not the case. The air seeps out of the adhesion pocket, the diseased area receiving no collapse. (5) (1)

In the presence of demonstrable adhesions pneumothorax should be tried; often they are misleading and a partial collapse can be obtained. (54)

Adhesive strings or folds may be stretched under a positive pressure. This should not be undertaken on the first few refills because the adhesions are still friable and may tear. Later on they may be stretched until a relatively satisfactory collapse is obtained.

Adhesions may be avoided by the early diagnosis and induction of pulmonary tuberculosis.

Intrapleural pneumonolysis may be of some value in pleural adhesions. Usually thoracoplasty is done although phenicictomy may be of some value. (45) (28) (1)

2. Pleural effusions may an obstacle to satisfactory collapse when they occur early in the phase of induction. They should be treated properly by aspiration and refill. (1)

3. Mobile mediastinim - A shifting mediastinum may cause the entire lung to be displaced into the pleural space. Under this condition there would be very little collapse of the affected lung. Collapse may be obtained by gradually increasing the pneumothorax as the lung retracts. Eventually a selective collapse is obtained. Rarely does a pleural irritant need be introduced into the mediastinum to sclerose

and immobilize it. If adhesions are present intrapleural pneumonolysis is most effective, especially if the lesion is suspended between the adhesions and a mobile mediastinum. Pleural irritants may be used but they are less successful. (1)

DURATION AND TERMINATION

(Desirable Reexpansion)

The duration of an artificial pneumothorax is probably the most important phase of a successful collapse. A definite duration cannot be determined for the types of pulmonary tuberculosis. No hard and fast rule can be set up. Each case must be considered as an individual problem in itself.

It must be remembered that following reexpansion the pleura becomes adherent. Any future attempt to inject air would be unsuccessful. If following reexpansion one discovers that a cavity has reopened and knowing that any further collapse would be futile, thoracoplasty, phrenicotomy or pneumonolysis must be resorted to at a much greater risk. (10) (45)

Termination of pneumothorax should depend upon the condition of the patient, the type of pathology, present before collapse, and the length of the collapse. (65)

Several methods for determining the condition of the patient have been advocated. When all symptoms

are gone, the sputum is negative, and the lung from all appeances is healed reexpansion may be done. (65) Some physicians rely upon the return of the sedimentation rate to normal. Harper and Jennings think that the sedimentation rate is invaluable in determining unhealed areas of the lung. (29)

The differential white count is used as an indicator. Medlar and Dugan say that an increase in lymphacytes signifies healing while an increase in monocytes means an extension of the disease with an increase in the number of tubercles. To them an increase in neutrophiles signifies abscess formation. (48)

Neal (54) believes that reexpansion should be not be attempted until the tuberculin skin test is negative. (54)

Partial test reexpansion is probably the best procedure for determining the fitness of the patient for reexpansion. Refills are given in wider intervals and in lesser amounts allowing the lung to expand gradually. During this gradual reexpansion the sputum must be examined routinely. Physical examinations of the chest should be done at frequent intervals. Above all, the chest should be watched closely with the

fluoroscope and x-ray. If at any time the sputum becomes positive, physical signs appear, or the x-ray shows signs of extension or reopening of a cavity the decompression should be stopped. At this stage the pneumothorax can be recompressed without any difficulty. (61) This procedure should be followed in all reexpansion cases. Often the apparent healing of cavities is misleading. As Harter has said, "Closing of a cavity with pneumothorax and healing of the cavity are two different things." (30)

The length of the collapse and the pathology present in the lung are interdependent factors. Generally, we might say that if before collapse the patient had a progressive, exudative, recent infiltration without cavitation regression and resorption should occur in a short time. On the other hand, the fibro-caseous type with thick walled cavities should require a longer collapse of perhaps five to six years. (65) These considerations should aid the physician in prognosing for the patient's benefit as to how long pneumothorax will have to be carried on.

Although these indications are of some value they are by no means absolute. Termination should

rest entirely with the individual case, the experience of the operator, his results and the results of others. (30)

De Weck (18) reporting 51 cases of successful pneumothorax presented the following:

Duration of Collapse	Percentage Relapse
0-1 yrs.	34%
1-2 yrs.	0%
2-3 yrs.	16%
3-4 yrs.	14%
4-7 yrs.	7%
8-10 yrs.	0%

Dufault and Larache (20) in reporting 65 cases with demonstrable cavities and a positive sputum showed the following:

Percentage Collapsed	Duration of Collapse	Percentage Relapsed	Observation Period
27%	1 yr. or less	66%	2-3 yrs.
29%	1-2 yrs.	42%	3 yrs.
23%	2-3 yrs.	53%	3 yrs.
20%	3 yrs. or more	15%	----

Stafford (65) in a review of his work says that minimal cases should have 1-2 yrs; moderately advanced c ases without cavitation should have 2-3 yrs; and far advanced cases with cavitation should have 5 years or more of collapse. Hafter (30) draws exactly the same

conclusions.

Thus, it is apparent that pneumothorax must be carried on over a long period of time - a minimum of 1-2 years for the least involved cases. No doubt many physicians are premature in their reexpansion. (18)

Undesirable Reexpansion

Pneumothorax may be terminated regardless of the will of the operator in what is known as an undesirable reexpansion. This may occur as a result of:

1. Dense obliterating pleural adhesions.
2. Pleural effusions.
3. Sudden absorption of air from the pleura.

Adhesions starting at the base of a lung may gradually creep upward until they have obliterated the entire pleural space. Their contraction expands the previously collapsed lung.

Fluids in the pleural space fosters the laying down of a fibrin sediment within it. Fibrin bands soon form and these quickly develop into dense adhesions. Coughing and exercise may cause a rapid expansion of the collapsed lung. The reunited pleura becomes readily

adherent the pleural space being obliterated. These complications may be somewhat prevented by aspirating the fluid and replacing it with air, decreasing the interval between refills, increasing the quantity of air per refill, controlling the cough with codine, and insisting upon a sanatorium regime along with the collapse therapy. (17)

Pneumothorax may have to be discontinued upon an extensive involvement of the contralateral lung as a life saving measure.

Undesirable collapse is quite frequent. In a series of 324 cases of artificial pneumothorax Rubin showed that 31% had to be discontinued because of dense pleural adhesions. He places empyematous effusion and contralateral extension on a par as causes of reexpansion. (64)

Myers and Levine reported 52 cases in children in which seven cases had to be discontinued because of extension in the contralateral lung. In three cases pleural adhesions caused an undesirable reexpansion. (50)

Dangers of Reexpansion

After a period of collapse the diseased portion

of the lung becomes firm and contracted with scar tissue. It is drawn toward the hilus of the lung and anchored there rather firmly. There are no peripheral attachments to this area and the negative intrapleural pressure has little effect upon it.

During reexpansion the entire lung moves peripherally and in doing this may draw the heart, trachea, and mediastinal structures toward the involved side. Torsion of the heart and great vessels are of little consequence; however, when the bronchi and trachea are deviated there may be a resultant dyspnea, or mechanical asthma. Bronchitis and a secondary toxemia may be produced. (65)

This may be prevented by doing a phrenicectomy before the reexpansion or by replacing the pneumothorax with oleothorax.

Under a tension such as this it is easy to see how healed or partially healed cavities might break open, and reinfection occur. Thoracoplasty then becomes the only alternative. (17)

COMPLICATIONS

Immedfate Complications, Danger Signals and Precautions

During the induction of artificial pneumothorax meticulous care and technique must be exercised. Even then accidents are unavoidable.

1. When the needle is outside the parietal pleura slight monometric fluctuations may be noted. These are due to the displacement of the parietal pleura with each respiration and are of no significance.

2. When the needle is in the lung tissue proper a free ascillation from negative to positive will be obtained. This equal fluctuation should not be confused with intrapleural pressure. The needle should be withdrawn.

3. Coughing, hemoptysis, and tasting of the anaesthetic by the patient are not uncommon findings. This means the lung has been penetrated by the needle.

4. Sudden, severe pain in the chest during the induction may indicate a spontaneous pneumothorax. Absence of a monometric reading is no criterion that pneumothorax has not developed.

5. Adhesions should receive great concern. If they are torn spontaneous pneumothorax, hemorrhage, or air embolism may result.

6. The pressure in pulmonary veins is constantly negative and should not be confused with intrapleural pressure.

7. If free oscillations are obtained on the negative side of the monometer few accidents will occur. (44)

8. Air embolism is a serious immediate danger. It may occur at induction or during refills and is usually a result of injecting air into a pulmonary vein. (44) (69) The injection may not be directly into a vein. A sharp pneumothorax needle may tear a rent in the lung opening a pulmonary vein to the air of an alveolus or to the intrapleural air. (1) (69) (9)

In pleural adhesions there is often an anastomosis between the blood vessels of the lung and those of the chest wall. Tearing of an adhesion might open a communication between a pulmonary vein and the intrapleural air. (9)

Air entering the pulmonary venous system goes directly to the left heart. Any air reaching the

coronary or cerebral vessels produces severe symptoms. The patient may complain of pain. He may show focal symptoms of cerebral envolvement or even hemiplegia. He may lapse into unconsciousness or exhibit signs of shock. Death may ensue almost immediately. (44) (9) (39)

The cerebral symptoms of air emboli are tonic or chronic convulsions, usually unilateral and focal in nature. Retrograde amnesia and depressive states may occur. Emboli lodging in the retinal arteries may cause blindness. The "red marbling" appearance of the skin is due to a local stasis of blood in the peripheral system.

Sudden deaths resembling heart failure are caused by air emboli lodging in the coronary arteries. Pulmonary emboli are more serious than systemic emboli because less air is required to produce fatalities. In the systemic type the air is filtered out by the lung. (69) (9)

Prophylactic measures include the use of blunt needles, introduction of air only when the intra-pleural space is definitely obtained, and lowering of the patient's head. (1) (69) (9)

Treatment for air embolism consists mainly of

oxygen inhalations to support the cardio-respiratory system and adrenalin intravenously with atropine hypodermically to stimulate the heart. (69) (9). Heaton (32) does not try to differentiate between air embolism and pleural shock. He thinks they are very closely related. In his series it occurred in 1.1% of cases with a .2% mortality.

9. Spontaneous pneumothorax may be due to needling of the lung, tearing of adhesions, or to the rupture of a perpheral cavity. Either will result in a broncho-pleural fistula. It may heal over quickly or a mixed empyema may result. (39)

Collapse of this type is evidenced by a sudden, severe pain in the chest with dyspnea. If the pneumothorax is is of the ball valve type each inspiration may increase the pressure in the intrapleural space. Compressing the lung, mediastinum, heart, and contralateral lung. The patient exhibits a cold perspiration, feeble pulse, cyanosis, and an anxious expression with a feeling of asphyxia.

Treatment consists of oxygen for the cyanosis, digitalis for the heart, morphine for pain, and codine for the cough. If a compression pneumothorax should develop air should be withdrawn by reversing the

pneumothorax machine. (44) (61)

Heaton found that spontaneous pneumothorax occurred in 2.6% of 2,742 pneumothorax cases. (32)

10. Pleural shock may kill the patient suddenly upon introduction of the needle. This curious phenomenan has not been fully explained. It is evidenced by a sudden fall in blood pressure and pulse rate. There is a gradual loss of consciousness with flaccidity, disturbed reflexes, sweating, and clonic movements of the face, upper limbs, and trunk. The condition may be a result of direct pleural shock or it may be related in some unknown way to a vago-vagal reflex. (44) (14) Heaton suggests that this condition may be a result of pleural reflex, gas embolism, or both. (32) Aside from palliative treatment the operator is helpless.

These immediate complications, although tragic when they do occur, are quite rare. In Heaton's review of 3,381 cases he found that fatal complications other than empyema made up only 1% of the patients in whom artificial pneumothorax was performed. (32)

Later Complications

1. Pleural Effusion - This is the most frequent

complication of artificial pneumothorax. (39) Of 1,400 cases it occurred in 27%. (32) Krause estimates the incidence from 40% to 80%. (38)

The causes of effusion are numerous and rather indefinite. They may be due to infection from the induced air, tearing of adhesions, tuberculous pleurisy, rupture of subpleural tuberculous foci, the irritation of the pleural surfaces by the air, or the pressure of the pneumothorax. The incidence seems to be lower when low intrapleural pressures are used. (38) (3)

If a spontaneous pneumothorax has occurred the effusion will be of a mixed type originating from the broncho-pleural fistula. This is really a mixed empyema and is accompanied by rather severe symptoms and a stormy febrile course. (52) (39)

The fluid may be sterile and when present in small amounts cause no trouble. If large quantities are present pressure symptoms may develop. It may contain tubercle bacilli. About 2% of all effusions develop into tuberculous pneumonia. (52) (39)

Small effusions need no consideration. The larger effusions may aid in the compression of the lung. It is the opinion of some that the fluid need not be removed unless pressure symptoms develop. (61)

However, in the presence of fluid adhesions are prone to develop. They may creep up the chest wall obliterating permanently the intrapleural space and the possibility of a future pneumothorax. (67) Touissant (67) recommends replacing fluid of an appreciable amount with air. Small amounts may be absorbed quickly allowing expansion of the lung, and permanent obliteration of the intrapleural space.

2. Subcutaneous Emphysema - This condition is a rather minor complication of artificial pneumothorax. It occurs frequently and may be quite extensive causing considerable local pain and tenderness. It is never serious. (1) (32)

Subcutaneous emphysema may be caused by the use of large needles, coughing following induction, extrapleural injection of air, lateral movements of the needle, multiple punctures of the pleura, a thickened pleura which fails to close the needle hole, or failure of the operator to massage the area in which the puncture was made. (1) Intrapleural air under positive pressure may escape into the subpleural fascia. From here it may work to any part of the body. Emphysema of the fascial layers of the neck result from this type of escape. (1) (52)

Although the condition is not serious the patient does become very uncomfortable. Refills may have to be delayed because of soreness. This delay is especially objectionable following the initial induction.

Treatment here is merely symptomatic. Prevention rests mainly in massaging the punctured area and following that with a proper colladian or compressive dressing. (1) (52) (59)

3. Mediastinal Emphysema - Like the subcutaneous type this condition is not dangerous. It is in infrequent. The condition may be produced by the injection of air directly into the interstitial lung tissue. By creeping along the septa of the lung it reaches the mediastinum. Intrapleural air under pressure may dissect through or burrough around adhesions and enter the mediastinal area.

Here, also, the symptoms are those of compression - the mediastinal organs.

Prevention is practically impossible although avoiding high intrapleural pressure may reduce its occurrance. Symptomatic treatment is required for several days until the air is absorbed.

4. Bilateralization - The appearance of new lesions

or a flare up of old lesions in the contralateral lung is probably the most serious complication of pneumothorax and the most common indication for early bilateral collapse. (1)

Heaton (32) found that when the contralateral lung was normal spread occurred to that lung in 12% of 182 cases. When the contralateral lung showed some previous infection extension occurred within that lung in 23% of 236 cases.

This type of extension usually occurs early in pneumothorax therapy. It may be a result of the patient sleeping on the affected side or turning on that side to receive refills. In other words, gravity may have something to do with the extension.

More commonly bilateralization is due to the improper closure or a reopening of cavities, the extension occurring by aspiration into the good lung. Thus, careful observation by x-ray is required to prevent bilateralization. The proper behavior of collapsed cavities should be checked routinely.

During the induction of a unilateral pneumothorax there may be an extension or flare up of lesions already present in the opposite lung. This

may be due to over work of the lung or perhaps the lesion was extending just at this time. This is not the common occurrance. Usually contralateral lesions improve following the collapse of the originally infected lung with control of its lesions.

In the event of either an extension or flare up in the opposite lung bilateral, partial collapse should be induced at the earliest opportunity. The first pneumothorax should not be abandoned. It will not relieve the burden of the opposite lung and will foster the extension of its own lesions. If bilateral collapse cannot be done the case is usually hopeless. (1)

5. Empyema - Tuberculous and Mixed - As mentioned under paragraph 1 pleural effusion is a rather common sequela of pneumothorax. In exudative, progressive or pneumonic cases of tuberculosis that have extended to the visceral pleural the pleural effusion may become tuberculous early in the treatment. The development of the tuberculous empyema is usually accompanied by few symptoms.

The occurrance of this condition later in the treatment is probably due to improper collapse of the pulmonary lesion. Prevention of early tuberculous

empyema is unknown. It can be prevented later by repeatedly aspirating effusions and replacing them with air. In the presence of an unclosed cavity pneumothorax may have to be replaced by diaphragmatic collapse or thoracoplasty.

A pleural cavity may be infected by pyagenic organisms this may occur from infection by the pneumothorax needle, a break in the visceral pleura, or a broncho-pleural fistula. Pyagenic empyema is usually accompanied by rather severe symptoms and a stormy febrile course. (39) (52) (1)

Empyema cases should be aspirated and the intrapleural space irrigated with a mild antiseptic - boric acid has been used. In tuberculous empyema a 10% solution of gomenol has been recommended. (61) Alexander reports some success with dyes but he recommends surgical intervention with drainage and collapse. (1)

6. Adhesions - Pleural adhesions or obliterative pleuritis occurs most commonly following an early pleural effusion. In the presence of an effusion there is a predisposition for the laying down of fibrin. This fibrin soon changes to a fibrous net work from which dense adhesions develop, firmly

uniting the parietal and visceral pleurae. If this condition is present following the initial induction when the lung is still close to the thoracic wall the adhesions form quickly. The pleural space may be obliterated between refills. Rapid absorption of fluid may cause a union of visceral and parietal pleurae.

Effusions coming on later have the same tendency to form adhesions. Since the lung at this stage is farther from the thoracic wall the adhesions are more easily broken up.

Adhesions may start in an insidious manner at the base of the lung and gradually extend toward the apex in spite of any efforts on the part of the operator.

Prevention consists mainly in close observations by x-ray and replacing effusions with air.

Positive pressures may be tried in breaking up recent adhesions however, when extensive other measures must be instigated. Diaphragmatic collapse, pneumolysis, oleothorax, or thoracoplasty may have to be done. (1) (32)

7. Refill Reactions occurring 4 to 24 hours after each refill are uncommon. They are characterized by

fever chills, perspiration, and pain in the chest. They occur in those who have had pleural effusion or pleurisy and are not an indication for stopping pneumothorax. Treatment is symptomatic.

8. Atelectasis may occur in cases of complete collapse with the blocking of a bronchus. Secondary infection usually sets in and is followed by a rather extensive fibrosis. Reexpansion of this area is impossible.

This condition may be prevented by removing broncial plugs with the bronchoscope or by adhesions already present which allow only partial collapse. Atelectasis is of little consequence.

9. Neuralgia and Neuritis following collapse is due to pleural irritation. It is of no consequence. Treatment is merely symptomatic. (32)

Fatal complications may be depicted in 5% of all pneumothorax cases. Of this group 4% are due to empyema and 1% to all other causes. (32)

Hemothorax, contraleral effusions, mediastinal hernia, pneumoperitonium, fibrin bodies, puncture of the heart, and acute dilitation of the stomach are very rare complications. (32)

RESULTS

The immediate results of artificial pneumothorax therapy are often very striking, especially where successful collapse has been obtained. The temperature becomes normal, the cough decreases, the sputum becomes negative, and night sweats disappear. The patient increases in weight and in general shows a marked improvement.

This same result may be obtained at times with a sanatorium regime and is obtained with other types of collapse. (35)

In reviewing the literature one will find many converse reports on results. Supporters of the thoracoplasty, artificial pneumothorax and sanatorium treatment each present clinical results and statistics which support their method of treatment. (31) This condition exists because statistics are too relative. They should be qualified as to the selection of cases, technique, and associated treatment. (33) They are not.

It should be evident that results would be best in unilateral cases. In fact, it would be impossible

to rest both lungs by collapse. An active extensive lesion in one lung does much better than a smaller less active lesion in both lungs. (11) Bilateral lesions, however, are not a contraindication. In bilateral disease the most diseased lung should be collapsed first. The immediate results are usually an attenuation or disappearance of symptoms with rapid improvement. This is followed by an extension or reoccurrance in the contralateral lung and should be treated by partial or complete collapse allowing the first lung to reexpand. At the best, the end result is usually a chronic fibrotic process and although not arrested maybe prolonged for a considerable time. (11)

Some authorities say that the pneumothorax patients would do just as well under a sanatorium regime. In reviewing 3,021 cases treated with artificial pneumothorax at the King Edward VII Sanatorium and comparing the results with 2,750 contralateral patients they were unable to find any distinct advantage or any more favorable ratio of actual to expected deaths among those treated over the ones untreated. However, in this sanatorium artificial pneumothorax was used in only 1% of the

cases regularly. (7)

Burrell (11) gave his patients a trial period of six months and induced pneumothorax in those who showed no progress. In reviewing 190 cases after two years of treatment 82 were arrested, 25 improved, and 14 showed no change. These patients were doing badly under sanatorium treatment.

In 1933 Burrell reported 71 cases of unilateral tuberculosis in whom artificial pneumothorax was induced after a six month trial of sanatorium treatment with no improvement. Over half of these patients were alive and free from symptoms ten years later. In 5% of his cases with some disease of the contralateral lung 46 are dead. Those who had over one-third of the better lung affected died within two years. From these results Burrell concludes that a 50% chance of recovery is offered by artificial pneumothorax in unilateral cases regardless of the extent of the disease. He suggests that a higher percentage would be obtained if collapse were done at once instead of waiting through the preliminary observation period of six months. (12)

In reporting 460 cases in 1935 Miller stated that the simple productive types of tuberculosis showed

more promise of response to artificial pneumothorax than the mixed-exudative types. In his cases none of the productive types were dead. Among the living and well their percentage was higher. His best results were obtained with a collapse of 50% or more. The moderately and far advanced cases with 50% to 75% collapse showed a much lower mortality rate than those with less than 50% collapse.

Of his 460 cases 363 had pneumothorax and 97 were without pneumothorax. The most outstanding results were among the moderately advanced cases where 58.6% with pneumothorax are well 22.7% of the untreated are well. Among the far advanced cases 25% of the treated are well while only 5.7% of the untreated are well. In the moderately advanced group with pneumothorax 2½ times as many are at work as compared with those not having pneumothorax. In the far advanced group five times as many who had pneumothorax are at work as compared with those having no pneumothorax.

Comparing moderately advanced cases with far advanced cases he found that of the moderately advanced 63% were well and working; 22% were dead.

In the far advanced group 26% were well and working while 36% were dead. (51)

Jessel reports an attempted collapse in 1929 on 139 cases and the results of these cases in 1932. 99 cases had a positive sputum while 40 cases had a negative sputum. 59 of the positive sputum cases received a satisfactory collapse. 26 of the 40 negative sputum cases obtained collapse.

The collapsed cases were compared with the similar series of cases where collapse was impossible because of adhesions. Of the cases with a positive sputum on whom collapse was performed 42% were working and fit in 1932 while 40% of the cases with a positive sputum in whom collapse could not be performed were also working and fit. Of the negative sputum cases 69% who had collapse were working and fit while only 36% without collapse were working and fit.

Notice the percentage of positive sputum cases with and without pneumothorax who were working and well three years later. They are almost the same. Also notice that collapse was impossible because of adhesions. Adhesions are a fibrosis and fibrosis is evidence of healing process or a tendency of that

individual to heal. Therefore, the control cases presented here have a tendency toward healing which is not evidenced in the collapsed cases. A satisfactory result in those cases would not be unlikely. In addition some had phrenicictomy. Thus, the above group of statistics are very unreliable. They need qualifying.

It is important that the percentage of negative sputums after 1932 was twice as high in those with pneumothorax as compared to those without pneumothorax. As a means of preventing spread this measure becomes valuable. (33)

In 1921 Sangman reported 310 cases of pneumothorax which he had been able to follow up between 1907 and 1918. Pneumothorax was successful in 218 cases and impossible in 92 cases. Of the 218 successful pneumothorax cases, 74 or 33.9% were able to work, 7 or 3.2% were unable to work because of tuberculosis, 1 was unable to work because of other cases, 130 or 59.3% died of tuberculosis. Of the 92 unsuccessful cases, 10 or 10.9% were able to work, 1 or 1.1% were unable to work because of tuberculosis, 79 or 85.8% died of tuberculosis. (35)

Notice in this group of cases that 34% with

pneumothorax were able to work while only 11% of these cases without pneumothorax were able to work. Also, 59% with pneumothorax died of tuberculosis while 85% without pneumothorax died of tuberculosis. This group of statistics favor pneumothorax. Although it is not spectacular, remember that these observations were made 20 years ago when the procedure was quite new.

In 1924 Matsons reported on 600 cases of which 480 received artificial pneumothorax. Of these 480 cases, 235 received satisfactory collapse, 245 received partial collapse and 120 received no collapse. Their results are as follows:

No. Patients	Collapse	Well	Arrested	Dead
235	satis-factory	48%	18%	22%
245	partial	11%	12%	58%
120	control	5%	-	66%

(47)

This series shows the significance of a satisfactory collapse as far as cure and mortality is concerned.

In another series of cases it was found that of 400 effective pneumothoraces 67% became well and 6% died. In a similar group of ineffective pneumothoraces

34% became well while 40% died. (60)

In a review of 1124 patients treated at the Michigan State Sanatorium from June, 1, 1930 to June 30, 1934 a complete follow up 2-3 years later showed that 823 patients were discharged; 595 had collapse and 228 had no collapse. The collapse group of 595 were classified as follows:

Minimal cases --------- 7%
Moderately advanced -- 36%
Far advanced -------- 57%
Cavities present in -- 77%
Positive sputum in --- 76%

After treatment 55.5% were arrested; 22% quiescent or improved; 22% dead.

The 228 non-collapse group were classified as follows:

Minimal cases ------- 22%
Moderately advanced -- 21%
Far advanced --------- 57%
Cavities present in -- 57%
Positive sputum in --- 60%

The follow-up showed that 26% were arrested, 13% were quiescent or improved, and 61% were unimproved or dead. (40)

Note in this series that the far advanced cases predominate. Also, the percentage of minimal cases in the untreated group is more than three times the percentage in the collapse group. Then, notice the

results: in the non-collapse group 13% arrested and 61% dead. In the treated group 55% arrested and 22% dead. From this group of cases we can almost say that pneumothorax reversed the incidence of arrest and mortality.

Wilson presents a group of 120 cases in which artificial pneumothorax was maintained over six months. Results were based upon return to useful life. In 120 cases pneumothorax was effective in 72%, partially effective in 20%, and non-effective in 8%. In the moderately advanced group it was 89% effective while in the far advanced group it ranged from 82% down to 35% effective for the most extensive cases.

58 cases were reexpanded in from one to six years. Of these, 66% were working after an average of three years and three months of collapse, and 16% were dead after an average collapse of 2½ years. In 34% of these cases the lung underwent an undesirable reexpansion after an average collapse of two years and three months. Of these undesirable reexpansions 73% were working while of those reexpanded by choice after four years only 65% are working. This should indicate the value of a few months collapse.

In 548 attempted pneumothoraces 432 cases obtained some collapse. In 116 the space could not be found. Of those collapsed a negative sputum was obtained in 60%. 128 cases were carried only three months, and 13% were completely ineffective clinically. Pneumothorax successfully induced increases the chance of recovery some three times. (72)

Packard reviewed 100 cases of pneumothorax in which the lungs had been reexpanded, from 1-18 years. Of these cases 62% were well and 24% were dead. 19% were either improved or unimproved. (57)

Bosworth and Smith in Jaunuary 1939 reported on 130 patients followed up from 1 to 17 years. This is probably the latest report in the literature at the present time. Arrest of these cases was determined by present history, occupation, number of hours work per day, X-Ray, and sputum studies by concentration culture and smear. Of these 130 patients 63% were apparently cured or arrested; 10% were apparently arrested, quiescent, or active; 7.7% were living but nothing was known as to their condition; 19.2% were dead. (6) This series of cases seems to carry about the same percentages as those of other authorities.

In all the series presented I believe the percentage of arrests was much higher and the mortality rate much lower than in any series of control or untreated cases. In addition, the time of treatment is shortened and it creates a good attitude among the patients. Pneumothorax is an adjustment to all other types of treatment. (33)

EXTRAPLEURAL PNEUMOTHORAX

In the past few years a type of collapse therapy - extrapleural pneumothorax - has been reviewed. This procedure is not new. It was first performed in 1891 by Tuffier and by 1910 he had done three cases. (4) J. B. Murphy in his "Orations on Chest Surgery" at the A. M. A. convention in 1898 mentioned three types of collapse - thoracoplasty, intrapleural pneumothorax, and extrapleural pneumothorax. Murphy said that if adhesions are firm and the visceral and parietal layers of the pleura cannot be separated, then, the parietal layer should be separated from its costal attachments and allowed to sink in with the lung. (53)

Sporadically this procedure has been carried on since that time, especially in Europe.

Two German surgeons, Graf and Schmidt, are responsible for the recent revival. Since their work several years ago it has been taken up by Drs. Bilsey, Edwards, Churchill, Overhalt, and Vinton in America.

The results are indefinite because it has not been in use long enough. The German articles are not available for this paper. Therefore, I shall merely present the work of our American surgeons who have used it.

There may be some objection for including it in this paper. I well realize that it does involve a small rib resection and therefore could be placed in the realm of thoracoplasty. However the collapse by injecting air is of equal importance. Since this procedure is apparently a very important link in the methods of collapse therapy, since it has been used very little and is new to us, I deem this the most important part of the paper.

The terminology on this subject is somewhat heterogeneous. Articles are written under the common term, extrapleural pneumothorax, and also extrapleural pneumolysis, extrapleural pneumonolysis, and pleurolysis.

Dr. Pol. N. Caryelas, a Greek physician in New York City draws issue over this terminology and brings out some interesting points in grammar. First, pneumolysis is a misnomer and should be replaced with

the more proper, pneumonolysis. Pneumonolysis means a freeing of the lung and should never be used synonymously with extrapleural pneumothorax. The latter should be termed pleurolysis because the pleura is freed from the chest wall. (15)

Therefore, it seems that pneumonolysis and pneumolysis should be discarded and only pleurolysis used in speaking of extrapleural pneumothorax.

In reviewing 262 cases collapsed by this method Dr. Belesy has presented the following indications for the procedure:

1. Following a decision for collapse therapy use pneumothorax. If unsuccessful and the patient unsuitable for thoracoplasty use pleurolysis.
2. Use pleurolysis in preference to intrapleural enucleation of adhesions.
3. Use pleurolysis in cases where thoracoplasty is desired but contraindicated because of the poor condition of the patient such as, asthma, emphysema, poor respiratory function, costal rigidity, or post operative complications due to diaphragmatic paralysis. (4)

Jones and Churchill say that it is indicated in the very young and the senile; those in which thoracoplasty could not be risked. (13)

Dr. Richard H. Overhalt working in Boston with Dr. O. S. Tubbs who brought the procedure over from England, reported a series of 31 cases. Dr. Overhalt states that pleurolysis is not a therapy introduced to replace a selective thoracoplasty. It should only be used after intrapleural pneumothorax has been unsuccessfully tried and thoracoplasty is contra-indicated. (56)

Thus, after an attempted pneumothorax had failed the possibility for doing thoracoplasty must be evaluated. In the cases of Overhalt and Tubbs thoracoplasty was contraindicated because of the following factors:

A. Lesions were too active.
    1. Toxic appearance
    2. Fever
    3. Rapid sedimentation rate
    4. White count favoring marked activity
    5. Serial x-rays showed extension of an exudative lesion with cavitation.

This type of lesion occurred most frequently in young patients in their teens or early twenties in whom intrapleural pneumothorax was impossible.

B. Patients with extensive bilateral fibro-cavernous lesions.

1. Selective thoracoplasty would be too long and hazardous, requiring the revmoal of the upper six ribs on both sides

C. Factors complicating the pulmonary tuberculosis

1. Inefficient cardio-vascular reserve
2. General emphysema
3. Asthma

In patients with extensive bilateral cavitation the removal of the upper six ribs in thoracoplasty would be too severe. Selective pleurolysis solves this problem. (56)

Technique of Extra Pleural Pneumothorax

The parietal pleura is attached to the endothoracic fascia by a loose layer of easily disrupted connective tissue. It is in this plane that blunt dissection is performed. (4)

1. Cyclopropane anasthesia is used. (56) Local anasthesia may be sufficient. Graf and Schmidt use it entirely in Germany. American surgeons prefer general anesthesia because it facilitates control of intra thoracic pressure, permits enlargement of the approach at a moments notice, and aids in the suction of secretions from the air passages. (4)

2. A curved 8 inch incision is made parallel to the vertebral border of the scapula with its mid-point over the 4th rib. (56)
3. 2-4 inches of the 4th rib are resected laterally from the transverse process. (4) (56)
4. The periosteum is incised and the extrapleural fascia plane is identified - usually by the presence of some fat. (56)
5. The pleural layer is stripped from the thoracic wall, locally under direct vision, with the finger. (4)
6. Introduce an illuminated retractor and bluntly dissect away the entire pleura either with the finger or with a blunt instrument. All adhesions should be cut. (56)
7. Extend the dissection two segments below the lowest radiological evidence of disease. (56)
8. Hemostosis is obtained by compression (56) or by electro coagulation.(4)
9. Irrigate the cavity with normal saline.(56)
10. Make an air tight closure by using a flap from the serratus posterior superior muscle.
11. Overhalt and Belsey agree on an immediate injection of air into the space until the monometer fluctuates through zero. (56) (4)

Belsey (4) advises the second refill on the first post-operative day, increasing the interval by one day thereafter until in a well established case 2-3 week intervals may be sufficient.

The Post-Operative Care of Overholt

1. Oxygen and intravenous fluids are rarely necessary. The latter is used if the systolic blood pressure goes below 80 mm.
2. Assume the sitting position as soon as possible to avoid the formation of adhering blood clots.
3. Usually there is very little after pain. As an analgesic use Dilaudid gr. 1/32 to 1/48 in the evening. This may be repeated for the first 48 hours.
4. Interstitial emphysema is common during the first 24 hours and is insignificant except for tenderness.
5. Cough should be controlled with codine.
6. After 36 hours expectoration is more efficient than following thoracoplasty.
7. On the second day inject air until the monometer oscillates through zero from plus 6 to minus 6; 100 to 400 cc. are required.

8. Subsequent refills on the second, fourth, sixth, ninth and twelfth days. 50-75 cc. are required to produce oscillations of plus 4 to minus 4.
9. The refill interval should increase until 25 to 50 cc are sufficient every two weeks.
10. High positive pressures should not be used to force the extent of collapse because bronchial fistulae may be produced.
11. The presence of an exudate may be advantageous. It may form a rigid, fibrous covering over the collapsed lung. If present in great quantities the fluid should be aspirated and replaced with air.
12. Atelectasis of the lower lobe is unknown. (56)

Complications encountered in this procedure may be divided into those of the immediate operation and post operative complications. Operative complications are: (4)

1. Puncture of the pleura.
2. Injury to the mediastinal vessels.
3. Hemorrhage - either visceral or parietal
4. Severing of dense adhesions between the

pleura and the extra pleural fascia.

Post Operative Complications:

1. Hemothorax - the space becomes filled with blood clots. They should be aspirated through a trocar and this followed by saline irrigations. (56)
2. Effusion into the extra pleural space - of no significance unless extensive. (4)
3. Infection of the extra-pleural space. This usually occurs as a result of a bronchial fistula and should be treated by aspiration and irrigation. (56)
4. Broncho-extrapleural fistula. This inevitably occurs when a large cavity is located near the periphery of the lung. Dissecting away the pleura severs the parietal blood supply of the lateral cavity wall. This area is prone to necrose. (56)
5. Obliteration of the extra-pleural space. This may be avoided by frequent refills and the proper care of effusions. (4) (56)
6. Contraction of the released pleura due to fibrosis. The collapse becomes less complete. (4)

7. In all the cases reviews by Belsey only moderate shock and poast-operative collapse occurred. (4)

Dr. Jones presents 25 cases on whom pleurolysis was done. Only one complication occurred - tuberculous infection of the extrapleural sac. (13) The etiology of such is questionable. Newton operated a febrile case using pleurolysis. In dissecting the pleura from the thoracic wall he encountered lymph spaces containing one-half teaspoonful of white fluid. This was associated with edema and gluing together of the tissues. The envolvement was more pronounced on the mediastinal side. Tuberculous empyema could have its origin from such a lymphatic envolvement. (55)

Jones suggests an initial injection of 300 to 400 cc. of normal salint instead of air. The weight of the fluid aids in collapse, the cavity is easier to find later on and in case aspiration becomes necessary the diluted blood is easier to aspirate. (13)

Results

Extrapleural pneumothorax is entirely too recent

a procedure for the proper evaluation of results at this time. In 40 cases operated by Roberts and Churchill the results are as follows:

1. In 12 early cases where pneumothorax had failed the cavities are all closed and the clinical condition in all is improved.
2. In 28 cases unsuitable for thoracoplasty, 17 improved clinically and in 13 the cavities are closed. Two died and three operations were abandoned.

These cases have been observed about two years. (4). Overholt and Tubbs make no attempt to evaluate the results in their 31 cases. (56)

Just what to do with the extrapleural cavity following arrest has not been determined. However, four alternatives present themselves: (56)

1. Maintain the cavity.
2. Make collapse permanent with thoracoplasty.
3. Allow reexpansion of the lung.
4. Replace the air with sterile oil.

The procedure will be determined by time and experience.

Prognosis for Pleurolysis

Pleurolysis will definitely replace extrapleural

pneumonolysis with plumbage-oleothorax, etc. With air the extent of collapse can be controlled. Air does not tend to perforate the lung or act as a foreign body. Collapse is more complete with air. Wax acts in a reverse manner. (15)

As all new procedures this one is likely to be abused. It will, no doubt, be used many times in place of other procedures. At present it is being abused in Europe. (13) Never should it be used in lieu of intrapleural pneumothorax or thoracoplasty. (4) (13) (56) Never should pleuralysis supplant a selective thoracoplasty. (4) (13) (56) Insufficient experience with the procedure probably is responsible for this universal conception in America. Overholt does state that since thoracoplasty results are so satisfactory in the eight cases that pleurolysis should not be substituted unless further experience shows as good results with less risk to the patient. (56)

It will find its greatest uses in:

1. Extensive bilateral disease when selective collapse and intrapleural pneumothorax are impossible.
2. Less extensive but more active disease where

> pneumothorax is impossible or inadequate, diaphragmatic paralysis is inadequate and thoracoplasty is contraindicated or too risky. (56)

Thus, at present this procedure fills a definite gap in the treatment of pulmonary tuberculosis with which we were unable to cope. It fills in the "missing link" therapeutically of a very definitely limited group of cases. Those cases, briefly, are those in which intrapleural pneumothorax is impossible and at the same time thoracoplasty is contraindicated or too risky. Within this restricted group the procedure is invaluable.

From a more or less superficial view point it seems possible that pleuralysis may some day replace thoracoplasty. The men who have used the procedure are thoracic surgeons "que nou". Naturally, they should be reluctant to give up a procedure with which they are familiar for one so new and untried. Wisely they are waiting for results. Should these results be favorable extrapleural pneumothorax may some day supplant thoracoplasty.

Although seemingly simple, neither the operation nor the post-operative management is simple. (4)

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