

Continuous Immobilization of the Lungs by Residence in the Equalizing Pressure Chamber in the Treatment of Pulmonary Tuberculosis*

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Studies on the physiology of respiration have resulted in profound modifications of the breathing pattern of man in various pulmonary diseases. When dyspnea is due to lack of oxygen, inhalation of oxygen-enriched atmospheres results in relief of dyspnea due to diminution in the volume of breathing. In clinical entities characterized by respiratory obstruction the inhalation of helium with oxygen is responsible for a decreased physical effort although the total volume of ventilation may be unchanged. Similarly, the physical effort of breathing is decreased in obstructive dyspnea when atmospheres are inhaled under positive pressure. Cessation of all chest movement may be produced by hyperventilation with 100 per cent oxygen, after which the normal individual may show arrest of lung movement for periods as long as five minutes without cyanosis or discomfort. The chemical regulation of breathing depends on an adequate exchange of oxygen and carbon dioxide between the pulmonary capillaries and the outside air.

In 1926 Thunberg¹ constructed the barospirator in which an alternating pressure of one-sixth of an atmosphere was produced 25 times a minute. A person enclosed in a chamber of this type obtained an adequate pulmonary ventilation. The device was used to maintain artificial respiration in patients with polio-myelitis in whom respiratory paralysis had taken place. The principle of the method depends on the physical law that the number of gas molecules in a container, with the volume and temperature constant, varies with the degree of pressure to which the gas is exposed. If the lungs contain 3000 cc. at the end of a normal expiration, an increase of pressure of one-sixth of an atmosphere would result in an increase in the number of gas molecules present in them equivalent to the inlet of 500 cc. of air. When the pressure wave

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is reversed, with a decrease in pressure of one-sixth of an atmosphere, a corresponding decrease in the number of molecules in the lung takes place comparable to expiration. Although slight chest movement may be observed in normal subjects, our studies indicated that the walls of the thoracic cage were flexible and that an initial compression was observed when the positive pressure wave was applied to the thorax and conversely a slight expansion of the chest during the negative phase.

When patients with pulmonary disease were studied, alternating pressure by itself resulted in a variable compression and expansion of the chest depending upon the degree of constriction of the passageway between the nose and the pulmonary alveoli. In patients with asthma and pulmonary emphysema the effect of alternating pressure was a marked increase and decrease in the volume of the chest. It was also observed that expansion of the chest took place during the negative phase of pressure, during which time the influence of the rarefaction of air was toward the elimination of air from the lungs. In other words, in cases with constriction in the bronchial passageway the inspiratory cycle was expanding the lungs at a time when an opposite influence was being exerted, i.e., withdrawing air from the lungs.

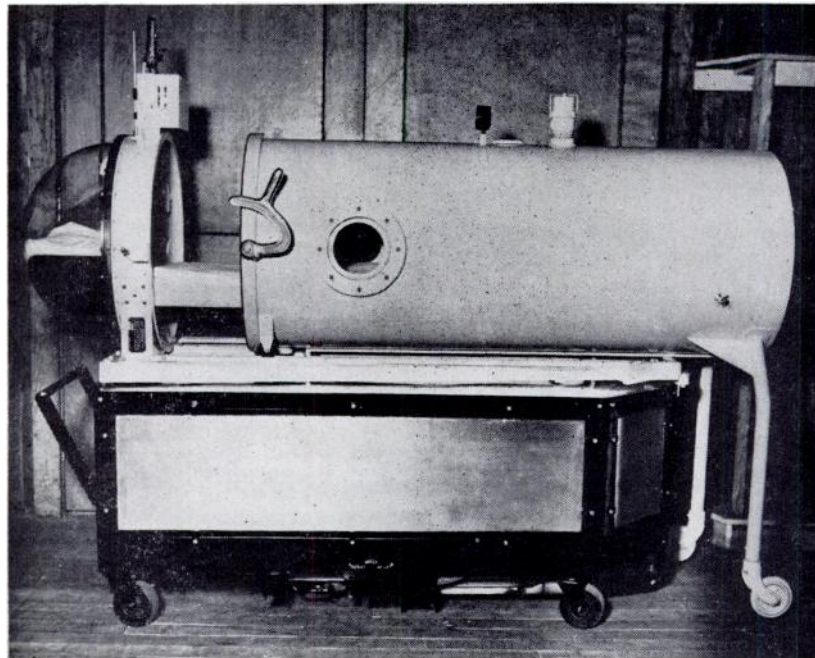


FIGURE 1
Equalizing pressure chamber with ventilation and air-conditioning apparatus suspended under the body compartment.

Since the air which enters the lungs swiftly builds up a pressure on the inner surface of the chest and on the upper surface of the diaphragm, a certain time interval was necessary to equalize the pressure on both sides of the chest wall. Furthermore, the resistance in the tracheo-bronchial tree was observed to consume about 5 cm. of water pressure. In the first chamber of this type the patient was placed in a chamber within a chamber and the air was passed through small holes in the inner chamber so that the total pressure arriving on the external surface of the chest wall was 5 cm. less than that which entered the head compartment and arrived at a fraction of a second later in time.^{2,3,4,5} Subsequently

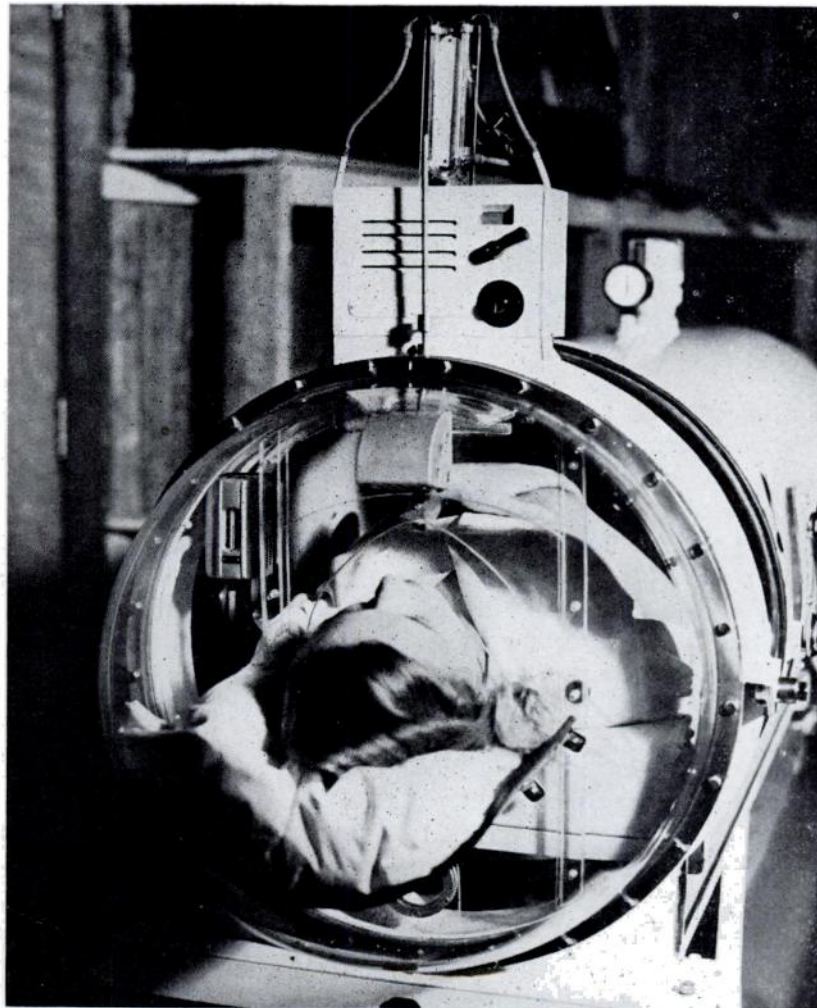


FIGURE 2

Transparent plastic hood on the equalizing pressure chamber.

a suitable chamber was used in which the air pressure wave entered the head end of the chamber first and then passed through a moveable partition surrounding the neck of the patient into the body end. In this chamber (Figs. 1 and 2) the patient is completely enclosed, the pressure wave arriving in the head compartment and then, momentarily delayed and slightly decreased in total pressure arrives at the body compartment.

It was soon found that patients not only were able to reside comfortably in the chamber without chest movement, but also that they were able to hold their breath for indefinite periods of time. When these patients were exposed to alternating pressure alone the impulse to breathe recurred after variable periods. Furthermore, in experimental respiratory paralysis in dogs, it was shown that alternating pressure alone did not maintain a normal arterial oxygen saturation and CO_2 tension. A progressive increase in anoxia and retention of CO_2 in the blood took place until equalizing pressure was added, when an increase of oxygen and decrease of CO_2 was produced. Previous studies^{2,3,4,5,6,7,8,9} indicated that equalizing pressure therapy was not only, therefore, more efficient in maintaining a chemo-respiratory exchange, but also was required to produce continuous arrest of chest movement. When immobilization of the lungs has been produced in the trained subject, an increase in the rate of cycling may wash out carbon dioxide beyond that required. In the cases treated in our series spontaneous breathing asserts itself within 10 to 15 seconds after the patient has discontinued equalizing pressure therapy. In many instances, spontaneous breathing begins immediately. In no case has there been symptoms of alkalosis. Residence in the immobilizing pressure chamber, therefore, provides a form of lung rest which is not obtainable in any other way. From the known experience in healing of pulmonary tuberculosis, the treatment, such as is made possible by equalizing pressure chamber therapy, would appear to be physiologically sound.

METHODS

When the chamber is opened the patient reclines and pulls his head through the aperture between the body and head compartment. The neck is surrounded by a soft towel and the partition lowered to approximately 1 cm. from the neck. The alternating pressure motor is then turned on and the gauge is observed to determine whether a pressure of 53 to 55 mm. Hg is present. The water manometer is then inspected and if a pressure of plus 5 cm. H_2O is indicated, the patient is observed to see whether any gross movement of the chest wall is present. When the pressure is initially found to be other than 5 cm. the partition is moved up and

down until the water level in the manometer arrives during the positive cycle to a point 2.5 cm. above the level of the atmosphere. (This is generally marked on the water manometer as 5 cm., since an equal and opposite excursion takes place on the other arm of the manometer).

The pressure is thus slightly higher as it arrives in the nose or mouth, also earlier in time than that which exerts itself on the chest wall and abdomen. Since this decrease of pressure applied to the chest wall is ultimately made equal to that which is consumed in the respiratory passageway, a comparable pressure is maintained on both sides of the thorax, and on the upper and lower surfaces of the diaphragm simultaneously. No movement of the chest wall should take place in patients who have learned to arrest their breathing. Minimal alterations in volume of the lungs may occur, but these are obviously of exceedingly small degree when compared to the chest expansion and contraction in ordinary respiration. It should be understood that the lungs are not compressed any more than they would be in an individual swiftly ascending to an altitude 1400 feet above sea level. There is alternate compression and rarefaction of the air within the respiratory system, which achieves an inflow and outflow of approximately 500 cc. of air.

The actual introduction of the patient into the technique of arresting lung movement is of considerable importance. The patient is dressed lightly so that his chest is exposed when he is in the machine. The exact alternating pressure used may vary but a rate of 28 times a minute with an alternating pressure of 52 to 54 mm. Hg is generally best suited to the average patient. The dial on the body end of the chamber reveals the *alternating* pressure, which can be modified by a control in the box containing the motor blower unit. The partition, which is raised or lowered from the outside until a +5 cm. water pressure is indicated on the manometer, regulates the equalizing pressure.

At the start the patient is told, through the connecting phone, to take a breath each time the pressure turns to the positive phase. This is conveniently done by raising the hand as the pressure starts toward the positive phase, as revealed by the dial; it may also be revealed to the patient by a colored ribbon attached to the head end of the chamber. In other words, when the hand is elevated the patient takes a small breath and when it is lowered the patient exhales slightly for three or four breaths. When the ribbon is attached to the head end of the chamber the patient is instructed to take a small breath when the ribbon is thrown upward and to exhale when the ribbon comes down. After he has breathed in this fashion, i.e., *with the machine*, he is instructed

to draw in less and less air until he takes in none at all. It will then be found that he will be able to stop breathing perhaps for two or three minutes. In some cases it is equally effective to tell the patient simply to take three or four breaths and then stop breathing after a normal expiration.

If the patient begins to breathe, he may find himself inhaling when the negative pressure phase is present. This is undesirable since he will be then expanding his lungs at a time when the air will be rarefied and therefore coming out of his lungs. The patient may or may not be aware that he is not breathing with the machine. He is then instructed by the nurse or technician, or doctor, to start again and breathe at first with the rhythm of the machine, i.e., taking a small breath when the ribbon goes upward for two or three times and then ceasing to breathe again. After a variable period, in some cases several hours, in others three or four days, the patient learns to arrest all movement and the chest becomes quieter and quieter until little or no chest movement is seen.

In individuals who have a full abdomen a slight quivering of the abdomen is observed due to alternate compression and expansion of the gas in the intestine as the pressure changes from positive to negative. This does not mean that diaphragmatic movement is present because pressure on the abdomen is transmitted to the undersurface of the diaphragm and is there met by an opposing pressure coming in from the nasal passage.

The sensation on the eardrums is that of going up and down in an elevator and this is perceived by patients at first with slight discomfort, but gradually the patients themselves become oblivious of the alternating pressure effect on the eardrums. In some cases pain will be experienced and the treatment may then be stopped for a day or two and then continued. In no instance has it been necessary to terminate treatment because of the effect of oscillating pressure on the eardrum. A radio-phone or rubber earpiece is used by some patients. A pressure effect on the sinuses may be felt due to the fact that the orifices between the nasal cavity and the various accessory sinuses are not always patent. In some cases congestion of the sinuses and a feeling of stuffiness of the nose may be present for several days. This may be dealt with by spraying the nose with $\frac{1}{4}$ per cent neosynephrine or half strength privine in the morning before going into the chamber and in the afternoon as well. The treatment itself may be stopped for a day, or two or three days, if the congestion in the sinuses persists and then chamber treatment again instituted. In none of 12 patients who have been treated for periods of four months at a time, some of them for two courses, has either the pressure effect on the sinuses or eardrums resulted in cessation of immobilizing therapy.

The length of a course of treatment has been arbitrarily set at three and one-half to four months since in many of the cases treated substantial improvement took place by this time. Longer courses of therapy may be desirable in certain patients since relapse has taken place in some patients who have stopped treatment at the end of this time and necessitated a second course. The duration of treatment is the major part of the day, such as from 9 to 1 in the morning, 2 to 6 in the afternoon and 7 to 9:30 in the evening. In the patients who responded favorably, 8 to 11 hours a day of immobilizing lung therapy has been used. In the majority of patients, although not in all, no treatment was given on Sunday. This interruption of treatment for one day a week is theoretically less desirable than continued treatment. However, some of the patients that have done well have had treatment only 6 days a week. In some cases this has been due to the inability to provide supervision on Sundays. Some of the patients have expressed a desire to be treated every day without interruption.

Patients may cough in the chamber in a suitable receptacle. The effect of absence of lung movement is to decrease the impulse to cough and in some cases, after the first three or four weeks of treatment, there has been x-ray evidence of puddling of the secretions with slight increase in infiltration suggesting a small area of atelectasis. It may be an improvement in technique to ask these patients to cough three times a day when they are taken out for meals.

The cooperation of the patient is in our experience invariably obtained as soon as he has learned to arrest all spontaneous lung movement. The restlessness which patients frequently have during routine rest in bed is apt to disappear as soon as ventilation of the lungs takes place without effort or chest movement. Patients are not generally bored; they do not require anyone to read to them, nor do they usually demand entertainment in other ways. It is possible for them to listen to a radio if they wish. The feeling of relaxation is such that voluntary movements of the extremities, so common in ordinary bed rest are few and far between in patients treated in the equalizing pressure chamber. Furthermore, even in those people in whom smoking has become an urgent habit, the desire to smoke is not present when breathing is accomplished by the machine and not by chest movement.

The patient himself very frequently gains confidence and encouragement from the fact that he can feel his chest with his hands and determine that his lungs are not moving. Since he has been taught that rest is a healing therapy in the disease, the fact that he can immobilize his own lungs often gives him new hope that something more profoundly curative is being done than the

ordinary bed rest to which he has been previously exposed. This is especially true in many of the chamber treated patients who had previously witnessed their disease getting worse, even with as much body rest as they were able to obtain.

CLINICAL RESULTS

In this communication the clinical results of 11 cases previously reported in part will be reviewed and an additional case very recently treated will be presented.

Of the 11 cases treated in the equalizing pressure chamber the first case was in the chamber for a period of approximately two months, 5 hours a day. Although slight improvement was evident, this was not maintained after discharge from the hospital. The second patient was treated for a period of three and one-half months and following this course obtained a full clinical recovery. The accompanying x-ray photograph (fig. 3) shows the degree of clearing that took place before and 17 months after treatment. Sufficient clearing had taken place at the end of three months to warrant the assumption that continued improvement might occur. This patient has had negative sputa for six years and with the exception of one period of three months bed rest has been at work. He has been more fully described as Case 1 in an earlier publication.⁸ Another patient who was treated with a single course of three and one-half months therapy was apparently free from disease at a city hospital subsequently. Although numerous sputum tests have been negative the appearance of a single positive test led to pneumothorax therapy which was soon abandoned. His follow-up observation for a period of one year did not reveal re-

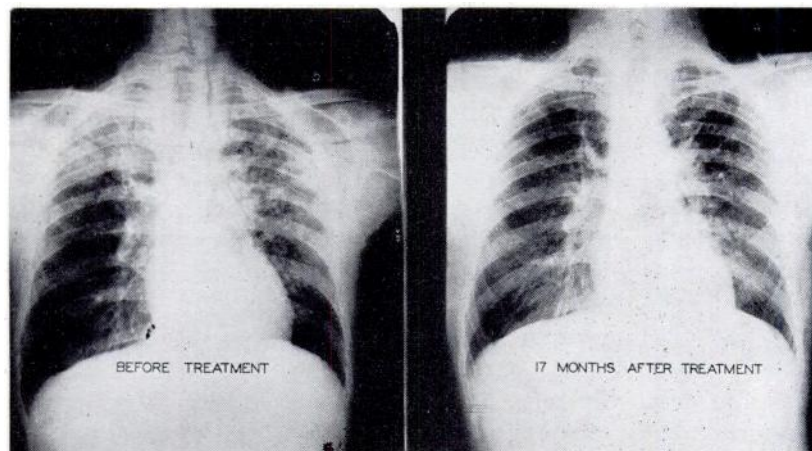


FIGURE 3

X-ray before and 17 months after one course of treatment in Case 2.

currence of the disease (Fig. 4). (Case 3 in an earlier publication⁸).

There were two patients who had two separate courses of treatment before clinical recovery took place. In the first one (Fig. 5) the follow-up results have been carefully observed for a period of 4 years, the patient being at work in our hospital, sputum tests having been consistently negative. (Case 5 in an earlier publication⁸). In the second case that was treated for two separate courses, the follow-up observation included one year during which sputum tests were negative (Fig. 6). (Case 9 in reference 8).

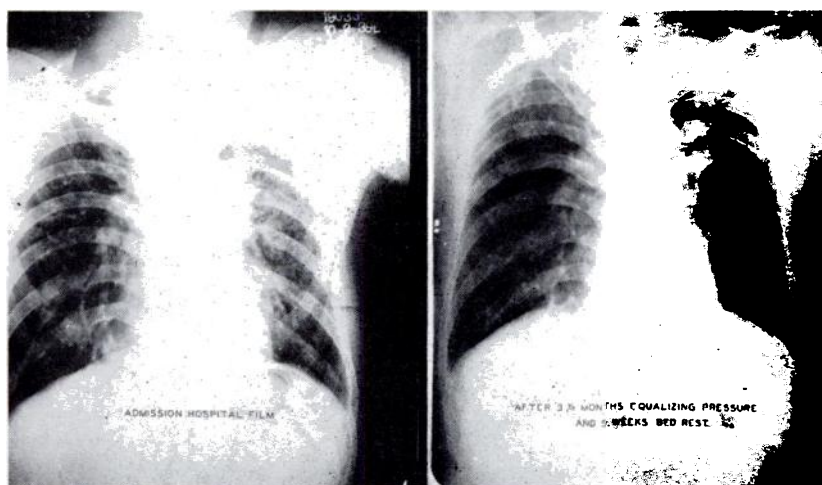


FIGURE 4
X-ray before and after one course of treatment.

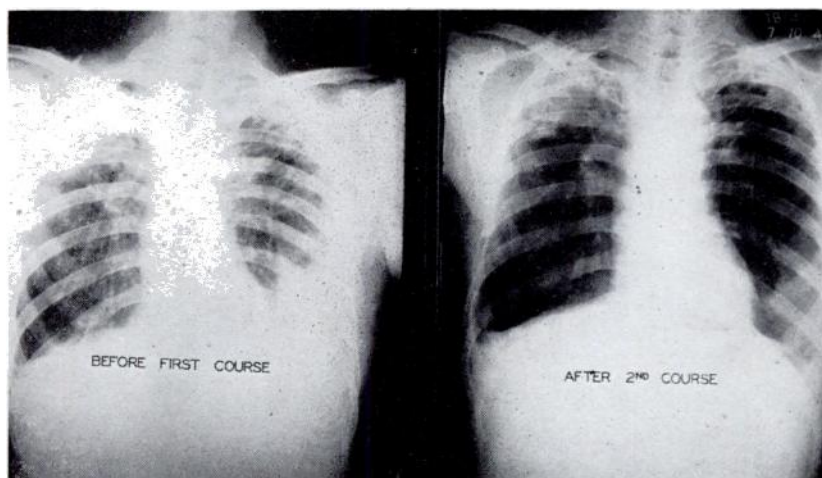


FIGURE 5
X-ray before and after two courses.

The sixth patient of this series, the third who had received two courses of therapy, revealed a collapse of cavity on each course and following his last treatment has had negative sputum tests for three and one-half years. At the site of the original cavity there is now a suspicious highlight that suggests either a cavity or an area of emphysema. He is considered as markedly improved, although not a completely arrested case. The accompanying illustration indicates the condition before the first treatment and after the second treatment (Fig. 7). (Case 4 in reference 8).

One of the recovered cases was treated in three separate courses

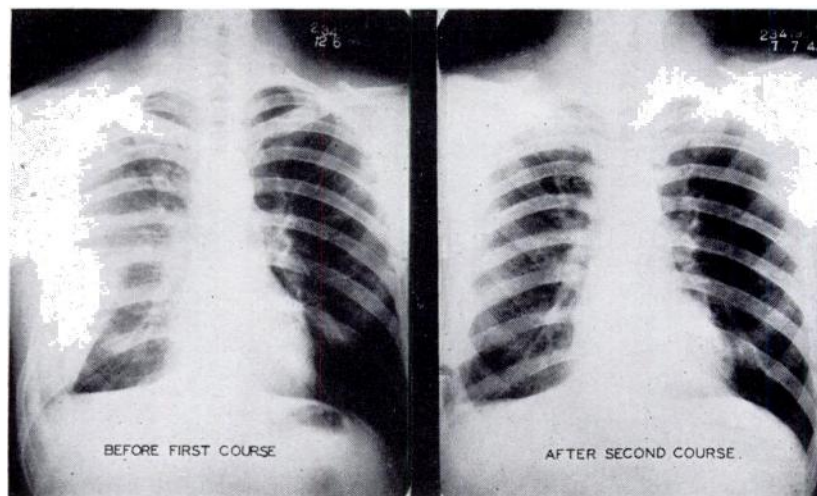


FIGURE 6
X-ray before and after two courses.

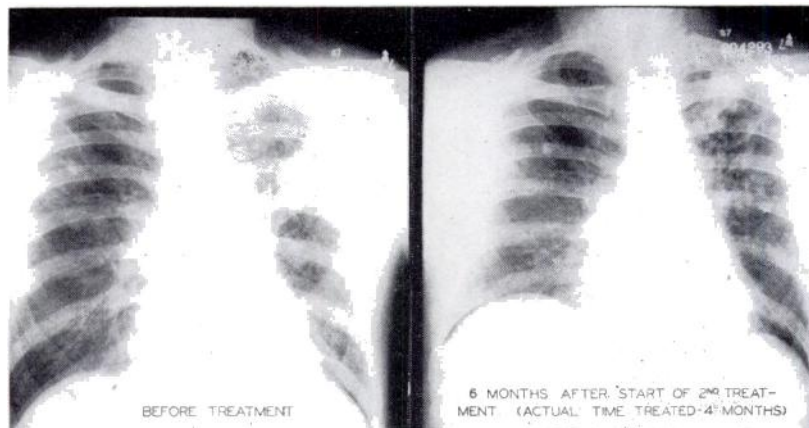


FIGURE 7
X-ray before treatment and 6 months after start of second treatment (actual time treated, 4 months).

and each time closure of cavity was demonstrated. (Case 2 in earlier publication⁸). In the accompanying illustration (Fig. 8) the x-ray picture before treatment and after the third course is shown. In figure 9 the planigraphic film of the cavity before and after 11 weeks of the second course is shown. In this patient during a follow-up period of four years there were consistently negative sputum tests during a time when he was actually engaged in work. Of the remaining cases, three manifested slight to moderate improvement which was not maintained after treatment was terminated (Cases 7, 8 and 9). There were two cases that showed no change as the result of immobilizing pressure treatment. In one of them it was thought that the cavities were adherent to the chest wall. In the other patient a tendency to fall asleep and to assume spontaneous breathing was often noted.

Results of Immobilization of the Lungs in Bilateral Advanced or Moderately Advanced Pulmonary Tuberculosis

	No. of Cases	Clinical Recovery	Marked Improvement	Slight to Moderate Temporary Benefit	No Change
Treated with One Course	8	3	..	3	2
Treated with Two Courses	3	2	1
Treated with Three Courses	1	1
TOTAL	12	6	1	3	2

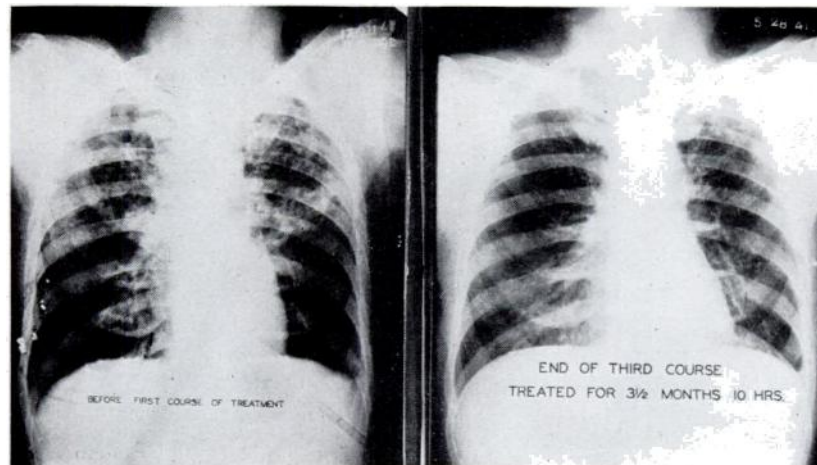


FIGURE 8

X-ray before first and after third course of treatment.

The summary of the cases above briefly reported may be stated as follows: Immobilizing pressure therapy was of no benefit in 2; of slightly moderate benefit of a temporary nature in 3; and of marked benefit in 5, 4 of whom obtained a clinical recovery. The most recent case treated will now be presented.

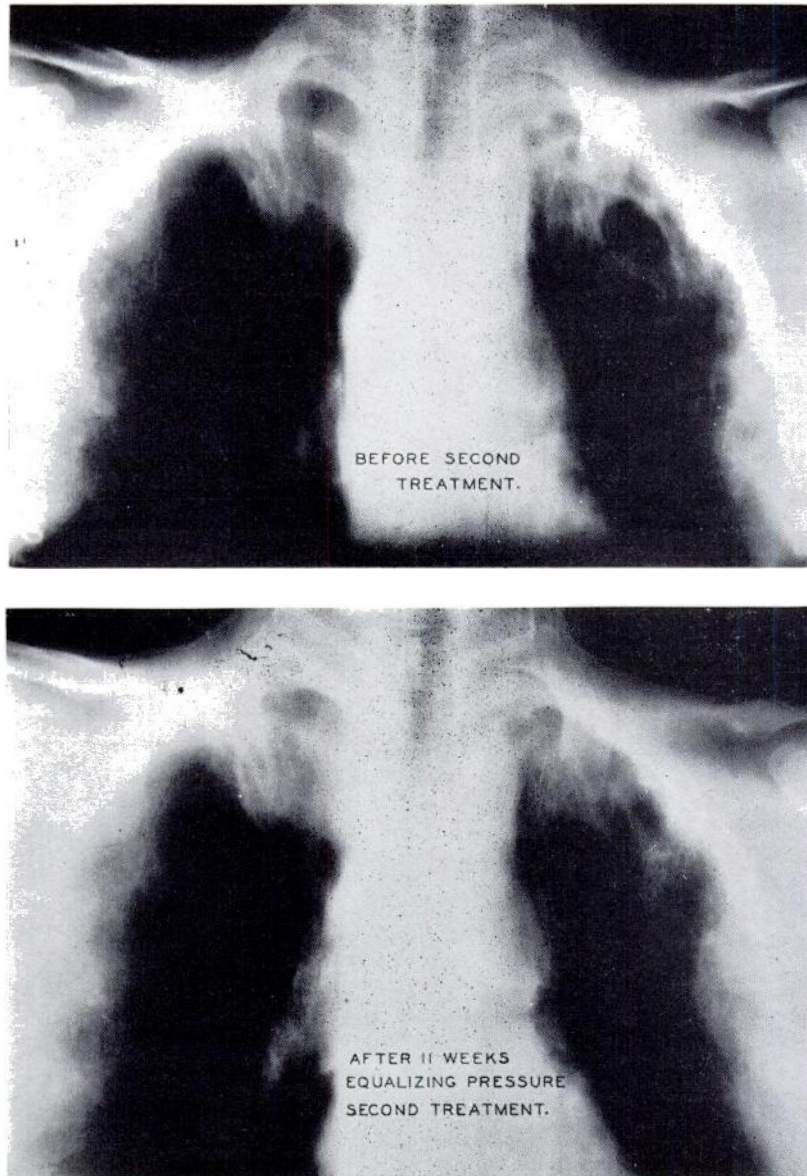


FIGURE 9

Planigraphic x-ray before and after 11 weeks treatment
in the second course.

CASE REPORT

Case 12: A man, 49 years of age developed active pulmonary tuberculosis with positive sputum following an attack of apparent bronchitis that lasted two months. Six years previously the patient had suffered from hemoptysis and a low grade fever for two months. At that time the sputum was consistently negative, but x-ray examination of the chest disclosed a dense, productive and apparently calcified lesion in the right upper lobe. Physical examination of the lungs was now essentially negative except for dullness at the right apex. X-ray showed an increase in the width of the involved area. The sedimentation rate was 50 mm. after 1 hour. Repeated sputum tests were positive. For a year following the diagnosis of pulmonary tuberculosis he was treated with strict bed rest. During the succeeding six months he was allowed very slight activity, such as sitting up two hours in the afternoon and one to two hours in the evening and allowed to walk 50 to 100 steps twice a day. At the end of this time, following a cold and an apparent bronchitis, he developed increasing symptoms and x-ray showed a spread of the disease to the right hilum and right base. The sputum then showed a hemolytic streptococcus on culture and he was treated with 7 injections of 300,000 units of penicillin in beeswax with marked improvement in cough and decrease in sputum. However, during the following year as well as for the six months prior to this time the patients' sputum tests were un-failingly positive each week. Complete bed rest was re-instituted and slight improvement in the x-ray was observed without, however, the development of negative sputum.

At the end of approximately two years of active pulmonary tuberculosis and six months after the spread of the disease from the right upper lobe to the right hilum and right lower lobe, the patient was started on equalizing pressure chamber treatment at home 8 hours a day. In two and one-half weeks the sputum became negative; the concentrate sputum test continued to be negative during the following three months on 12 of 16 examinations. Sputum culture was negative

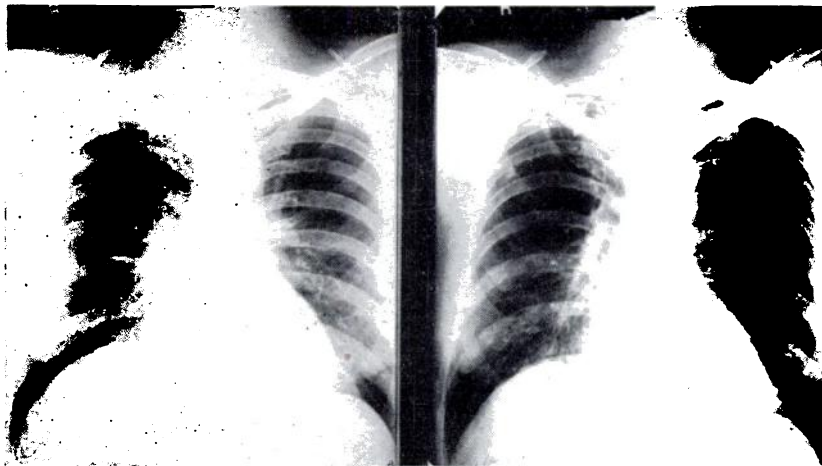


FIGURE 10

Decrease in infiltration in left hilum, left apex and base after two months immobilizing pressure therapy.

for tubercle bacilli. At the end of two months there was marked improvement in the x-ray as shown in the accompanying photograph (Fig. 10), in which it will be seen that there was contraction of the area at the right apex and marked clearing of the infiltrate between the right border of the heart and the bronchial markings, as well as at the right base. The patient had a hiccoughing episode for a period of 12 hours and for four days thereafter the sedimentation rate and fever were slightly elevated. The total period of treatment was approximately two and one-half months. The patient is now undergoing convalescent care and continues to have negative sputum tests. Although it is too early to decide whether this patient will obtain a complete clinical recovery and permanent arrest of the disease, the response to immobilization of the lungs by residence in the equalizing pressure chamber was swift and dramatic in terms of prompt termination of positive sputum tests, decrease in cough, increase in well being and clearing of lesions by x-ray.

Considerable difficulty was encountered in this patient during the first four days in learning to arrest spontaneous movement of the chest. He had no ear symptoms that bothered him, but he did manifest throughout most of the treatment a stuffiness in his nose and a mucoid discharge from the sinuses. When he was out of the chamber for two or three days this subsided, but recurred during chamber treatment.

It was of interest that after the first full week of treatment the temperature dropped from a range of between 97.6 and 99° F to 96.4 and 98° F. There was a decrease in pulse rate from a range of 78 to 88 to 46 to 60. Since this patient was already well nourished, dietary precautions prevented an undue gain in weight. It may be mentioned at this point that some of the patients previously treated, such as Case 2 of this series, showed a marked gain in weight as the sedimentation rate came to normal, even though there had been no prior weight gain on bed rest. In the accompanying chart (Fig. 11) the gain of weight is shown in Case 1, from 124 pounds to 156 pounds during three and one-half months of treatment.

In a recent analysis of the cases referred to in this series it was pointed out that collapse of cavity was shown to be a specific result of immobilizing therapy in three patients. In the man who had three separate courses of therapy closure of the cavity in the right lung followed the first course of treatment with diminution of the cavities in the left lung. On bed rest the cavities in the left lung subsequently coalesced and formed one large cavity that was closed after the second course of treatment. When the patient returned one year later the cavity had re-expanded and again was shown to collapse after the third course of immobilizing lung therapy with subsequent clinical recovery. In a second case (Case 6 of this series), a large cavity in the left upper lobe closed after four months treatment and reopened and expanded to its original

size subsequently during 5 months of ordinary rest in bed at a municipal hospital. The second course of treatment resulted in closure with the apparent formation of a fibrous scar at the site of the original cavity. In an additional patient, labeled as moderate but temporary improvement, a large cavity in the left upper lobe collapsed during treatment, but expanded to its original size two weeks later on marked activity.

The appraisal of a new remedy in the treatment of pulmonary tuberculosis is fraught with obvious difficulty. In the series of advanced bilateral and moderately advanced cases here presented the conclusion was reached that local lung rest as provided by the equalizing pressure chamber does initiate healing and results in collapse of cavity in some cases that are unresponsive to previous methods of treatment. Further investigation is required to determine the ultimate value in this type of case as well as in earlier forms of the disease that have not been investigated.

In two earlier studies of comparable cases of advanced or moderately advanced pulmonary tuberculosis treated by continuous residence in an oxygen chamber¹⁰ and by residence in a filtered air room,¹¹ the criteria for selection, the source of material and the type of food and nursing care were the same as in this series. Nevertheless, neither clinical recovery nor marked improvement took place in either of these groups, who represent control cases insofar as it is possible to control medical management, hospital

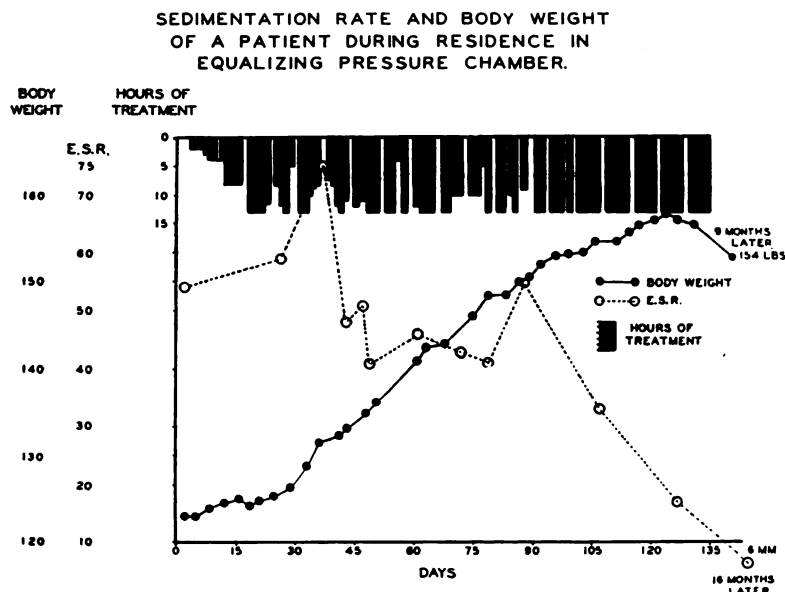


FIGURE 11
Sedimentation rate and body weight of a patient during
residence in the equalizing pressure chamber.

routine and nature of the disease. In a comparable period of time, a characteristic therapeutic response was observed in the majority of the cases treated by immobilization of both lungs.

SUMMARY AND CONCLUSIONS

The results of 11 previously treated cases of bilateral advanced or moderately advanced pulmonary tuberculosis have been reviewed and a case history of a patient recently treated has been presented.

Of the 12 cases, 6 obtained a clinical recovery, including the recent case with a short follow-up period of observation.

In one patient three courses of approximately three and one-half to four months each were given, in three other cases, 2 courses of treatment were given and in the remaining 8 cases a single course of therapy was employed.

The provision of local lung rest by residence in the immobilizing pressure chamber promotes the process of healing and closure of cavity in some cases of advanced and moderately advanced pulmonary tuberculosis. This favorable response has been observed in cases for whom no other form of treatment was possible or who had been exposed to other types of tuberculosis therapy without benefit. In comparable groups of cases under the same medical management and in the same hospital, treated either with residence in an oxygen chamber or in a filtered air room, no such therapeutic benefit was observed.

RESUMEN Y CONCLUSIONES

Se repasan los resultados obtenidos en 11 casos de tuberculosis pulmonar bilateral, avanzada o moderadamente avanzada, previamente tratados, y se presenta el protocolo de un enfermo recientemente tratado.

De los 12 casos 6 se repusieron clínicamente, inclusive del caso reciente que sólo cuenta con un corto período de observación.

Un enfermo recibió tres series terapéuticas, aproximadamente de tres y medio a cuatro meses cada una; tres casos recibieron 2 series, y los otros 8 casos una sola serie.

El descanso local del pulmón, proporcionado por la permanencia en una cámara inmovilizadora de la presión, estimula el proceso de cicatrización y el cierre de cavernas en algunos casos de tuberculosis pulmonar avanzada o moderadamente avanzada. Se ha observado este efecto favorable en casos a los que no les podía aplicar ningún otro tratamiento o que habían sido sometidos a otros tratamientos sin beneficio alguno. En grupos comparables de casos, bajo la misma atención médica y en el mismo hospital, tratados mediante la permanencia en una cámara de oxígeno o en un cuarte de aire filtrado, no se observó un beneficio terapéutico semejante.

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Discussion

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Dr. Marach to-day is introducing to us a new approach in the treatment of pulmonary tuberculosis. It is a physiologic approach. It aims to induce local rest in an organ which heretofore could not be immobilized without serious consequences. If the lung stops functioning, oxidation is disturbed and death results. Doctor Barach's chamber by utilizing a fundamental law of physics produces oxygen carbon dioxide exchange without the necessity of expansion or contraction of the lung. It splints the lung without disturbing normal physiologic processes. It is the first time that any one has been able to completely immobilize the lung without hazard.

Rest is the fundamental basis in the treatment of disease and especially tuberculosis. Until some means is found to act directly on the tubercle bacillus and the mechanism in the host that makes him susceptible to clinical tuberculosis, all of us must utilize rest in some form or other to treat our patients who have clinical tuberculosis.