Treatment of Tension Cavities with Pneumothorax

I. D. BOBROWITZ, M.D., F.C.C.P.*
Otisville, New York

Various authors1-5 from clinical, roentgen, contrast substance or necropsy studies have emphasized that the essential condition in the healing of tuberculosis cavities consisted in the closure of the draining bronchi. Pinner6 stated that bronchial occlusion might be one method of healing cavities, but that it was not the only possible mechanism. He showed an open bronchus running into the scar of a closed cavity.

It is agreed that cavity closure can occur with the draining bronchus closed or open but not when partial bronchial obstruction causes a valve mechanism. The valvular bronchial obstruction can be due to changes within the lumen of the bronchus (caseous material, tenacious secretion or mucopurulent exudate), the bronchial wall (mucosal edema, tuberculous inflammation, ulceration, or hyperplastic infiltration, caseous bronchitis, fibrostenosis, or peribronchial fibrosis), or extra bronchial conditions (lymph node pressure). Under these conditions, with inspiratory dilatation of the bronchi, air enters the cavity and with expiratory contraction of the bronchi less air leaves the cavity, entrapping air and increasing the cavity pressure and tension.

Pulmonary collapse with relaxation or retraction, or actual compression of the lung will fail to close a tension cavity, for the positive pressure prevents collapse of the cavity walls. Eloesser7 has stated that cavities ballooned from within, resist collapse measures unless the anatomy of the communicating bronchus can be changed, which will either open it and release the intracavitary pressure, or close it entirely so that the air within the cavity can be absorbed.

There is general agreement among phthisiologists that tuberculous tension cavities are not successfully treated by pneumothorax. Surgical measures have been considered necessary although there has not been a unanimity of opinion about the most efficacious operative procedure. The use of a Monaldi type of drainage alone has not often resulted in permanent cavity closure. A combination

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**Medical Superintendent, Municipal Sanatorium, Otisville, N. Y. (one of the institutions of the Department of Hospitals, City of New York).
of transthoracic intracavitary suction drainage and thoracoplasty has been advocated by some, while pulmonary resection has been the choice of Maier, and the utilization of skin-flap drainage in conjunction with other collapse measures has also been tried.

However, the closure of tension cavities by partial re-expansion of pneumothorax has been mentioned by Rafferty and others. Several series of cavity closures with re-expansion have been reported. Brunn, et al. observed 14 cases where, in spite of an adequate pneumothorax collapse, the cavity remained open and with re-expansion of the lung the cavity promptly closed. They believe this was associated with a subsidence of an allergic inflammation in the bronchus.

Steele, et al. described 12 cases of unexpected closure of cavities following re-expansion after ineffectual pneumothorax (usually because of adhesions), though no conclusions were made as to the mechanism of closure.

Shipman described a case of bilateral pneumothorax with open bilateral cavities where, on re-expansion of the lungs, the cavities closed. This is explained as a result of the draining bronchi opening up.

The bronchial factor in cavity closure is indicated in a report by Meyersburg, et al. They describe 3 pneumothorax cases with a ball-valve type of bronchial obstruction proximal to cavities that remained open. After bronchial aspiration, a satisfactory pneumothorax was obtained in each patient. The dynamics of the cavity closure was not explained.

Slavin would use positive pressure pneumothorax to compress tension cavities. He describes two cases successfully treated in this manner.

The purpose of this paper is to present illustrations of the closure of tension cavities with pneumothorax. Tension cavities comprise such a significant cause for failures in collapse therapy that any method that can achieve success in their treatment is important. We have also attempted to determine the modifications of the pneumothorax or the factors responsible for the closure. Our cases could be classified according to specific groups which will be described.

**GROUP 1 — Closure Of A Tension Cavity By Considerable Re-expansion Followed By Increase Of Pneumothorax**

**Case 1, Group 1:** Prior to the initiation of pneumothorax, the cavity in the left upper lobe (Fig. 1) had several characteristics of a tension type—its large size, thin wall and scant surrounding infiltration. With the pneumothorax well established (Fig. 2) a definite change in bronchocavitary drainage had taken place and the cavity now had evidence of tension or positive pressure. It was huge and stood out, uncollapsed
in the pneumothorax space, while the remainder of the lung was markedly collapsed. It was not held out by adhesions (an intrapleural pneumonolysis had been performed with severance of all adhesions) but was ballooned out by the intracavitary positive pressure. The cavity enlarged with pneumothorax to this huge size after it had been originally diminished by the collapse which showed the assumption of intracavitary tension. A fluid level appeared only after induction of pneumothorax and this indicated the development of some degree of bronchial obstruction with impaired drainage from the cavity. The production of this tension cavity could be ascribed to a partially obstructed bronchus that permitted more air to enter during inspiration than could leave with expiration and the retained air built up the pressure within the cavity. The pneumothorax by its collapse of the lung, therefore altered the dynamics of the bronchocavitary drainage and was instrumental in the creation of the valvular bronchial obstruction. The distention of the cavity seen in Figure 2 was enhanced because the intrapleural pressures were always subatmospheric after refills and this increased the

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**Fig. 1, Case 1, 9/10/43:** A.F., 25 year old white female. Admitted 9/9/43. Cavity in apical part of L.U.L., balloon shaped, 5 cm. x 4 cm., thin wall, scant surrounding infiltration. Nodular infiltration scattered throughout remainder of left lung and in 2nd and 3rd right anterior interspaces. Sputum highly positive.

**Fig. 2, Case 1, 1/12/44:** Left artificial pneumothorax induced 9/16/43; intrapleural pneumonolysis 12/18/43. Marked collapse of left lung with tension cavity 5 cm. x 4 cm., with fluid level in L.U.L. Small cavity, 1.3 cm. x 1.3 cm., below large cavity. Little fluid in costophrenic angle. Infiltration in right lung unchanged. Sputum persistently positive.

**Fig. 3, Case 1, 2/10/44:** Following discontinuation of refills for one month. Lung considerably re-expanded, cavity in L.U.L. smaller (3.8 cm. x 3.8 cm.) and more collapsed than remainder of lung. Small cavity below large vomica unchanged. Sputum positive.

**Fig. 4, Case 1, 5/23/44:** Marked collapse of left lung. No cavity visualized. Fluid below level of 10th posterior rib. Resolution in right lung with residual slight nodular fibrosis. Sputum negative.

**Fig. 5, Case 1, 12/5/44:** Marked collapse of L.U.L. maintained. Lower lobe re-expanded with lung margin at level of 9th posterior rib in axillary line. Fluid on level with 5th posterior rib. Chest tap revealed yellow, turbid, thin fluid, positive for tubercle bacilli on culture. Sputum negative.
difference between the positive intracavitary pressure and the negative intrapleural pressure.

The pneumothorax was obviously ineffective but surgery was not approved because stability of contralateral lesion was not certain. Re-expansion of the lung was decided upon with the possibility that cavity closure might occur with this procedure.

With discontinuation of pneumothorax for one month (1/11/44 to 2/11/44), sufficient re-expansion took place to alter the dynamics of the draining bronchus and change the intrabronchial valvular mechanism. Now (Fig. 3) without the addition of any intrapleural air, the lung expanded to a degree of 50 per cent collapse and the type of collapse showed interesting modifications. The cavity no longer protruded but showed more collapse than the remainder of the lung, indicating a diminution of tension or pressure within it. In other words, the collapse was becoming more selective and the cavity smaller. This result which occurred while refills were stopped, demonstrates that the attainment of a selective collapse with pneumothorax depends entirely on the changes within the bronchi and lung.

The marked changes in this case followed alteration of the bronchial drainage mechanism. Either the draining bronchi closed, permitting

Fig. 6. Case 2, 6/23/44: J.M.G., 23 year old colored female. Admitted 6/22/44. Large, thick walled cavity, 4 cm. x 4 cm., in lateral portion of R.U.L. Soft infiltration throughout R.U.L. Sputum highly positive.

Fig. 7. Case 2, 12/1/44: Right artificial pneumothorax induced 6/29/44. Refills stopped from 10/12/44 to 11/8/44 and then reinstated. Right lung markedly collapsed and uniformly dense except for protruding, huge, tension cavity with fluid level. Inside of cavity 5 cm. x 4 cm. Sputum positive.

Fig. 8. Case 2, 1/31/45: Right lung about 85 per cent collapsed. R.U.L. sticks out very slightly. Lung airless except for cavity which is smaller, 2 cm. x 2 cm., without a fluid level. Sputum positive.

Fig. 9. Case 2, 6/27/45: After discontinuation of refills for 3 months, right lung collapsed about 60 per cent and no longer homogeneously dense, indicating increase in air content. Cavity in R.U.L., 2.5 cm. x 1.3 cm. and with apparent fluid level. Sputum positive. Fluid in pleural space at 11th rib posteriorly.

Fig. 10. Case 2, 9/29/45: Right lung maintained at 60 per cent collapse. Cavity for first time not visualized and replaced by dense homogeneous area. Sputum negative. X-ray picture unchanged for remainder of patient's stay in Sanatorium.
air in the cavity to be absorbed, or it more fully opened and this allowed the lung to relax and retract. However, one thing was certain—the check-valve mechanism in the draining bronchus no longer persisted. It was, therefore, now possible to continue pneumothorax effectively with the rapid closure of the cavity. Refills were re-instituted 2/11/44.

After one month of pneumothorax treatments following the re-expansion of the lung (or 7 weeks after re-expansion was started) the sputum was converted and a patient who had been persistently and highly positive for 7 months (from 9/12/43 to 3/7/44) became negative. Actually 3 months after pneumothorax was re-instituted the lung was markedly collapsed again (Fig. 4) and for the first time no cavity could be visualized on the roentgenogram. Refills were continued at less frequent intervals and re-expansion of the left lower lobe occurred, but a marked selective collapse of the upper lobe was maintained (Fig. 5). There were no further roentgenographic changes while the patient was in the institution.

She remained negative until her discharge (2/25/45) on 14 48-hr. sputum concentrates, 7 gastric concentrates, and 6 gastric cultures (except that 1 gastric culture was positive, 6/21/44).

The sputum has continued negative during a 10 months' follow-up period after discharge. Her general condition has remained excellent. A satisfactory pneumothorax has been maintained with a minimal amount of fluid in the left pleural cavity.

In this individual a totally ineffective and harmful pneumothorax with a huge tension cavity was converted into a satisfactory pneumothorax by alteration of the lung collapse, by considerable re-expansion and then re-institution of refills. Sputum conversion and cavity closure rapidly followed this procedure. A thoracoplasty or pneumonectomy, which had been considered but delayed because of the contralateral lesion, then became unnecessary.

GROUP 2-A — Closure Of A Tension Cavity By Considerable Re-expansion of Pneumothorax

Case 2, Group 2: The roentgenogram prior to pneumothorax (Fig. 6) revealed a cavity which, although of huge size, was not characteristic of a tension one. But with collapse therapy the cavity assumed the typical appearance of a positive pressure or tension type. As in Case 1, the pneumothorax must have altered the cavitory drainage mechanism and formed a valvular obstruction which produced the tension cavity. Corroborative evidence of this was furnished by a bronchoscopy done 10/21/44. (Dr. M. S. Lloyd): "The mucous membrane throughout the right side is doughy and cyanotic, particularly in the lower lobe, and the branches of all the lobes are markedly reduced in diameter. The lower lobe and middle lobe contain stagnant, frothy secretion. The upper lobe is completely closed by a mucopurulent collection without air. The mucous membrane bleeds easily on being touched. On inspiration this bronchus can be seen to open and it closes at the beginning of expiration producing a check-valve mechanism."

An attempt was made to remove this check-valve by re-expansion of the lung. The method successful in Case 1 was tried and refills were stopped for one month (10/12/44 to 11/8/44). The lung re-expanded and showed a 50 per cent collapse and then refills were again resumed. However, unlike Case 1, the cavity did not close. In fact, after one month
of pneumothorax, following the partial lung re-expansion, the cavity (Fig. 7) was larger than it had ever been. A lobectomy was considered at this time but the patient refused surgery. The huge cavity stood out, uncollapsed, with the remainder of the lung markedly collapsed, indicating a positive pressure and tension within it. Because the intrapleural pressures had always been negative, the cavity would tend to balloon out more. Either the lung had not been re-expanded sufficiently or kept out with a partial collapse for a long enough period to produce the necessary changes in bronchial drainage. However, with continuation of pneumothorax, the lung collapse could be increased and the cavity became smaller (Fig. 8).

This change in the roentgen picture indicated that the check-valve mechanism or partial bronchial obstruction had been altered, for while the pneumothorax had been maintained with negative pressures, the collapse of the right lung was considerably changed. The right upper lobe was collapsed more and did not protrude as much as before and the cavity was much smaller and was no longer ballooned out because the tension or positive pressure was diminished.

But as the cavity persisted, it was decided to permit the lung to be re-expanded for a longer period of time. For 3½ months, from 3/27/45 to 7/10/45, no refills were given. Changes were rapid after this re-expansion period. On 7/17/45 the sputum was last reported positive (having been persistently positive for 13 months) and it subsequently remained persistently negative till the patient left on 11/22/45. The negative reports consisted of 7 sputum concentrates, 3 gastric concentrates and 3 gastric cultures.

By 6/27/45 the lung had re-expanded and had a 60 per cent collapse and the cavity was considerably reduced (Fig. 9). Three months later (Fig. 10) with the pneumothorax maintained at this degree of collapse, the cavity was definitely closed and thereafter no longer visualized. Four months after discharge the condition was unchanged.

The re-expansion of the lung to a degree of 60 per cent collapse was apparently responsible for the closure of the cavity. The lung expansion must have altered the bronchial drainage from the cavity so that the bronchus either opened (permitting the cavity to retract) or it completely closed, causing the cavity to collapse. In either case the partial bronchial obstruction or check-valve, the cause of the positive pressure or tension cavity, no longer existed. With the expansion of the lung and increase in its air content, sufficient pulmonary tissue was available to fill in the space of the shrinking cavity.

Once the proper degree of lung collapse was determined, it was easy to maintain the pneumothorax at an effective and satisfactory level. It was fortunate that a good clinical result was obtained with pneumothorax in this case for thoracic surgery had been refused.

GROUP 2-B — Closure Of A Tension Cavity By Partial Re-expansion Of A Pneumothorax Limited Because of Adhesions

Case 3, Group 2: * Prior to pneumothorax the cavity (Fig. 11), though not spherical in shape, had several characteristics of a tension type for it was very large, with a thin wall and fluid level. The fluid level indi-

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cated interference with bronchial drainage. During the first few weeks that the pneumothorax collapse was slightly increasing, the cavity first diminished in size and then enlarged, showing the development of intracavitary tension. That pneumothorax could produce variations in bronchial obstruction and drainage was shown by transitoriness of the cavity fluid level while the treatments were given.

A conditioning factor in this case was the presence of adhesions (Fig. 12), for by holding the lung out, the adhesions could prevent the typical appearance of a tension cavity. An intrapleural pneumonolysis had been attempted but was unsuccessful. After 5 months of pneumothorax (Fig. 13), the right upper lobe was collapsed 75 per cent and the cavity, though smaller, persisted. Pneumothorax refills were stopped at this time in expectation of doing a thoracoplasty. However, one month after discontinuation of refills (Fig. 14), the right upper lobe re-expanded and was only 40 per cent collapsed, and the cavity closed and the sputum turned negative. Refills were reinstituted and the pneumothorax maintained.

The rapid closure of the cavity with re-expansion points to the fact that with the variation in lung collapse, some change in the draining

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**Fig. 11, Case 3, 11/17/38:** L.P., 33 year old colored male. Admitted to Kingston Avenue Hospital No. 1938. Cavity in R.U.L. between 1st and 2nd anterior ribs, 4 cm. x 4 cm., and with a fluid level. Soft mottled infiltration throughout R.U.L. except apex. Superior part of cavity wall visible and not thick. Sputum highly positive.

**Fig. 12, Case 3, 1/27/39:** Right artificial pneumothorax induced 11/22/38. R.U.L. about 50 per cent collapsed and diffusely airless except for large cavity, 3.5 cm. x 2.5 cm. No definite cavity fluid level. Several adhesion bands present. Lower lobes about 70 per cent collapsed. Sputum positive.

**Fig. 13, Case 3, 4/26/39:** R.U.L. collapse 75 per cent. Cavity smaller, 1.5 cm. x 1.5 cm. Lower lobes about 25 per cent collapsed. Sputum positive.

**Fig. 14, Case 3, 5/26/39:** One month after discontinuation of refills. R.U.L. about 40 per cent collapsed and well aerated. Cavity no longer seen and only scattered nodular and linear infiltration visible in its place. Lower lobes almost entirely re-expanded. Sputum negative.
bronchus must have occurred and the most plausible explanation would be the alleviation of a valvular or check-valve bronchial obstruction. In other words, the draining bronchus was either opened or closed and no longer partially obstructed and the cavity closed. Otherwise the cavity would have enlarged with re-expansion.

It may be argued that if the pneumothorax could have been further increased, the cavity would have closed as it had shown much diminution before re-expansion. But if more pneumothorax would have closed the cavity then with less pneumothorax on re-expansion the cavity should have become more apparent.

A phrenic crush was done on 8/23/39. After a few months a moderate effusion appeared in the right pleural space and the lung collapse was slightly increased.

Once the cavity was closed, the pneumothorax was easily maintained and it made no great difference if the collapse was then increased for there was apparently no check-valve bronchial mechanism to interfere.

The patient was in the Municipal Sanatorium, Otisville, N. Y., from 2/29/40 to 9/2/40. The chest picture remained about the same and all sputum examinations were negative.

During a follow-up period of 3½ years no cavities were seen and the sputum was negative.

GROUP 3 — Closure Of Tension Cavity Within Well Collapsed Lung By Considerable Re-expansion

In this group are considered pneumothoraces which are anatomically good but clinically ineffective. With re-expansion of the pneumothorax, a therapeutically satisfactory result is obtained.

Case 4, Group 3: Prior to pneumothorax the cavity in the right upper lobe (Fig. 15) had characteristics of a tension type, for it was large, spherical and with a thin wall (and slight surrounding infiltration). Several days after the initiation of pneumothorax (Fig. 16), the cavity had a fluid level, evidence that some degree of bronchial obstruction existed. After two months of pneumothorax therapy (Fig. 17) the right upper lobe was markedly collapsed and appeared homogeneously dense. For 10 months this marked collapse was maintained but the sputum was constantly positive. Re-expansion of the right upper lobe was attempted to obtain healing. Refills were stopped for one month (12/27/41 to 1/24/42) and the lung gradually re-expanded. The month that refills were stopped and the right upper lobe began to re-expand, a negative sputum was reported for the first time in a year. The second month after re-expansion was started the sputum definitely turned negative and remained so thereafter, and the third month the cavity closed (Fig. 18). During this period the right upper lobe was maintained in this same condition of re-expansion (at a degree of 50 per cent collapse). The conversion of the sputum and cavity closure was directly associated with the re-expansion and was no coincidental occurrence.

The patient was discharged on 11/8/42 as an arrested case with a daily work tolerance of 3 hours. The same lung collapse as illustrated in Fig. 18 was maintained and there were no other changes except that the round density or filled cavity slowly became smaller. Prior to discharge he had 11 negative sputum concentrates, 3 negative concentrates and 4 negative cultures. During a follow-up period of three and one-half years the patient has remained in excellent condition.
The lack of an endobronchial lesion (when a bronchoscopy was done all the visible bronchi showed no ulceration), and the persistently positive sputum pointed to an uncollapsed cavity in the right upper lobe. A cavity could reasonably persist in a markedly collapsed lobe only if a bronchial valvular obstruction existed that caused a tension or positive pressure within the cavity so that it could not collapse.

The fluid level in the cavity, before it was lost to view within the collapsed lung, indicated some bronchial obstruction. This obstruction could become valvular in nature, forming a typical check-valve mechanism. We have seen that pneumothorax, as in Cases 1 and 2, could be instrumental in altering bronchial drainage so as to produce marked tension cavities. The size and distensibility of a tension cavity will vary with many conditions—the degree of bronchial closure, accumulation of material in the cavity, thickness of the cavity wall, amount of infiltration, degree of elasticity, or presence of atelectasis in the surrounding lung, pressure in the intrapleural space and the presence of adhesions. Although a tension cavity is typically huge because of the marked positive pressure and considerable amount of air within the cavity and air accumulation with inspiratory phases of respiration, still it is possible to have a small tension cavity. In other words, the amount and entrapment of air and degree of positive pressure in the cavity can be slight or great. In Case 2, for example, a huge tension

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Fig. 15, Case 4, 2/21/41: W.W., 39 year old white male. Admitted 2/20/41. Thin walled cavity in right sub-apical area. 3 cm. x 3 cm. Slight mottling, medial and inferior to cavity. Few nodules in 2nd anterior interspace. Sputum highly positive.

Fig. 16, Case 4, 3/13/41: Right artificial pneumothorax induced 3/10/41. R.U.L. about 50 per cent collapsed. Cavity 3 cm. x 2 1/2 cm., with a definite fluid level. Rest of lobe diffusely dense. Marginal collapse of lower lobe. Minimal fluid in costophrenic sinus. Sputum positive.

Fig. 17, Case 4, 5/19/41: R.U.L. about 80 per cent collapsed and homogenously dense. No cavity visible. No adhesions. Lower lobes about 70 per cent collapsed. Sputum highly positive.

Fig. 18, Case 4, 3/19/42: Right lung considerably re-expanded. Marginal collapse of lower lobes. R.U.L. about 50 per cent collapsed. No cavity visible. In its place a round homogenously dense shadow undoubtedly filled-in cavity seen. Slight mottling medial to this round focus. Sputum negative.
cavity became much smaller with an increase of pneumothorax collapse, yet evidence of bronchial obstruction and intracavitary tension persisted. In this patient, Case 4, soon after pneumothorax was initiated, the appearance of the fluid level showed the cavity partly filled so that with an increased collapse, a good part of the cavity could be filled and only a small cavitary space might remain and persist because of a check-valve bronchus. Eloesser found from manometric studies in post mortem lung cavities that even irregular, ragged walled cavities in densely infiltrated, largely airless lung, contain air which is under more than atmospheric pressure much of the time. He stated that cavities may not appear to be blocked or ballooned yet the bronchi are not freely open and secretions, pus or necrotic bits of material block them partially part of the time and inflation results by entrapped air.

Although the cavity in this patient could not be seen within the markedly collapsed lung, I believe it existed within the collapsed right upper lobe as a small tension cavity hidden by the dense surrounding lung. The rapid conversion of the sputum with re-expansion is explainable on the basis of cavity closure resulting from modifications in the draining bronchus. As the lung re-expands, there is an alteration in the direction of the bronchus and a change in the size of the bronchial lumen and variation in bronchocavitary drainage. As has been emphasized, a cavity can close only if the draining bronchus is open or closed, but not check-valve in nature. With re-expansion the valvular obstruction must have been relieved and the bronchus was either opened or closed.

There were 2 other patients observed similar to Case 4. In both individuals, white male adults, thin-walled, right apical cavities were present, which were spherical in shape and measured 2 cm. in diameter. In each instance there was practically no surrounding infiltration. The sputum was positive and pneumothorax was initiated.

The pneumothorax was unsatisfactory and both patients required intrapleural pneumonolyses in order to sever apical adhesions and entirely free the upper lobe. The degree and type of collapse obtained after operation was similar in each case. The right upper lobe was about 90 per cent collapsed with no cavity visible within the lung. The lower lobes were collapsed 80 per cent in one instance and 50 per cent in the other. The pneumothorax was continued with the upper lobes 90 per cent collapsed. The sputum remained highly and persistently positive in spite of the excellent collapse. Bronchoscopies failed to reveal endobronchial tuberculous ulceration in either case. One patient remained positive for 9 months under these conditions and the other was positive for 13 months (but only 9 months with the upper lobe 90 per cent collapsed).

Re-expansion of the lung resulted in a rapid conversion of the sputum. In one case, within one month after re-expansion was started and with the right upper lobe 50 per cent collapsed, the sputum turned negative. The right upper lobe was allowed to expand to a degree of 25 per cent collapse and maintained that way with the patient constantly negative. At the site of the original cavity only an area of irregular fibrosis was seen. This patient, after sputum conversion, remained persistently negative for 11 months in the sanatorium on 13 sputum concentrates, 10
gastric concentrates and 10 gastric cultures. He was discharged as an arrested case with a work tolerance of 4 hours daily.

In the second patient, within 6 weeks after re-expansion was started, with the right upper lobe 60 per cent collapsed, sputum conversion occurred. No cavity was visible and only a coalescent nodular lesion remained in the right upper lobe. This person remained negative for 6 months on 11 sputum concentrates and 3 gastric concentrates. He was discharged as an arrested case, with a daily work allowance of 2 hours.

These patients are very similar to Case 4. A marked (90 per cent) collapse of the right upper lobe was present for many months, yet the sputum remained persistently positive. No endobronchial lesion was observed. These findings pointed to the presence of an uncollapsed cavity in the markedly collapsed lobes as the source of the sputum. With re-expansion of the lung, sputum conversion occurred rapidly (within 4 weeks and 6 weeks respectively) and no cavities were seen in the re-expanded lobes. The explanation offered is the same as for Case 4—that the cavities persisted in the markedly collapsed lobes as small tension cavities because of valvular bronchial obstruction, and with re-expansion the valvular obstruction was relieved, permitting rapid closure of the cavities and sputum conversion.

An anatomically satisfactory pneumothorax is usually considered a requisite for a proper clinical result. The degree of collapse may be progressively increased with the expectation that a good or marked collapse will be therapeutically effective. The experience in this group indicates that this is not necessarily so. A marked pneumothorax may be ineffective because of a hidden tension cavity within the collapsed lung. In these cases, in spite of an adequate collapse and lack of adhesions, if the sputum is not converted in a few months, re-expansion of the pneumothorax should be considered.

GROUP 4 — Closure Of Tension Cavity With Small Pneumothorax Collapse

Case 5, Group 4: The roentgen picture before pneumothorax was quite typical of a check-valve or tension cavity (Fig. 19). The cavity was very large, almost spherical in shape, with a thin wall and little surrounding infiltration and suggestive fluid level.

After pneumothorax was initiated there was further evidence of changes in the cavity drainage mechanism. There were transitory appearances of the intracavitary fluid level which indicated alterations in the lumen of the draining bronchus. The cavity decreased in size and then temporarily enlarged, even though there was no change in the amount of pneumothorax space, showing variations in the intracavitary pressure, probably secondary to bronchial changes.

The huge cavity, when closed, formed a very small, filled focus, indicating that the cavity had been under tension and there had actually been little lung destruction.

In this case there was rapid diminution in the size of the cavity with closure four months after initiation of pneumothorax (Figs. 20 and 21). Since then to date (four months after cavity closure), there has not been much change on roentgen examination. The closed cavity has become smaller. The sputum has been negative on 15 sputum concentrates, 4 gastric concentrates and 2 cultures.

This cavity closure took place in the presence of a small and anatom-
ically unsatisfactory collapse. This points to the closure mechanism being related principally to changes in the draining bronchus. This is also indicated by the fact that the cavity decreased in size and closed while the same degree of lung collapse was maintained. Apparently the partial pneumothorax was sufficient to alter the draining bronchus in such manner as to modify the bronchial check-valve and cause closure of the bronchus. With this the air within the tension cavity absorbed and the cavity collapsed and closed. The space left by the shrinking cavity was filled in by normal or emphysematous lung. Moreover, the adherent lung would prevent relaxation and retraction of the lung necessary to obtain closure with an open bronchus, and this would corroborate the idea of bronchial occlusion.

**Fig. 19, Case 5, 12/15/44:** R.E., 22 year old white male. Admitted 12/14/44. Thin walled cavity in L.U.L. 4.2 cm. x 3.7 cm. with suggestive fluid level and little surrounding infiltration. Bronchocavity junction widened at inferior medial angle of cavity. Slight nodular infiltration scattered in 1st and 2nd anterior interspaces. Scattered soft coalescent lesions on right between 2nd and 5th anterior ribs. Sputum highly positive.

**Fig. 20, Case 5, 1/31/45:** Left pneumothorax induced 1/23/45. L.U.L adherent to chest wall to level of 3rd anterior rib. Cavity smaller, 3 cm. x 2.7 cm., with a faint fluid level. Narrow peripheral collapse of rest of left lung. Air in front and around lung as some seen forming a pocket along upper mediastinum. Collapsing inner or medial portion of lung slightly. Fluid fills costophrenic sinus. Sputum positive.

**Fig. 21, Case 5, 5/31/45:** Collapse of L.U.L. increased to about 30 per cent but it is adherent between 1st and 3rd ribs with air present in inner apical region. L.L.L. collapsed about 70 per cent. Cavity closed and forms small oval homogeneously dense focus, 1.5 cm. x 1 cm. Heavy adhesion band from closed cavity to chest wall. Intrapleural pneumonolysis attempted 4/8/45 but adhesions could not be cut. Good deal of resolution in right lung lesion. Sputum negative.
There was much contralateral pathology in this case and the success in the closure of the tension cavity with a small pneumothorax collapse was very important. Otherwise the patient would have had a difficult therapeutic problem and a poor prognosis.

There were 4 other patients observed similar to Case 5. These individuals all had typical tension cavities prior to pneumothorax. The cavities were large, the diameters measuring 2½ cm., 3 cm., 4½ cm., and 5½ cm. respectively. They were spherical in shape and all but one had a thin wall. In 3 instances there was practically no infiltration surrounding the cavity and in one case the infiltration was very slight, although 2 of the patients had mixed infiltration in other areas of the homolateral lung. Contralateral productive infiltration was present in two of the patients. Cavity fluid levels were present in all before pneumothorax. In two of the patients a well-defined draining bronchus could be seen extending from the hilus area to the inferior and medial border of the cavity, with narrowing at the broncho-cavity junction demonstrated in one of them.

Two of the cavities were located in the right upper lobe; one was in the left upper lobe and one in the right lower lobe. The pneumothorax in each case was maintained with the use of subatmospheric pleural pressures.

Only a partial peripheral pneumothorax collapse was obtained for the lower lobe cavity. All of the upper lobes showed the apices adherent with many adhesions over the cavity area. Intrapleural pneumonolyses were attempted in all of the cases. In only one separation of adhesions was possible and this only slightly improved the pneumothorax space. The total collapse of the upper lobes was estimated to be about 20 per cent, 25 per cent, and 35 per cent, respectively. The point to be emphasized is that only a slight collapse of the lung was obtained for a very large cavity.

The complete closure of the cavities was definitely demonstrable within 5 weeks, 2½ months, 5 months and 7 months respectively. Before cavity closure, fluid levels were apparent in 3 of the 4 patients.

The sputum turned negative at intervals of 1 month, 7 weeks, 4 months and 4½ months after the initiation of pneumothorax. A negative sputum means that sputum concentrates, gastric concentrates and cultures were negative. These patients remained negative for 10, 11, 12, and 20 months' observation respectively.

The cavity at the time of closure appeared as a small, homogeneous, round focus twice and in the other two, only minimal nodular and linear infiltration remained. The closure of these cavities with pneumothorax avoided the need for more aggressive surgical procedures and preserved a maximum of good lung. This was doubly important as some patients could not have surgery done, and even with pneumothorax could tolerate only a slight collapse.

The roentgenograms showed definite evidence of valvular bronchial obstruction in these patients before and during pneumothorax therapy. There was rapid closure of these large tension cavities with a small pneumothorax collapse. This is explainable, as in Case 5, on the basis of closure of the draining bronchus which would remove the check-valve mechanism and cause collapse of the cavity.
It has been emphasized in several reports (Newton,17 Hurst and Schwartz,18 and Thompson and Greenberg19) that adhesions attached to diseased areas of the lung should be released, if possible, because of their responsibility for exacerbations and relapses, particularly after re-expansion. A perfect selective or anatomic collapse of the diseased part is the criterion and not alone conversion of the sputum and closure of cavities. In other words, to avoid poor, late results, an effective collapse must also be a complete one without adhesions.

We believe that adhesions should not be disregarded. We recommend the consideration of intrapleural pneumonolyses for adhesions over areas of pathology that prevent satisfactory collapse of diseased lung even in negative cases. In these patients of Group 4 intrapleural pneumonolyses were attempted but were unsuccessful. There was then the choice to re-expand the pneumothorax that though anatomically poor, had closed the cavity and converted the sputum, or to use another surgical procedure. Surgical therapy was, however, not always possible or was definitely contraindicated.

In these cases also there was no use of positive pressure pneumothorax with its deleterious effects. In tension cavities the actual amount of tissue destruction is much less than the size of the cavity indicates and therefore a partial pneumothorax may be adequate and control the disease. With these considerations in mind, the usual views about the hazards of incomplete collapse may be modified for these tension cavities.

Discussion

This paper is not a plea for the use of pneumothorax in the treatment of tension cavities. Its purpose is to describe the conditions under which pneumothorax can be successful in the closure of tension cavities. These cavities frequently cause failures in collapse therapy, particularly pneumothorax, and their control is of importance. This consideration is of special significance in those patients for whom thoracic surgery (the accepted form of treatment) is contraindicated and pneumothorax is desirable. Appreciating its limitations and infrequency, it is of value to know that pneumothorax can close tension cavities. We attempted in this study to determine the factors responsible in those cases where pneumothorax was effective. The follow-up period after closure of some of the cavities described has not been too long. Better evaluation of the treatment and the permanence of cavity closure will be possible after a longer observation period. This is important as cavities can re-open. Nevertheless, the successful methods
employed in these cases are worthy of trial in pneumothorax therapy.

The pneumothorax had to be modified in the following manner to obtain cavity closure: (1) A markedly collapsed lung had to be considerably re-expanded and then refills were re-instituted with an increase of the collapse again obtained; (2) a markedly collapsed lung was considerably re-expanded and the pneumothorax was then maintained in this condition of partial collapse; (3) only a slight pneumothorax collapse was obtained after initiation and this was continued throughout the course of therapy.

Tension cavities are caused by valvular obstruction in the draining bronchus. As mentioned above, there are conditions in the lumen of the bronchus or its wall that can be responsible for the partial obstruction. In addition, the pneumothorax changes the direction and angulation of the bronchus, alters the size of the bronchial lumen and modifies the amount of cavity drainage. Variations in the degree of pneumothorax can therefore create, accentuate or remove a bronchial check-valve mechanism. In the cases described it was noticed that not every cavity had typical characteristics of tension prior to pneumothorax. However, after collapse was started the appearance of the marked tension cavities showed that the pneumothorax was responsible for the formation of the tension by bronchial changes. Cavity fluid levels were more often seen after pneumothorax was initiated, indicating that the pneumothorax made the bronchial drainage less efficient.

The effectiveness of pneumothorax depends upon many factors in the cavity, lung and pleural space, but especially the condition of the draining bronchus for if a valvular obstruction exists that creates a tension cavity, closure will not occur. The closure of the tension cavities obtained with the above modifications in the degree of pneumothorax is explained as being due to a release of the valvular bronchial obstruction with a resultant opening or closing of the draining bronchus and under these circumstances cavity collapse occurred.

Ordinarily one would expect re-expansion to cause opening of the bronchi. It may be considered paradoxical to state that bronchial closure will occur with lung expansion. As mentioned above, there are many conditions in the bronchial lumen or wall responsible for a valvular obstruction. It is possible for a partial obstruction because of the bronchial changes (angulation, drainage, etc.) that occur in expansion to close with a small degree of pneumothorax and to persist with a marked pneumothorax. We have shown that tension cavities closed with a small pneumothorax and in the Group 4 cases, evidence indicated that only the mechanism of bronchial closure was responsible.
The cases presented also demonstrated the importance of individualization in the pneumothorax therapy. Pneumothorax is a complex, skilled procedure and much more than merely introducing air into the pleural space to get a maximum amount of collapse. Each pneumothorax has its optimum collapse required for cavity closure. A selective collapse can be a partial or marked one. This satisfactory degree of collapse must be determined for each patient. The type of collapse (particularly in relation to changes in the draining bronchus) is the important consideration and not the amount of collapse per se. Although a selective collapse is not a matter of choice but depends upon the changes within the lung, still the degree of collapse can be regulated, and as illustrated by our cases, proper variations in collapse can determine whether the pneumothorax will be successful or not.

Many cavities gradually diminish in size as the pneumothorax is increased, and close only with a considerable collapse. Moreover, not all tension cavities will respond to re-expansion as did the cases described in this paper. It is probable, however, that some pneumothoraces are collapsed too fast and too much. By slowly increasing the pneumothorax and carefully observing changes in the cavity and sputum, a point may be reached where the therapy will be effective with less collapse than usually used. The most desirable degree of pneumothorax is the smallest amount which will close the cavity and control the diseased area and keep uncollapsed a maximum of good lung.

Re-expansion of the lung and modification of the degree of collapse, as suggested in this series, should be considered early. It is undesirable to continue an ineffective pneumothorax for a long time. Unfortunately, unsatisfactory pneumothoraces are too often maintained longer than they should. There should be no delay in any necessary surgical procedure because the closure of tension cavities with changes in the pneumothorax collapse becomes rapidly evident. It is desirable, prior to thoracoplasty, to have the lung completely re-expanded. Before the operation is done the sputum and roentgenogram should be re-checked because of the possibility of cavity closure with re-expansion. Likewise, whenever ineffective pneumothoraces are stopped, the lung should be carefully observed during re-expansion for changes in the cavity.

In some cases (as in Cases 1 and 2) with huge tension cavities, and the lung markedly collapsed, the expansion was much better than could be hoped for from examination of the roentgenogram. The actual destruction of lung was much less than indicated by size of the tension cavity. With removal of the tension and positive pressure from within the cavity the lung tissue around the cavity,
which had been compressed by this tension, expanded readily and filled in the space left by the closing cavity.

There was an interesting correlation between the sputum and x-ray findings. Frequently the sputum concentrates turned negative before the cavity was completely closed on roentgenogram. An ascending order of sensitivity in the examinations used for finding tubercle bacilli was also indicated, for in many of the cases with closure, sputum concentrates were converted first, the gastric concentrates next, and the cultures were last to turn negative.

**CONCLUSION**

Cases illustrating the closure of tension cavities with pneumothorax have been presented. In order to achieve these results the pneumothorax was modified by (a) considerable re-expansion, then increase of collapse; (b) considerable or partial re-expansion, and (c) a small degree of collapse. The relationship of the pneumothorax to the formation and closure of tension cavities has been discussed. The role of the draining bronchus in these processes has been described and emphasized.

**CONCLUSION**

Se han presentado casos ilustrativos del cierre de cavernas de tensión mediante el neumotórax. A fin de obtener estos resultados se modificó el neumotórax en las formas siguientes: (a) considerable reexpansión seguida de aumento del colapso; (b) considerable reexpansión y (c) pequeño grado de colapso. Se ha discutido la relación entre el neumotórax y la formación y el cierre de cavernas de tensión. Se ha descrito y recalocado el papel que desempeña en estos procesos el bronquio de desagüe.

**REFERENCES**

I. BOBROWITZ


Discussion

BENJAMIN L. BROCK, M.D., F.C.C.P.

Oteen, North Carolina

I would like to discuss briefly the physiology of the bronchial tree, particularly as it relates to the pathogenesis of pulmonary tuberculosis. It has long been my belief that lack of adequate drainage from the lungs and bronchial tree plays a major role in the pathogenesis of this disease. Drainage of exudates from the bronchial tree is accomplished in the following ways:

1. Through the ciliary action.
2. Through the cough mechanism, and
3. Through a peristalsis like action of the bronchial tree during respiration. During inspiration the bronchial tree elongates and the diameters of the lumina of the bronchi become wider. During expiration the bronchi shorten and the lumina are narrower.

This latter mechanism plays a large part in the evacuation of exudates which may accumulate within the bronchial tree and where adequate drainage is instituted disease may be prevented, or where disease already exists, it may clear.

To illustrate very clearly the part that drainage plays in the clearing of a tuberculous lesion we may consider the sequence of events which take place when endobronchial tuberculosis develops...