THESIS PRESENTED TO THE UNIVERSITY OF GLASGOW

FOR THE DEGREE OF DOCTOR OF MEDICINE.

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THE TREATMENT OF TUBERCULOUS LUNG CAVITIES BY CLOSED SUCTION DRAINAGE — MONALDI'S METHOD.

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T A B L E O F C O N T E N T S.

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INTRODUCTION.

In a disease like tuberculosis which takes such a heavy toll of the youth of the country, any new method of treatment which offers promise of help is worthy of extended trial. So few have been our effective weapons in the battle against tuberculosis, that any new procedure deserves special consideration, especially if it includes a new conception of, or a new principle in, treatment.

In recent years the surgical treatment of pulmonary tuberculosis has been a valuable adjunct to conservative measures, yet there exists still a large number of cases in which surgical help is impracticable, either because of the extensiveness of the disease, or the declining condition of the patient. In almost all such cases, cavities within the lung predominate and are responsible for untoward symptoms, perpetuation of the disease, and often an early fatality. It was in an effort to overcome the malign features of cavitation that Monaldi and his co-workers conceived the idea of direct drainage of cavities by a technique associated with his name.

The method consists of the introduction of a catheter into the cavity, whereby continuous suction may cleanse and possibly deflate it.

The practice is of recent origin, and its merits are not yet fully settled. Accumulated experience by any one worker is, as yet, on a relatively small scale. It has been my endeavour to collect and correlate critically those features, pathological and clinical, which may lead to a helpful evaluation of this new practice. This, the object of my thesis, is the outcome of my immediate interest in the method when I undertook work in tuberculosis. I am fortunate to be able to add my own experiences gained during the past two years.

HISTORICAL.

The direct approach to tuberculous cavities is not a recent procedure, but is mentioned in ancient Medicine, and fairly frequently from the Sixteenth Century onwards. However, it is not certain whether the cavities treated in this manner were pleural or pulmonary in nature.

In 1845, Hastings and Stork introduced a rubber catheter into a large apical cavity where it remained in situ for one month. In 1873 Mossler, and in 1874 Pepper, attempted the injection of tuberculous cavities with sclerosing agents. In 1885 de Cerenville reported a small series of cases of open drainage, and expressed the belief that cavity drainage had a promising future. During the beginning of the present century, many Continental workers including Sarfert, Sauerbruch, and Tuffier used a similar method of drainage. Laennec proposed the use of suction drainage in empyema, and in recent years, lavage and closed suction drainage have been used extensively in chronic empyema associated with tuberculosis.

In 1933, Dick attempted direct drainage of a large tuberculous cavity with a fairly good result, but the persistence of a sinus track discouraged him from repeating his experiment.

Eloesser, in 1937, employed closed suction drainage in four cases, but his results were unsatisfactory and after a short trial he abandoned the method as "disappointing". He described open drainage with packing as "curative but restricted in application and troublesome".

At the Forlanini Institute in Rome, Monaldi and Morelli, a pupil of Forlanini, had been especially interested for a number of years in the behaviour of tuberculous lung cavities. While admitting the role of 'biological' factors in cavity formation, they became convinced that 'mechanical' causes were predominant in the vast majority of cases, and that atelectasis was a common and important component of cavity walls. Accordingly, they believed that persistent suction within the cavity would counteract the mechanical factors and allow the expansion of the atelectasis.

Monaldi's first cases were carried out in the spring of 1938 at the Forlanini Institute, and reported on June 15th of that year before the Antituberculosis Society. His first patient was a woman with a large cavitary lesion in the upper and mid zones of her left lung. A catheter was introduced into the cavity and the results were said to be dramatic - the toxaemia cleared rapidly, the sputum ceased, and the cavitated area gradually healed. Later the catheter was withdrawn and the patient was discharged in good condition, with the disease completely arrested.

This case and several others treated soon afterwards gave Monaldi and his fellow workers encouragement and hope that immediate and perhaps lasting benefit could be expected from suction drainage. More widespread trial of the method by workers in all parts of the world has helped to reveal its possibilities and limitations, and has brought to light some helpful criticisms.

THE AETIOLOGY AND PATHOLOGY OF CAVITY FORMATION.

Perhaps the most important feature of pulmonary tuberculosis is the presence of a cavity, or cavities, in the lung. "It is because of cavities", said Laennec, "that tuberculosis may develop in any organ, but 'phthisis' develops only in the lung". They are, in fact, the laboratories wherein the tubercle bacillus grows and multiplies, and they act as centres which distribute its metabolic products throughout the body, causing both local and general symptoms of phthisis. Without cavities, chronic pulmonary tuberculosis is a fairly benign disease: with cavities, it is a progressive and malignant one.

General opinion is fairly unanimous regarding the preliminary mode of production of cavities. Tuberculous lesions develop in the small bronchioli, the lumina of which become narrowed and more or less obliterated by cellular proliferation. This process may then be followed by caseous necrosis and liquefaction, and thus a small cavity is formed, enlarging by progressive caseation. Similarly, if a number of such foci be present, multiple cavities may arise.

Until fairly recently, all cavities were considered to be due to a continuation of this process. Observation of cavities of considerable size in patients whose general condition was fairly good, and in whom there were but limited signs of activity of disease in the lung, caused workers to look for a factor or factors other than that of increasing destruction of lung tissue. The variation in size of cavities and their occasional spontaneous closure were suggestive of some previously unconsidered factor in cavity formation.

Much discussion has arisen concerning the various theories postulated to account for the mechanism of cavity formation, and they will be discussed seriatim.

Progressive destruction of pulmonary tissue, as stated above, was considered for some time to be the sole method of cavity formation. Although recent investigations have shown that this is not always so, there is no doubt that cavities, especially if multiple and in the presence of dense infiltration, may be of this nature. The healing of such cavities depends largely on the resistance of the patient, the institution of general sanatorium regime and, if necessary, collapse therapy.

Pinner advanced the theory that around cavities are two sets of fibres, one set of concentric fibres acting as constrictors and so tending to close cavities, and another set of radiating fibres acting as dilators, and tending to open them. This theory, although rather ingenious, is not supported by anatomical, pathological, or clinical findings.

More recently, a number of workers in various countries have endeavoured to explain the mechanics of cavity formation by a theory involving elasticity of expansion of the lung, which causes it to expand, and elasticity of retraction of the lung, which causes it to retract. This theory allowed each of these elasticities to act independently, and to be able to increase, decrease, and even disappear, without influencing one another, assumptions which are physically unsound.

In the United States, Van Allen and Wu advanced a somewhat similar theory. They stated that the "increased elasticity of the diseased parenchyma" caused by the "thickening of the interalveolar septa" played the main part in cavity formation and closure. It is difficult to imagine how inelastic fibrous tissue, which causes the above mentioned thickening, could increase the elasticity - rather should it decrease the latter.

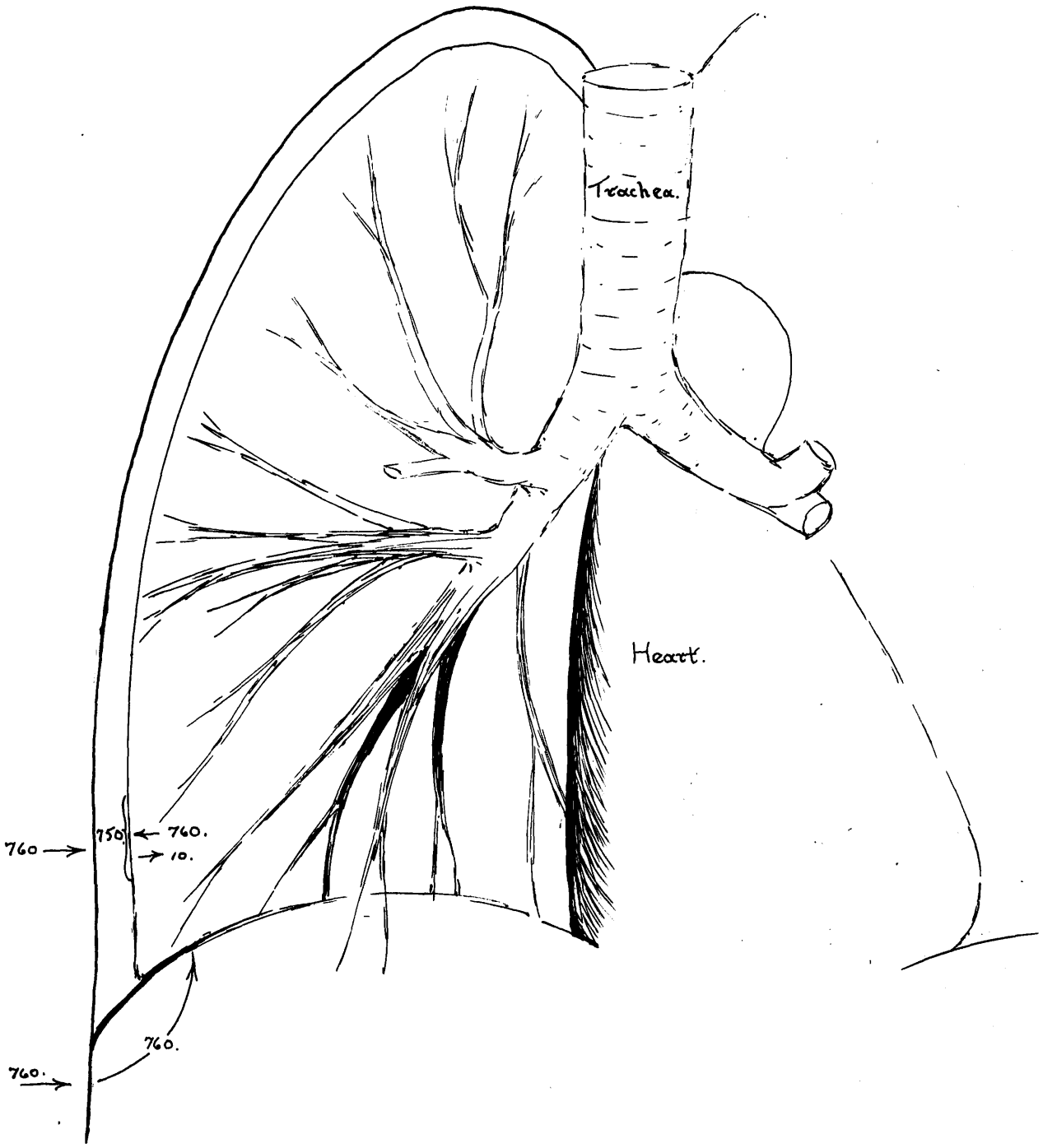
Parodi attributed cavity changes to the action of the weight of the lung on the diseased parenchyma, and treated the lung as a dead elastic body. He supported his conception by involved mechanical considerations which were sometimes at variance; for example, in some places he considered the lung to be a single unit, while in others, he stressed the independence of the various Lobes.

The most rational theories have been presented by Andrus and Coryllos, and these will be considered in more detail.

Andrus considers the factor most responsible for cavity formation to be the elastic pull of the lung tissue. In his conception of the nature of the pleural cavity, he agrees with many other workers, including Sir William Macewen, that the pleural cavity is merely a capillary interval containing a film of lymph which moistens the visceral and parietal layers of the pleura, and so keeps them in contact by the phenomenon of cohesion. A practical demonstration of the latter is seen when two microscope slides are placed together with a thin film of moisture between them; they do not fall apart, but adhere. A further demonstration of this phenomenon is afforded by the use of hydraulic traction in industry. There is a limit to the stress which a liquid bridge between two solids may resist without disruption of continuity, and this stress limit is that force necessary to reduce its pressure to that at which it boils at the temperature concerned.

Thus there is a fairly strong bridge between the visceral layer of the pleura and the parietal layer, which is attached to the chest wall. Accordingly, the lung is kept in a state of expansion by its attachment, via the pleura, to the chest wall whose move-

FIG. I.



Diagrammatic representation of intrapleural pressure.

Pressure in lung at inspiratory rest = 760 mm. mercury.
Pressure outside chest wall = 760 mm. mercury.
Elastic pull of lung = approx. 10 mm. "
∴ Intrapleural pressure = approx. 750 mm. "
or -10 mm. mercury.

ments it follows. That it is a state of expansion may be verified during a thoracotomy or post-mortem examination, when the lung is seen to be contracted down towards the hilum.

In this way Andrus explains the normal intrapleural negative pressure, and takes it as an index of the elastic pull of the lung. At all phases of respiration, therefore, the lung is stretched by a state of elastic tension in all directions. The degree of this elastic tension is increased with each inspiratory movement, and decreased with each expiratory movement, and so we have the variation in intrapleural pressure with inspiration and expiration (cp. Fig. I).

Every intrapulmonary chamber is thus constantly exposed to, and must resist, or be dilated by, this universally directed outward pull. Thus, Andrus states, any break in the lung surface by a tuberculous lesion will be pulled out into the form of a cavity without any necessary excavation of tissue. To prove this point, he inserted a scalpel into a human lung removed at autopsy, closed the pleural opening with string, and inflated the lung through a tube inserted into the bronchus. To prevent collapse of the lung when being sectioned, the specimen was frozen, and on examining the lung an obvious spheroidal cavity was seen.

It is fairly generally admitted that atelectasis of lung parenchyma causes an increase in the elastic tension of the lung (it is one of the main factors in dilatation of the bronchi in bronchiectasis), and so Andrus concludes that with atelectasis, the pull on the cavity is greater, and therefore the latter will tend to enlarge. In the variations of the degree of atelectasis commonly seen with alterations in the state of the tuberculous disease, he offers a theory to account for the changes in size of cavities and even their spontaneous closure - observations commonly noted radiographically.

Coryllos casts doubt on this hypothesis by stating that "it is difficult to understand how cavities could remain open under pneumothorax, which deprives these cavities of any conceivable support". Andrus answers this charge by stating that, when an

artificial pneumothorax is present, with the outward movement of the chest wall and parietal pleura, the gas pressure in the intrapleural space falls and a gas pressure difference is established between the contents of the pleural space and those of the lung. The contents of the pleural space being compressible, the visceral pleura is "pushed out" by the excess pressure of gas in the lung until the position of equilibrium of stresses is again attained.

He further states that if, in the presence of pneumothorax, the pulmonary tissue had, in fact, "no conceivable support", it is apparent that the lung must contract to a state of non-elastic tension, as is actually the case when the thorax is opened. The persistence of a negative pressure in the pleural space under these conditions is, he concludes, further evidence that the lung is actually stretched in a state of elastic tension.

His explanation of the positive pressures in cavities is not very impressive. He postulates the theory that, if a cavity having an obstructed bronchus is reduced in size by the atelectatic shrinkage of pericavital tissue, such a rise in gas pressure is a necessary consequence.

In 1932, Coryllos presented a new conception of the mechanics and biology of cavities, and in 1936 he again published a paper containing a more complete résumé of his work. Like Andrus, he was convinced that tissue destruction was not the sole determining factor in cavity formation. Many other workers including Goldman, Brunn, Ackerman, Shipman, and Eloesser have more recently pursued investigations along these lines and have agreed with him.

In his theory, Coryllos states that, in the majority of cavities the draining bronchus is affected, a fact borne out in a large series of cases reported by Brunn et alia, where 100 autopsies on patients who had cavitation showed interference with full patency of the draining bronchus in every case. In another series of cases, Shipman found that 10% of the cavities showed tuberculous involvement of the draining bronchi.

This disturbance of the normal cavity-bronchus relationship

may be due to several factors, either intrabronchial or extra-bronchial, the former being the commoner. In the early stages of the disease, the bronchus may be affected by an allergic inflammation, seen through the bronchoscope as a red and oedematous area without localised ulceration or necrosis. Thus the lumen of the bronchus is narrowed, and this may increase until finally there may be no air passage present. In many cases however, as the bronchi dilate during inspiration, an airway may be formed, and so air may pass into the cavity during this phase of respiration. This is the basis of Coryllos's theory of a one-way valvular arrangement, allowing air to pass predominantly from bronchus to cavity.

Apart from allergic swelling of the bronchus, a similar state of affairs may be caused by actual tuberculous bronchitis, a plug of fibrinous exudate or caseous material in the lumen, and emphysematous blebs. Extrabronchial stenosis may be due to constriction of the bronchus by neighbouring fibrosis and cicatrisation.

In a series of bronchoscopic examinations carried out in 350 patients by Brunn et alia, some evidence of bronchial involvement was seen in approximately one-third of the cases, i.e., in bronchoscopically visible bronchi. Simple oedema and haemorrhage were the most common causes: tubercles, polypi, ulcers, and hard and soft stenosis were less common.

Coryllos supports his theory by a number of experiments, the chief of which is the estimation of the intracavitary pressure, which gives some indication of the state of the valve mechanism.

In 1930, Pearson, writing in the British Medical Journal, reported a case of pulmonary tuberculosis in which needling of the cavity present revealed a positive pressure both in inspiration and in expiration (+15/+20 cm. water). Some months later he found the pressures to be approximately those of the normal bronchial tree. Since then many other workers have investigated the conditions fully and have published results similar to those of Coryllos, viz., that in a large percentage of cavities, the intracavital pressure is more positive than normal. The presence of a valvular constriction

FIG. II.

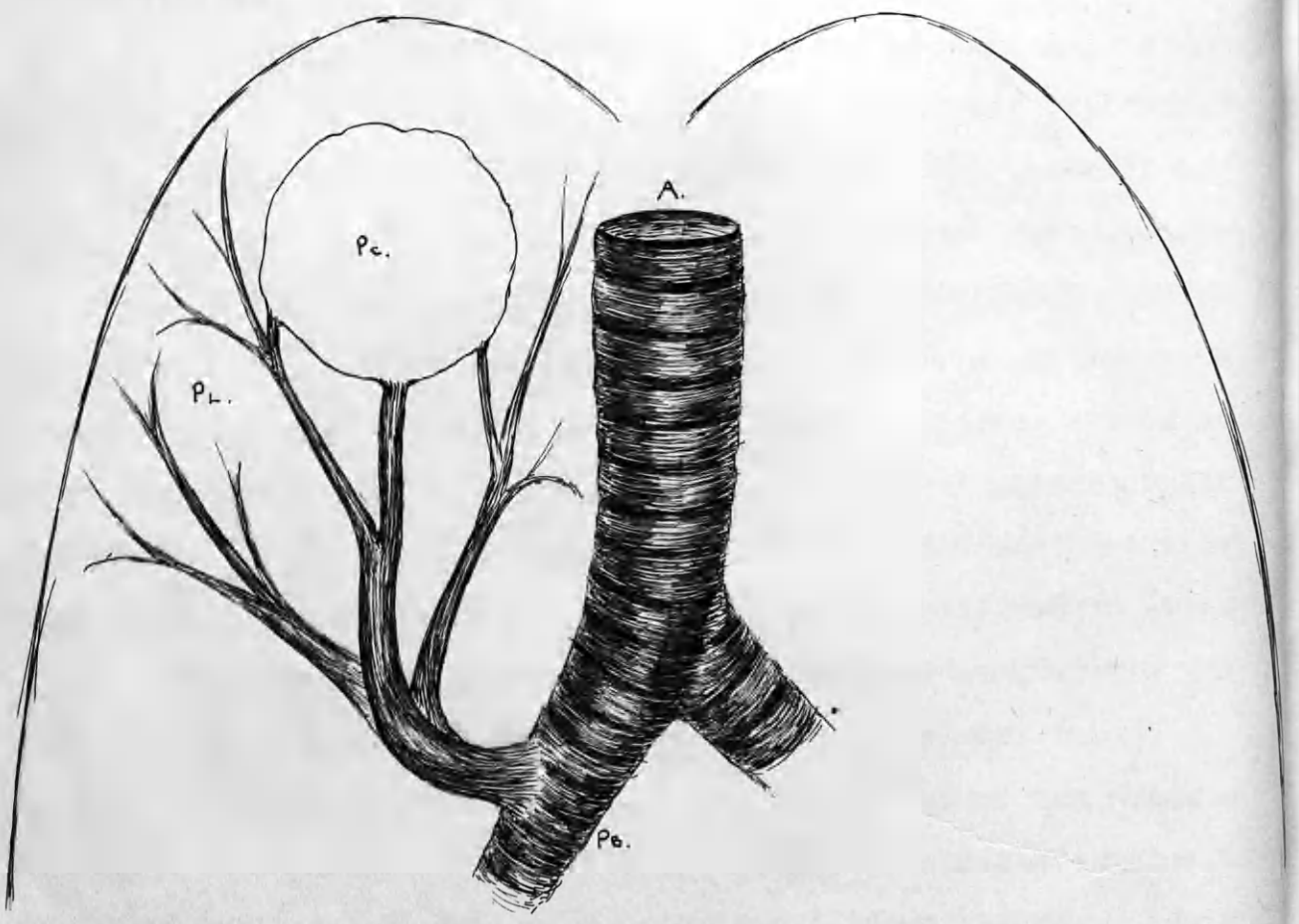


Diagram illustrating pressure variations in lung.

A = atmospheric pressure.
P_b = intrabronchial pressure.
P_c = intracavitary pressure.
P_l = pressure in surrounding lung.

of the bronchus allowing air to flow predominantly from bronchus to cavity, but not vice versa, could certainly explain this state of affairs. Not all cavities have a positive pressure and in these cases there is usually no efficient valve-like arrangement present, air thus being allowed to pass in and out of the cavity freely.

The explanation of the mechanism producing higher pressures within cavities than exist in the surrounding lung, is based on sound principles of physics (cp. Fig.II). Let A = atmospheric pressure, P_b = intrabronchial pressure, P_c = intracavitary pressure and P_l = pressures in surrounding lung. A is constant and numerically zero. P_b varies with the movements of respiration and, excepting for a slight lag, is equal to P_l. As air flows only from a point of higher pressure to a point of lower pressure, air can pass into the cavity only when P_b is greater than P_c. During cough, P_b becomes greater than P_c because of the lag in development of the high pressure in the cavity, especially if there is some disease in the draining bronchus. If a valvular arrangement preventing flow of air from cavity to bronchus exists, the air in the cavity will remain at a higher pressure. Kymographic tracings of intracavitary pressures show that air passes in this manner only periodically and therefore, it may be deduced that the pressure changes within the cavity with respiration are not caused by the flow of air in and out of the cavity, but are due to transmitted changes from the surrounding lung with the respiratory movements.

Coryllos, Eloesser, Brunn et alia attribute the occasional persistence of cavities in an otherwise well controlled artificial pneumothorax without adhesions, or in a thoracoplasty, to the upset of the normal bronchus-cavity relationship. They state that kinking of the bronchus occurring during collapse therapy may accentuate the condition by further narrowing the bronchial airway.

Just as Coryllos is of the opinion that disease of the bronchus is the major factor in cavity formation, he also believes that most cavities close by complete blockage of the draining bronchus. Auerbach and Green, in a pathological study of over 2000cavities, recorded that they did not witness a single open cavity with a diameter of three centimetres or more in which they were not able to trace a bronchus opening into the lumen of the cavity. Salkin, Cadden and McIndoe however, pursued investigations which, they stated, disproved this theory. To eliminate changes due to post-mortem handling, they outlined the tracheo-bronchial tree by post-mortem bronchography, using a radio-opaque mixture of potassium iodide, barium sulphate and milk. When a cavity did not fill by this method, they injected the suspension through a needle inserted into the cavity. They then proceeded to autopsy, and found that, in a series of 70 cases with cavities of three centimetres diameter and over, 18 did not permit the passage of the suspension through the bronchus into the cavity. They therefore concluded that cavities may exist without communicating with their relative bronchi. However, it is quite possible that there may have been a small bronchial opening through which air could pass without allowing the passage of the radio-opaque suspension used. Auerbach and Green ascribe the discrepancy between their findings and those of the former to an inadequate search for an open bronchus.

Coryllos states that, with the closure of the bronchus, the air entrapped in the cavity becomes absorbed, the rate of absorption being regulated by the degree of circulation of blood around the cavity. It will be rapid in small cavities with little infiltration and surrounding fibrosis, i.e. the so-called young and elastic cavities. It will be slow in large and thick-walled cavities or become impossible when a whole lobe is shelled out with complete destruction of the surrounding parenchyma. Thus, he asserts, as absorption of air progresses, the cavity will shrink and finally disappear and if, for any reason, the draining bronchus reopens, the cavity will reappear. In this way he explains the peculiar variations in the

size of cavities, their occasional retention of fluid, and their spontaneous closure sometimes observed radiographically.

The closure of cavities during treatment by artificial pneumothorax is likewise, according to Coryllos, due to the complete kinking of the draining bronchus as a result of the pneumothorax. Brunn et alia consider that certain cavities which do not disappear under pneumothorax therapy, but close on re-expansion of the lung, do so by virtue of a resolution of the allergic swelling or inflammation present in the bronchial wall, and so free ingress and egress of air and secretions and subsequent closure of the cavity may occur.

With the prominence given to the role of the bronchus in cavity formation, some workers have endeavoured to produce obliteration of the lumen of the draining bronchi by artificial means. Adams and Vorwald (1943) cauterised the bronchi of dogs and produced stenosis, with a high incidence of cavity closure. More recently (1943), Dillwyn Thomas and his co-workers in Wales produced artificial bronchial occlusion by the injection of plasma, which formed a clot. This procedure was carried out in six patients in the nature of a preliminary experiment and the results appear to be encouraging.

MONALDI'S THEORETICAL BASIS AND RATIONALE OF CAVITY DRAINAGE.

Monaldi divided the mechanical factors responsible for the formation of cavities into two groups - endocavitary and extracavitary. The former were valve-like in action, thus preventing free passage of air to and from the cavity. The extracavitary forces, he attributed to the elastic pull of the lung and to the compression of the cavity wall and surrounding lung tissue during expiration. This compression from without, in conjunction with the increased pressure within the cavity during expiration (often due to the valve-like action of the obstructed bronchus), played, he stated, an important role in the creation of a ring of atelectatic lung tissue around the cavity.

He experimented with suction drainage primarily with the idea of overcoming these unfavourable extracavitary and endocavitary

forces. He had recognized that the re-expansion of the ring of atelectatic lung tissue was an important feature in the healing of those cavities which closed either spontaneously or as a result of simple relaxation measures, such as hypotensive artificial pneumothorax or phrenic paralysis.

Further, from his experience with suction drainage in empyema, he felt that the method offered some hope of healing by the continual removal of infected material.

The classification of cavities adopted by Monaldi is based on their behaviour:-

(a). Retractile — such cavities may occasionally heal spontaneously or with simple relaxation therapy, but may reappear. As the cavity heals, the space it previously occupied becomes replaced by re-expansion of the surrounding ring of atelectatic tissue in which the elastic fibres are intact and, to a varying degree, by compensatory emphysema.

(b). Undeformable — cavities with absolutely rigid walls. Such cavities, he states, are not so frequent as one might imagine as, in his opinion, the majority may be at least reduced in size by the application of suction drainage.

(c). Inert — between the 'Retractile' and 'Undeformable' types there is an important group of cavities described by Monaldi as 'Inert'. Although the elastic fibres of the atelectatic tissue in their walls remain for the most part intact, these cavities have lost their power of elastic retraction as a result of the infiltration of their walls with the products of disease and the persistence of unfavourable mechanical influences. Monaldi considers that, by correcting the harmful mechanical forces and by removing the disease products by suction drainage, cavities of this type may be converted to the 'Retractile' group.

In explaining the modus operandi of his procedure, Monaldi considers that five features, which usually act concurrently, are brought into play.

1. An early hygienic effect is the cleansing of the walls of

the cavity, as a result of which, blood, pus, necrotic debris and other bacillus laden material become separated and are eliminated in the drainage secretion. Progressively, purulent fluid becomes thinner, then serous, and finally may cease. The resultant disappearance of tubercle bacilli from sputum and drainage is probably a major reason for the symptomatic improvement often noted in the patient.

2. Atelectatic elements in the cavity wall re-expand under suction and so help to obliterate the cavity space. This, Monaldi considers to be the most important factor.

3. Regression and absorption of alveolar exudation occurs as the suction attracts alveolar fluid towards the lumen of the cavity ("draining the marshes"). This is evidenced from the continuing serous secretion obtained from the catheter. However, excess of suction will bring about an engorgement, resulting in a greater X-ray density of the pericavital tissues probably due to dilatation of blood vessels, with resultant fluid exchanges. Even blood may appear as a result of excessive suction.

4. Compensatory emphysema of tissue in the vicinity of the cavity, or in the more distal parts of the lung, may occur and so help to fill the cavity space. Mediastinal and diaphragmatic displacement towards the cavity may be considered in a similar light.

5. When the cavity walls do come together, they consist of healthy granulation tissue. Firm and permanent healing, therefore is, a priori, more likely to occur than during the apposition of two diseased surfaces such as may occur, for example, in spontaneous closure or during the course of collapse therapy.

CONTRA - INDICATIONS TO THE PROCEDURE.

1. An absolute contra-indication is the presence of a free pleural space in the region to be drained. If such a space exists, pleural symphysis must be carried out.

2. The method must not be applied to a cavitated area in the midst of acute caseous exudative disease. However, drainage of a chronic cavity may occasionally be justified in spite of the

presence of acute disease in another part of the same lung, or in the opposite lung.

3. As a general rule, no attempt should be made to drain a bleeding cavity until the haemorrhage has ceased, but if the latter persists, the risks of intervention may be justified. The treatment was induced at Rome on a few cavities which were bleeding persistently and some benefit is believed to have resulted from the introduction through the catheter of small quantities of coagulant solution.

4. Cavities situated near the hilum should not be treated by intracavitary drainage on account of the proximity of the large root vessels, and the possibility of their perforation.

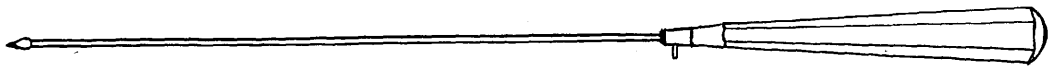
TECHNICAL FEATURES OF CAVITY DRAINAGE.

Fusion of the visceral and parietal layers of the pleura in the region of the catheter insertion is essential, as the presence of a free or potential space would necessarily give rise to the possible occurrence of an empyema or pyopneumothorax during the course of treatment. Before drainage can be considered, an artificial pneumothorax must be attempted in at least three different situations to ascertain that complete fusion of the pleura exists. If a potential space does exist, it must be obliterated artificially. This may be accomplished by the intrapleural injection of blood withdrawn from the patient, either whole or mixed with an equal volume of normal saline, or of a 20 - 50% solution of glucose. The pleura should be tested at fortnightly intervals and the above procedure repeated if necessary.

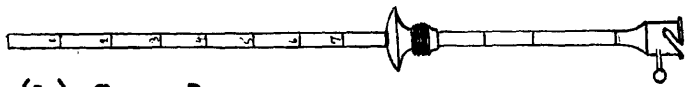
Sufficient localisation of the cavity is often possible with the information obtained from a postero-anterior radiograph, but in certain cases tomography is desired.

The cavity may be approached from the anterior or posterior aspect. The former is easier for the operator and more comfortable for the patient. It has the additional advantage that, should a subsequent thoracoplasty be deemed necessary, infection of the field

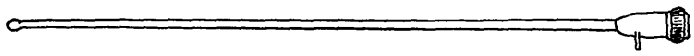
FIG. III. — CAVITY DRAINAGE EQUIPMENT.



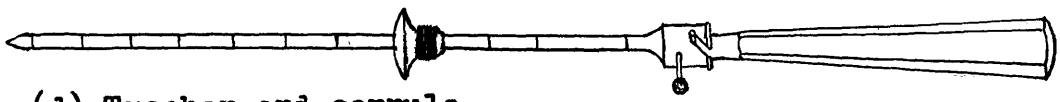
(a) Trochar.



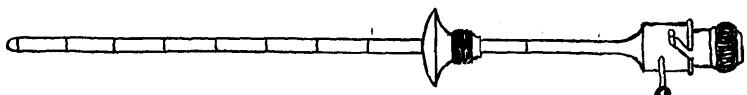
(b) Cannula.



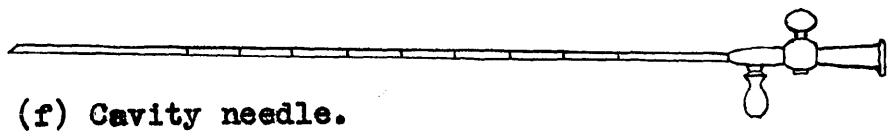
(c) Olive-ended trochar.



(d) Trochar and cannula.

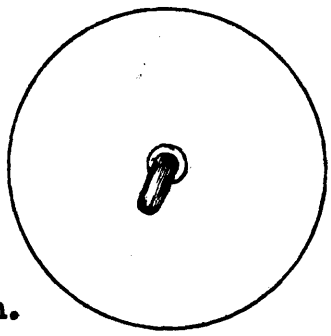


(e) Cannula with olive-ended trochar.

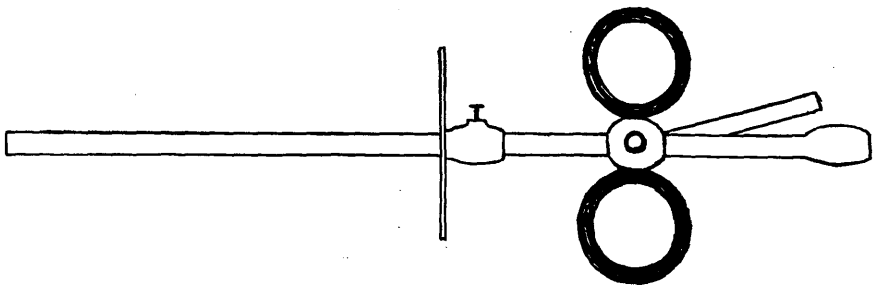


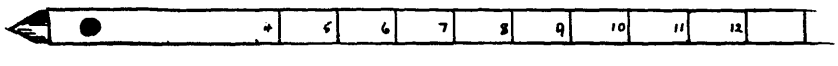
(f) Cavity needle.

(h) Catheter.



(g) Flange and sheath.





(i) Trochar and cannula devised by Bottari.

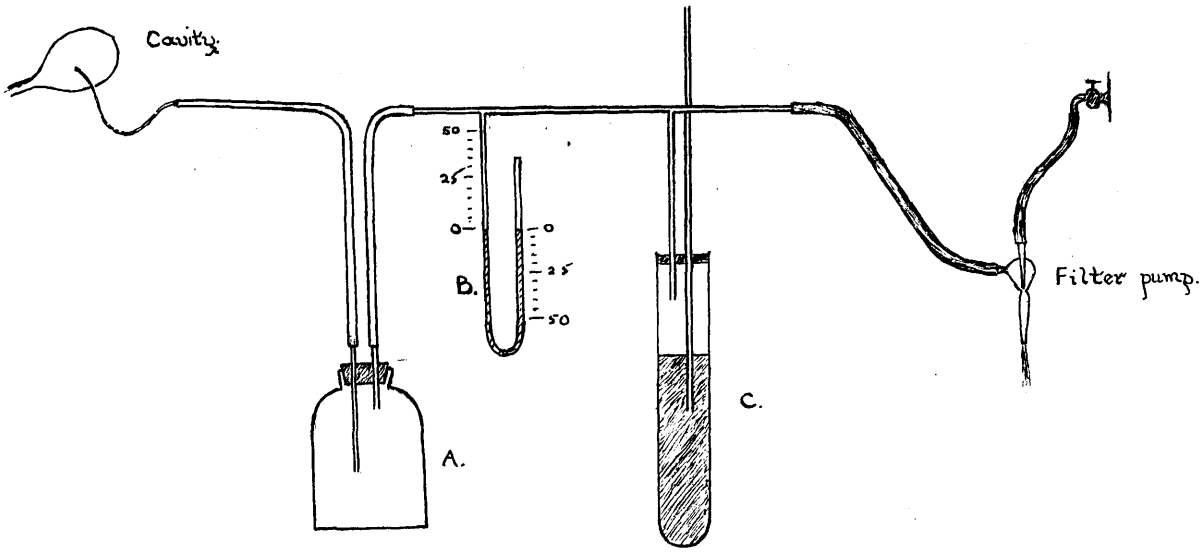
of operation is less likely to occur when the anterior, rather than the posterior, method of approach is used.

As the majority of cavities are situated in the upper zone of the lungs, the second interspace is the usual site chosen for puncture, thus allowing the catheter to enter the cavity at its middle or lower region. Cavity puncture is most conveniently carried out in the operating theatre. Screen control during the procedure, as advocated by Monaldi, has not been found necessary.

The apparatus required for cavity drainage is fairly simple and is, in part, similar to that required for pneumothorax induction, viz., local anaesthetic, syringe and needles, scalpel, and pneumothorax apparatus. The special instruments required are: cavity needle, trochar and cannula, catheter, and sheathed rubber flange. The cavity needle (fig. III$_f$.) is a long No. 17 gauge pneumothorax needle, graduated in centimetres. A modification of the trochar and cannula originally used by Bottari and Babolini (fig. III$_i$.), constructed on the same principle as the Kuss pneumothorax needle, is used (fig. III a,b,d.). The graduated barrel of the cannula is 14 cm. long with a lumen of 4 mm. diameter, admitting a No. 6 English catheter. A sliding shield may be fixed at a chosen point on the barrel to prevent penetration beyond a desired depth. There is a lateral arm near the outer end for connection with the manometer and two side openings near the inner end. The trochar has a broad head with a rather blunt point and a thin shaft of smaller diameter than the cannular lumen, thus allowing air to communicate freely with the manometer through the side openings of the cannula. The catheter (fig. III$_h$.) is 50 cm. in length, with either an end or a side opening, and is composed of radio-opaque rubber of No. 6 English gauge.

A preliminary injection of omnopon and scopolamine, or the administration of nembutal, is carried out an hour before the insertion of the catheter. The head of the operating table should be slightly lower than the foot, to avoid the possibility of cerebral air embolism. The chosen part of the chest wall is infiltrated with local anaesthetic and a long exploratory needle is introduced in a

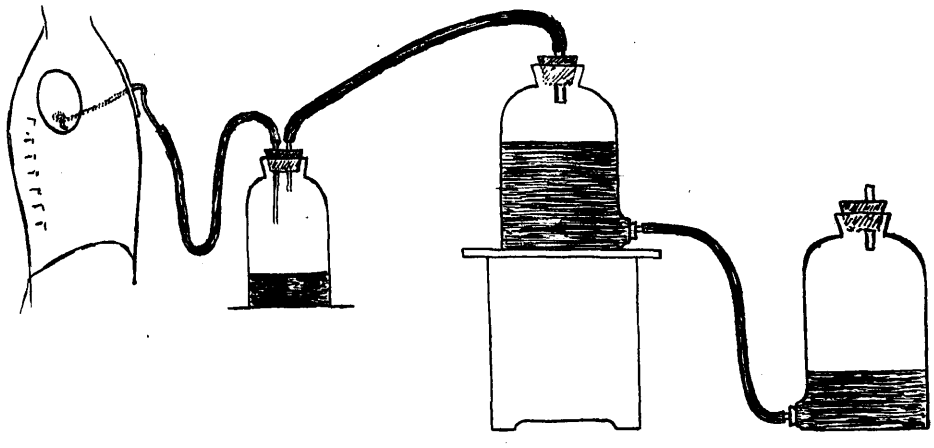
FIG. IV.



Suction aspiration by means of filter pump.

(A). Receiver for secretions.
(B). Manometer graduated in c.cm. of water.
(C). Pressure controller (Jeanneret and Joyet).

FIG. V.



Bottle suction as used by Monaldi.

predetermined direction towards the cavity. A three-way stop-cock connects it to a small syringe containing saline, and to the manometer. When the cavity wall is pierced, a sensation of overcome resistance is experienced, somewhat similar to that often obtained on piercing the dura in the course of a lumbar puncture. At the same time a characteristic manometric fluctuation occurs and, if the piston of the syringe is withdrawn, air bubbles freely through the saline.

The depth and direction of the needle having been noted, the latter is then withdrawn, the skin is incised and the trochar and cannula inserted. When the cavity is punctured (and the manometric fluctuations again obtained), the trochar is withdrawn and the catheter inserted into the cavity throught the cannula. The cannula is then withdrawn very gently, great care being taken to avoid dislodging the catheter. The latter was originally kept in position by means of silk thread and adhesive tape, but the rubber collar and flange (fig. III_g.) is a more stable and satisfactory method of fixation.

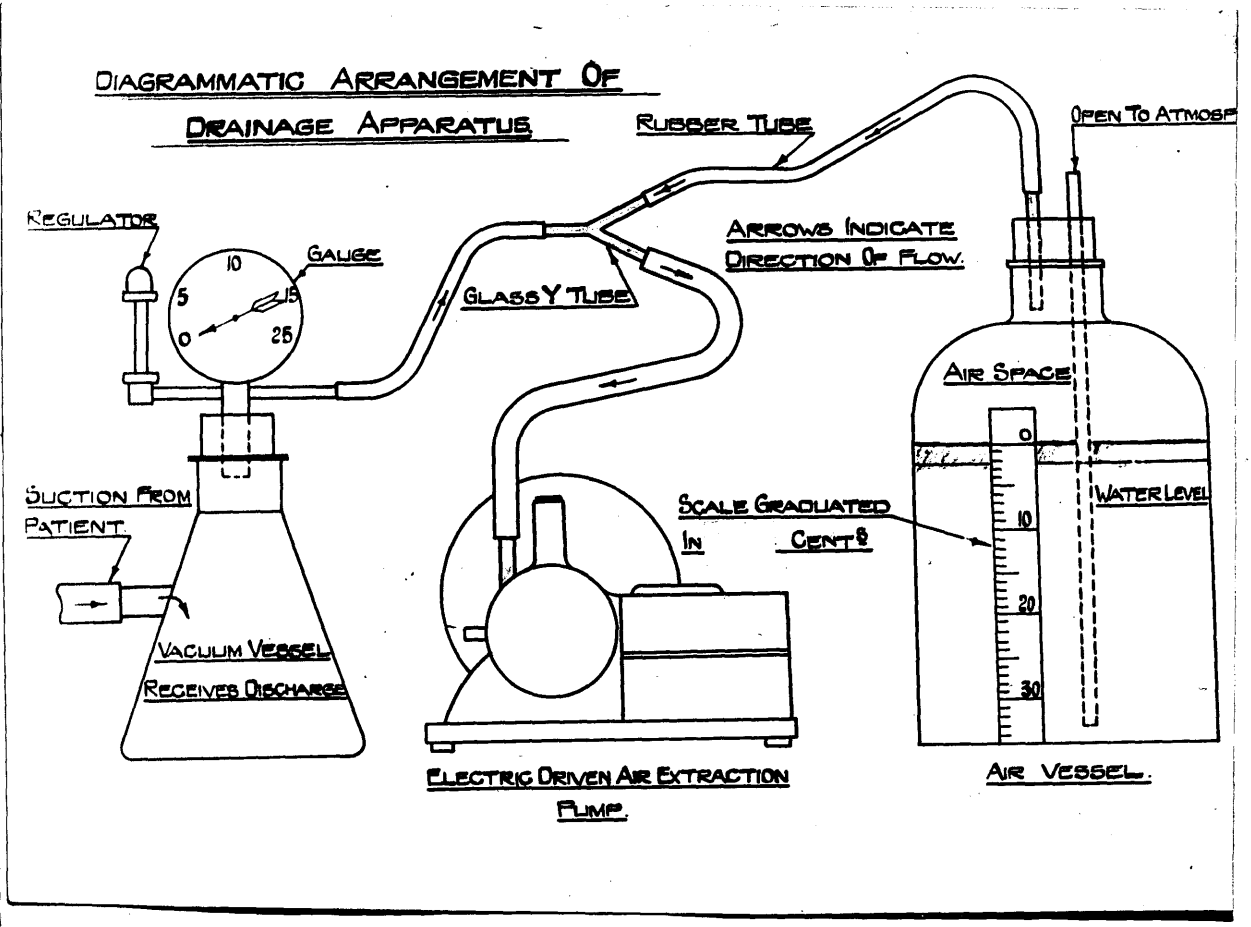
Suction aspiration is commenced on the day following the operation, by attaching the catheter to whichever form of suction apparatus is desired.

Bottle suction (fig. V.) is recommended and used by Monaldi and Kupka, but, while it is simple and inexpensive, it has the disadvantage of requiring frequent interchanging of the bottles. The negative pressure exerted on the cavity is determined by the difference between the water levels and consequently falls as the upper bottle empties.

The filter pump (fig. IV.) may also be used. The pressure controller devised by Jeanneret and Joyet ensures that, when the suction becomes excessive, atmospheric air is sucked through the long tube, thus limiting the negative pressure in the aspirating circuit.

This principle is also employed in the method of aspiration used in the present series, viz., the small electric suction unit (fig. VI.). The latter consists of a pump with a volume displacement of 30 litres per hour, an aneroid pressure gauge graduated in

FIG. VI.



Diagrammatic arrangement of suction unit used in present series.

centimetres of water, a vacuum bottle of one litre capacity, a pressure regulator and a large Winchester bottle acting as a pressure controller similar to that of Jeanneret and Joyet. A small trap bottle may be interposed between the patient and the pump to collect the cavity secretions.

The position of the catheter in the cavity may be ascertained by radiography or screening, and at the same time an outline of the base of the cavity, and the patency of its draining bronchus or bronchi, may be determined by the injection through the catheter of four or five ccs. of lipiodol. The catheter may require to be adjusted so that its tip lies in a suitable position for drainage.

Continuous suction is not applied for twenty-four hours but during this period the catheter may be gently aspirated on several occasions with a syringe, when air and blood-stained pus may be evacuated. The following day suction is commenced at an initial pressure of -2 to -4 cm. water and this reading is gradually increased each day until, at the end of 7 - 10 days, the pressure considered to be most suitable is reached. This varies a little in individual cases but is in the region of -15 to -25 cm. water. Too low pressures lead to insufficient drainage, frequent blockage of the catheter and arrest of cavity retraction. Excessive suction causes increase in cough, dryness in the throat, pyrexia, malaise, haemorrhagic secretion and blood-staining of the sputum. It may also produce a transudate into the lung around the cavity, shown radiographically as a peri-cavital opacity, and so interfere with the therapeutic action of the treatment.

Suction is not applied continuously, but intermittently. There is slight variation in the methods used to bring this about. It may be applied every alternate two hours throughout the day and night, but in the present series the method employed was to discontinue it for ten minutes in each two hour period and also to discontinue it during the night.

During the course of suction drainage, some information as to the state of the draining bronchus or bronchi may be elicited by the introduction of lipiodol or some coloured dye, such as

methylene blue, into the cavity. If the bronchus is patent, lipiodol will be seen radiographically to pass through its lumen: if methylene blue is injected, the sputum soon becomes tinged with the dye. Too frequent injection of lipiodol is to be deprecated as it may cause dissemination of the disease.

Intracavitary pressure readings may also be periodically recorded. With a widely patent bronchus, the readings approach neutral, e.g. -4/+4 cm. water: when a check valve mechanism is present, more positive readings are obtained, e.g. -3/+7, or 0/+6: when the bronchus is occluded, air is absorbed from the cavity and the readings then tend towards the negative side, e.g., -6/-1.

Repeated examinations of the sputum and drainage secretions are made to determine the presence, or otherwise, of tubercle bacilli. In favourably progressing cases, the sputum usually becomes negative shortly after the institution of drainage and gradually the cavity secretion also becomes negative. Should there be other tuberculous foci present in the lung, the sputum may not become converted in this manner.

The skin puncture wound should be dressed daily with a mild soothing antiseptic such as acriflavine emulsion. Discharge around the catheter varies: it may be slight but in a considerable number of cases it is fairly copious. The wound may grow firmly round the tube and maintain the state of air tightness, but more often than not, this is not so. Occasionally silver nitrate or copper sulphate is required to cauterise exuberant granulation tissue which may form at the surface.

The original catheter is left in situ as long as possible. The average life of radio-opaque tubing in the chest is about six months, but if sterilised frequently it is much shorter. Re-insertion of a fresh catheter may be required if the rubber shows signs of perishing or if the tube is accidentally expelled, an occasional occurrence in spite of the most adequate fixation. If such is the case, in the majority of cases re-introduction is

easily carried out and a well paraffined catheter usually slips easily along the sinus track into the cavity. Occasionally, however, owing to marked angulation of the track, or stricture formation at the pleural or cavitary level, re-insertion presents considerable difficulty. This may be overcome by threading the catheter over a metal stilette similar to the de Pezzer catheter introducer. More satisfactory results are obtained by the use of a cannula with an olive-ended obturator (Fig. IIIc) especially designed for the purpose.

The degree of diminution in size of the cavity may be observed by means of periodic radiographs. The length of time the catheter should be left in situ depends to a large extent on the progress of the particular case. When the cavity closes, the catheter becomes spontaneously expelled.

After removal of the catheter has been carried out, the period of time required for complete closure of the sinus varies considerably. According to Monaldi the average time is very short, but in the present series, wide variations have been noted. A few of the tracks healed within one month, but the majority required a much longer period and, in fact, in a number of cases, the sinus remained persistently open and continued to discharge pus which often contained abundant tubercle bacilli. Sound healing of the track is especially important if a subsequent thoracoplasty is to be performed and it is usually important that such a thoracoplasty be carried out as soon after cessation of cavity drainage as possible, to prevent the possibility of subsequent re-enlargement of the cavity.

COMPLICATIONS OF THE PROCEDURE.

Embolism and haemorrhage may occur during the introduction of the catheter. The danger of air embolism may be greatly diminished by having the patient lying flat, with the head at a slightly lower level than the chest during the operation, and by avoiding unnecessary manipulation of the trochar and cannula in the lung. One death from air embolism was reported in the original series of cases at Rome. One fatal case of haemorrhage due to

perforation of an intracavitary vessel, occurred in the present series. Weber reported a fatal case occurring as a result of the trochar entering a large vessel near the lung root. The possibility of traumatic haemorrhage appears most likely in hilar cavities, or as a result of puncture of a pulmonary aneurism in a cavity vessel.

Empyema has been reported by several workers who failed to ascertain the true degree of fusion of the visceral and parietal layers of the pleura.

Mild secondary infection of the sinus track occurs frequently. Monaldi considers it to be of little importance, but in our experience it may be troublesome and may cause much delay in closure of the sinus track. In one case, a secondary dermatitis in the neighbourhood of the sinus arose as a result of irritation from the drainage secretions. Tuberculous infection of the catheter track is uncommon, as is infection of the chest wall, although the latter complication did occur in Rome following an infected haematoma.

Exacerbation of pulmonary disease in the vicinity of the cavity is, in practice, comparatively infrequent, although theoretically it might appear to be one of the most common complications of the treatment, especially on account of the surrounding vasodilatation which takes place. Careful attention to technique minimises the risk of its occurrence.

Photograph to show Monaldi catheter in position and connected to small electric suction unit.

PERSONAL EXPERIENCES WITH PROTOCOLS OF CASES TREATED.

Case 1.

L. H. (aet. 26 years) was admitted to hospital on 22.7.40 with a history of lassitude of two years' duration, and cough and spit of seven months' duration. Her general condition was poor, cough was very troublesome, and copious sputum contained numerous tubercle bacilli. A radiograph showed the presence of bilateral fibro-cavernous tuberculosis with a huge right upper lobe cavity and a smaller cavity near the right hilum.

Left artificial pneumothorax was induced on 12.4.41, but following section of adhesions on 22.7.41, fluid developed in the left pleural space and the pneumothorax was abandoned. As cough had become very troublesome, often giving rise to dyspnoea, and sputum had increased in amount to 16 ozs. daily, a Monaldi catheter was inserted into the right upper lobe cavity on 18.9.41, when lipiodol cavernography demonstrated full patency of the draining bronchus. The effect on her cough was dramatic, and within twenty-four hours it was markedly diminished. During the course of drainage, repeated radiographs showed gradual diminution in the size of the cavity which on 10.3.42, was reduced in size by half, and the catheter was accordingly removed. Drainage secretions became negative for tubercle bacilli on 1.11.41, six weeks after the insertion of the catheter, and two weeks later the sputum also became negative. Her general condition was much improved, and weight, which at the onset of treatment was 8 sts. 3 lbs. increased to 9 sts. Sputum was reduced in amount from 16 ozs. to 5 ozs. daily, and drainage secretions, which averaged $\frac{1}{2}$ - 1 oz. daily, amounted in all to 113 ozs. over the total period of treatment. The sinus tract closed 3 weeks later, and progress in her condition was maintained for a further period of 4 months, when death occurred from a sudden massive haemoptysis. The latter presumably resulted from rupture of a vessel in the right hilar cavity, which had persisted in its original state.

PLATE A_{1-4}.

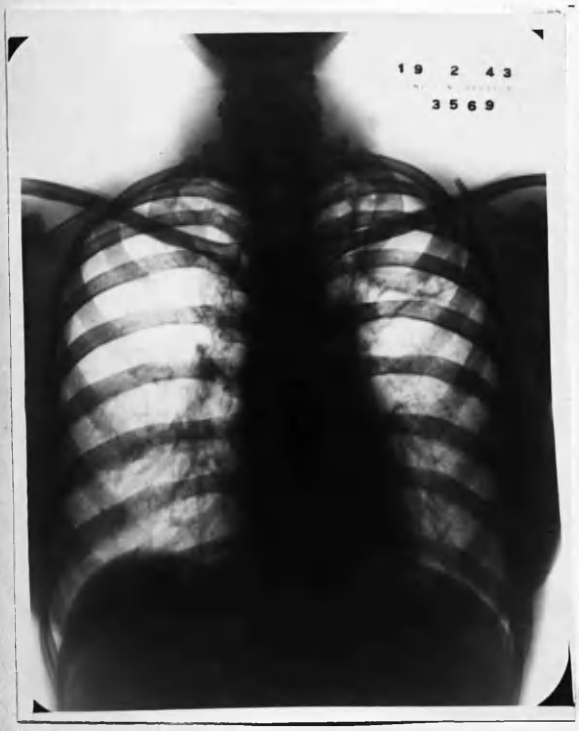


PLATE A_1.

Large left upper lobe cavity before onset of drainage.

PLATE A_2.

Monaldi catheter in cavity. Lipiodol cavernogram reveals blockage of draining bronchus.

PLATE A_3.

Cavity much smaller after 4 weeks' drainage.

PLATE A_4.

Catheter removed (3.5.43). Cavity very small with surrounding consolidation.

Case 2. (cp. Plate A_{1-7})

J. T. (aet. 24 years) was admitted to hospital on 23.10.41. Investigation revealed the presence of bilateral tuberculous infiltration of her lungs with a large cavity in her left upper zone, a fairly large cavity at her left apex and a similar cavity at her right apex.

A right artificial pneumothorax was induced on 6.4.42 and on 25.4.42 a left artificial pneumothorax was also induced. The latter was ineffective on account of dense adhesions and, as she complained of dyspnoea, it was abandoned. As the upper lobe was adherent, the right apical cavity was not affected by the right artificial pneumothorax which was, therefore, abandoned on 22.7.42. On re-expansion of the right lung, the cavity gradually diminished in size and finally disappeared six months later. On 21.2.43 a Monaldi catheter was inserted into the large left apical cavity, after fusion of the pleura had been carried out by the intrapleural injection of 40 ccs. of blood and saline. Lipiodol introduced through the catheter did not pass through the draining bronchus on account of bronchial blockage. Ten days later a radiograph showed marked reduction in the size of the cavity, and one week later a lipiodol cavernogram revealed full patency of the draining bronchus once again. The reduction in the size of the cavity continued and on 3.5.43, when it had almost completely disappeared, the catheter was removed. However, about ten days later the cavity re-expanded to approximately the size of a halfpenny and the catheter was re-inserted. A Bacillus Proteus infection of the catheter track occurred and the patient's general condition deteriorated slightly. The infection cleared up, and her general condition improved, on washing out the track with azochloramide and thiazamide. As the cavity was again reduced in size, the catheter was removed on 23.8.43 after having been in situ for six months. Her general condition improved steadily during the period of suction drainage and her weight increased by 14½ lbs. Cough became less troublesome and her sputum, which was reduced from ½ oz. to a trace daily, became negative for tubercle bacilli six weeks following the

PLATE A5-7.

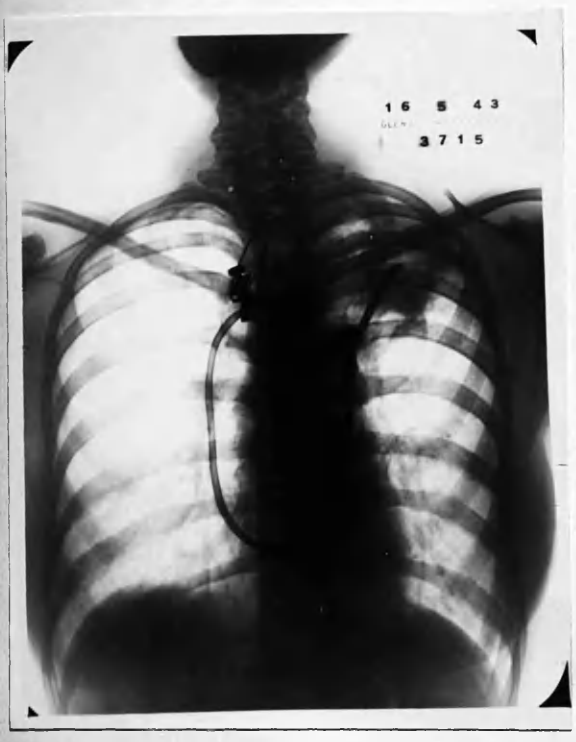


PLATE A5.

Monaldi catheter re-inserted following re-expansion of cavity.

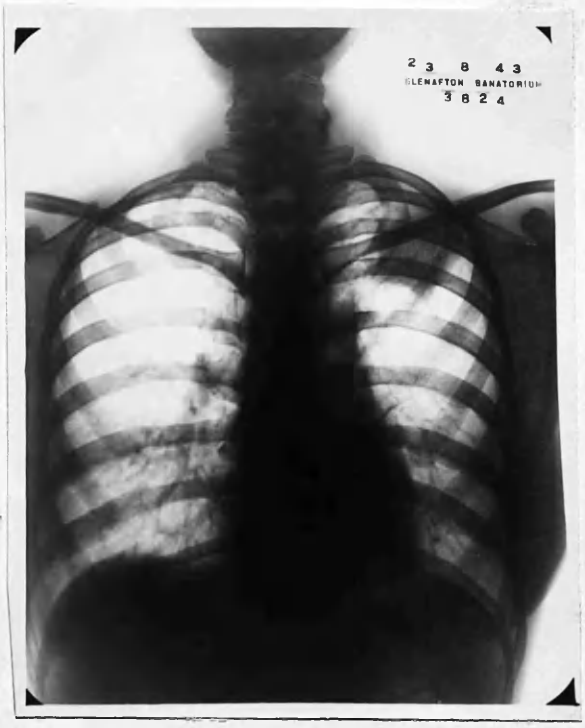


PLATE A6.

Cavity again very small.

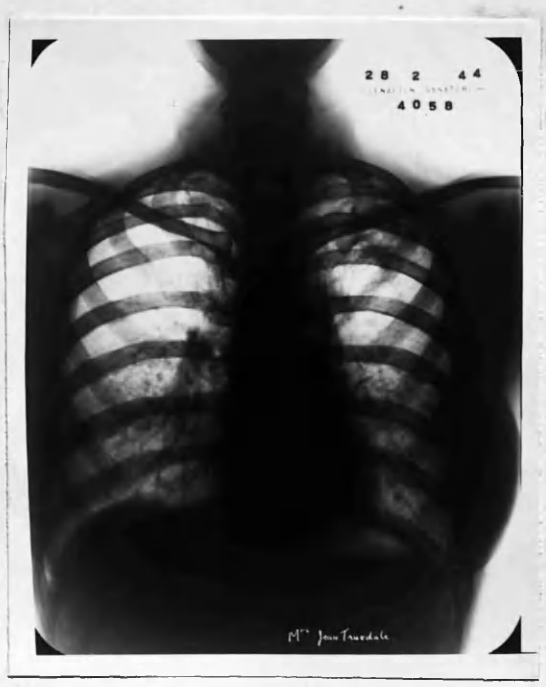


PLATE A7.

Re-expansion of cavity 6 months after final removal of catheter.

institution of drainage. The discharge from the cavity, which averaged 3 drachms daily, became free from tubercle bacilli ten weeks after the onset of treatment. Healing of the sinus was slow and complete closure did not take place until 3.10.43, six weeks after removal of the catheter. A subsequent X-ray on 28.2.44 revealed that the cavity had re-expanded to the size of a penny but, as her general condition remained excellent and cough and spit were neglible, she was discharged from hospital on 20.3.44.

Case 3.

G. A. (aet. 33 years) was admitted to hospital on 5.7.40, with a history of dry cough and dyspnoea on exertion of three months' duration. His general condition was good, but he was mildly febrile and X-ray showed tuberculous infiltration of the right upper lobe containing a medium sized cavity.

Right artificial pneumothorax was induced on 23.7.40, but collapse was contraselective and two months later a right phrenic crush was performed. His condition steadily improved and he was discharged in March 1941. The improvement was not maintained and he was re-admitted to hospital on 3.10.41, when X-ray revealed re-enlargement of the right apical cavity to the size of a tangerine, and tuberculous infiltration of the left lung. He was in poor general condition and weighed only 9 sts. 10 lbs. Cough was troublesome and sputum amounted to ½ - 1 oz. daily and contained tubercle bacilli.

A left artificial pneumothorax was induced on 3.11.41 and on 27.11.41 a Monaldi catheter was inserted into the right apical cavity, the intracavitary pressure readings being 0/+5, although a lipiodol cavernogram demonstrated patency of the draining bronchus. The cavity steadily diminished in size and on 6.3.42, when it was reduced to the size of a cherry, the catheter was removed after having been in situ for 14 weeks. His general condition was much improved although weight had remained constant. Cough was greatly diminished and sputum was reduced from 1 oz. to a fraction daily

and remained persistently negative for tubercle bacilli. Drainage amounted to 1 - 3 drachms daily, and during the first few days of treatment it was so thick that 5 ccs. of pepsin had to be injected into the cavity: apart from sporadic positive results, it remained negative for tubercle bacilli two weeks after the onset of treatment. He was discharged on 2.4.42 with a view to subsequent re-admission for the performance of a right thoracoplasty. He was re-admitted in the same satisfactory condition on 12.8.42 but, although the cavity had remained stationary in size, the sinus remained unhealed. A right thoracoplasty was carried out on 16.6.42, but infection occurred in the wound and he died from toxic absorption six weeks later.

Case 4.

J. C. (aet. 36 years) was admitted to hospital on 18.8.39 with a history of cough, spit and loss of weight of six months' duration. Her general condition was fairly good, but cough was troublesome and copious sputum contained numerous tubercle bacilli. X-ray showed the presence of a large cavity at her right apex with surrounding infiltration, and infiltration of the left lung root and lower lobe.

She improved considerably with sanatorium regime and was discharged from hospital on 13.10.39. She was re-admitted on 9.5.41, having remained well until three months previously when she developed an acute febrile attack, with gradual deterioration in her general condition. The cavity in her right upper zone had increased in size and a smaller cavity had formed opposite her left lung root. A left artificial pneumothorax was induced on 6.10.41, and on 8.10.41 a Monaldi catheter was inserted into the right apical cavity, the intracavitary pressure readings being -6/+3. There was a slight initial diminution in the size of the cavity, after which it remained stationary, and the catheter was removed on 27.12.41, after having been in situ for 11 weeks. Her general condition deteriorated a little during the period of cavity aspiration and her weight decreased from 8 sts. 4 lbs. to 7 sts. 2 lbs. However, cough was much ameliorated and sputum was diminished from ½ oz. to

PLATE B_{1-4}.

PLATE B_1.

Large left upper lobe cavity before institution of drainage. Right pleural effusion present.

PLATE B_2.

Monaldi catheter introduced. Lipiodol cavernogram reveals bronchial blockage. Right pleural effusion disappeared.

PLATE B_3.

Slight reduction in size of cavity 2 weeks after onset of drainage.

PLATE B_4.

Marked reduction in size of cavity 9 weeks after introduction of catheter.

a trace daily, although it remained sporadically positive for tubercle bacilli. Drainage secretions, which were heavily purulent, amounted to ½ oz. at the onset of treatment but latterly decreased in amount to 2 drachms daily; they became negative for tubercle bacilli three weeks after the insertion of the catheter. The sinus healed two months after cessation of treatment. Her general condition improved gradually although the cavity re-enlarged to its original size, and she was discharged on 4.3.42, reporting as an out-patient for pneumothorax refills. The cavity again diminished in size and, on 26.5.43 when it had become very small, she was re-admitted to have a right thoracoplasty performed. The latter was carried out on 4.6.42, but infection of the wound occurred, her condition rapidly deteriorated from toxic absorption, and she died on 3.8.42.

Case 5. (cp. Plate B1-6)

J. P. (aet. 18 years) was admitted to hospital on 26.2.41 with a history of cough, spit and increasing lassitude of three months' duration. X-ray showed active infiltration of the greater part of his left lung with a large cavity at the apex and a smaller one in the region of the second left interspace.

Left artificial pneumothorax induction was unsuccessfully attempted on 30.4.41, and he underwent a course of gold therapy, which seemed to bring about a slight improvement in his general condition. Four months later he developed a right sided pleural effusion which resolved rapidly. A subsequent radiograph revealed an increase in the size of the cavity and on 4.4.42 a Monaldi catheter was introduced, when a lipiodol cavernogram demonstrated the presence of blockage of the draining bronchus. Marked reduction in the size of the cavity occurred and five weeks after the institution of drainage it was one inch in diameter. A second cavernogram showed the bronchus to be patent once more. The subsidiary cavity persisted in its original condition, but two months later the apical cavity was very small, being about 1 cm. in diameter. The catheter was accordingly removed on

PLATE B_{5-6}.

PLATE B_5.

Re-expansion of cavity on removal of catheter.

PLATE B_6.

Cavity not visible 18 months after removal of catheter.

21.7.42, after having been in situ for 15 weeks. The cavity almost immediately re-enlarged to become about 1½" in diameter, but subsequently decreased in size and finally disappeared in October 1943. The subsidiary cavity also healed and was not visible radiologically eight months after the catheter had been removed from the apical cavity. The patient's general condition, which deteriorated a little after insertion of the catheter, gradually improved. His weight increased from 9 sts. 1½ lbs. to 9 sts. 6 lbs. and his B.S.R. fell from 15 mm. per hour to 4 mm. per hour. Cough was much diminished and sputum, which amounted to ½ oz. daily and contained tubercle bacilli before drainage was instituted, increased to 1 oz. immediately following the onset of treatment, but subsequently decreased to a fraction daily and was rendered negative for tubercle bacilli five months later. The discharge from the cavity, which averaged 2 drachms daily, did not become free from tubercle bacilli until a week before removal of the catheter. The sinus wound closed two months later. His general condition remained excellent and he was discharged from hospital on 10.11.43.

Case 6.

R. F. (aet. 29 years) was admitted to hospital on 20.1.42 suffering from chronic bilateral pulmonary tuberculosis, with a large cavity in the right lower lobe which had resisted closure during a previous stay in hospital, when a right artificial pneumothorax and phrenic evulsion had been performed.

On 26.1.42 a Monaldi catheter was inserted into the cavity, but a few hours later it was expelled. One attempt to replace the catheter failed and it was completely removed. Although he made no complaints, he died suddenly from a profuse haemoptysis twenty-four hours later. Permission for a post-mortem examination was not obtained, but it seems highly probable that death resulted from rupture of an intracavitary vessel during introduction of catheter.

Case 7.

D. W. (aet. 41 years) was admitted to hospital on 27.1.42 in very poor condition. He was febrile, his B.S.R. was 56 mm. per hour, and he weighed only 8 sts. 2½ lbs. Sputum, which contained numerous tubercle bacilli, amounted to 4 oz. daily, and cough was so severe that it kept the other patients awake at night. X-ray revealed the presence of gross tuberculous disease of the right lung, with a large apical cavity.

An unsuccessful attempt to induce a right artificial pneumothorax was carried out on 2.2.42 and two days later a Monaldi catheter was inserted into the apical cavity. The decrease in severity of his cough was dramatic and within twenty-four hours he was able to sleep undisturbed. Three weeks later the sputum was found to be negative for tubercle bacilli, although it was only slightly diminished in amount. On 9.3.42 a radiograph showed the cavity to be considerably smaller and there was a corresponding improvement in his general condition. On 13.5.43 the cavity was again slightly smaller, being about two-thirds of its original size, and the catheter was removed, after having been in situ for 14 weeks. The sputum was reduced to 2½ ozs. daily but was intermittently positive for tubercle bacilli. The daily amount of drainage varied between 1 drachm and 2½ ozs. and, apart from one occasion on 9.3.42, it remained positive for tubercle bacilli. His cough, however, was dramatically improved and there was a decrease in toxaemia with an improvement in his appetite and a slight gain in weight from 8 sts. 2½ lbs. to 8 sts. 4½ lbs. Following removal of the catheter, the sinus closed within five weeks, but re-opened again one month later and discharged intermittently. The cavity remained stationary in size and the improvement in his condition was maintained until February, 1943, when an exacerbation of the disease in his lung with accompanying amyloid disease occurred. His condition deteriorated steadily and he died seven months later.

PLATE C_{1-3}.

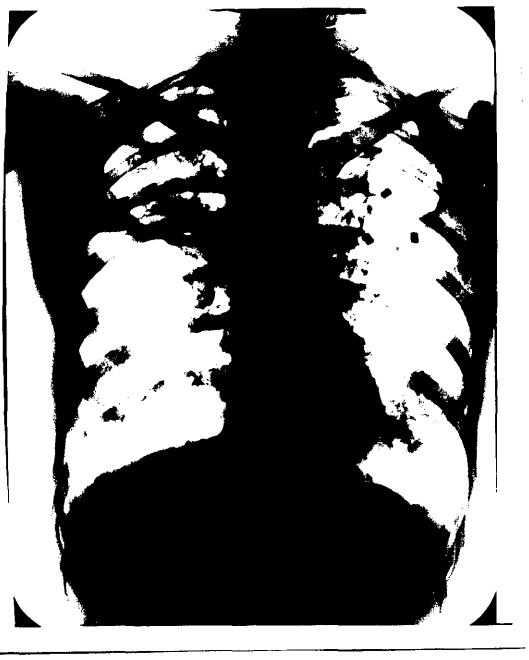


PLATE C_1.

Large left upper lobe cavity before onset of drainage.

PLATE C_2.

Slight reduction in size of cavity 4 weeks after introduction of catheter.

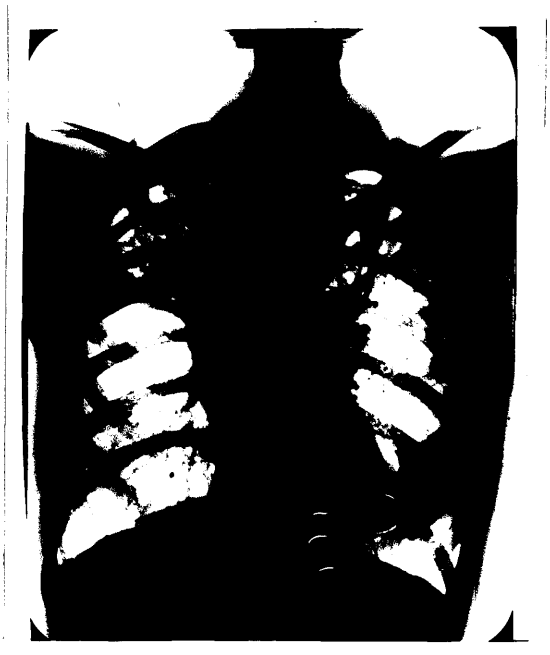


PLATE C_3.

Catheter removed. Further reduction in size of cavity, with further cavity formation.

Case 8. (cp. Plate C_{1-3})

A. C. (aet. 25 years) had undergone sanatorium treatment for 9 months in 1938, when a right pneumothorax, which was abandoned in 1940, was induced. Her general condition was satisfactory until April 1941, when she developed a 'cold' and had a haemoptysis of 2 ozs. She was re-admitted to hospital on 11.8.41 and, although pale, was fairly well nourished and weighed 9 sts. $2\frac{1}{2}$ lbs. Her B.S.R. was, however, 66 mm. per hour and daily sputum amounted to 3 ozs., containing numerous tubercle bacilli. X-ray showed fibrosis of the right lung and infiltration of the upper half of the left lung, containing a large thin-walled cavity about the size of a walnut.

Left artificial pneumothorax was induced on 13.8.41 but was not satisfactory as dense adhesions, which could not be divided on thoracoscopy, prevented complete collapse of the upper lobe. The cavity increased a little in size and the pneumothorax was abandoned on 21.11.41. Complete re-expansion of the lung gradually occurred and on 17.8.42 a Monaldi catheter was inserted into the cavity, the intracavitary pressure readings being -3/+2. Cough was alleviated and slight reduction in the size of the cavity occurred, but the disease in the right lung broke down again, becoming fibro-cavernous in nature, and her general condition deteriorated. The catheter became repeatedly blocked and was finally removed on 5.10.42, after having been in situ for seven weeks. Drainage secretions amounted to 4 drachms daily and contained numerous tubercle bacilli. Although the cavity was reduced to the size of a penny piece, further cavity formation had taken place just below it, and slight advance in the disease on the right side had also occurred. Her general condition remained very poor and the cavity gradually returned to two-thirds of its original size. The sinus, which had closed slowly following removal of the catheter, re-opened on 2.6.43 and remained in this state until her death. The presence of albumen was detected in her urine in May 1943, and she was discharged three months later with the same gross bilateral fibro-cavernous disease and well established amyloid disease, from which she died seven

months later.

Case 9.

V. D. (aet. 42 years) was admitted to hospital on 6.10.41 with a complaint of cough, spit, and loss of weight of three years' duration. Her general condition was poor, her weight being 7 sts. 9 lbs. and her B.S.R. 60 mm. per hour. X-ray showed the presence of coarse tuberculous infiltration of the whole of the left lung with cavitation at the apex, and infiltration of the upper half of the right lung.

A right phrenic crush was performed on 10.10.41, but her general condition gradually deteriorated. Her cough became very troublesome and she produced 5 ozs. daily of positive sputum. A right artificial pneumothorax was unsuccessfully attempted, and on 7.5.42 a Monaldi catheter was inserted into the left upper lobe cavity, the intracavitary pressure readings being -2/+4. Lipiodol cavernography revealed the presence of blockage of the draining bronchus. On 9.6.42 the cavity showed a reduction in size of about 20 per cent, and a further slight decrease was noted one month later. On 16.7.42 a second lipiodol cavernogram demonstrated that the draining bronchus had become patent once more. As no further decrease in the size of the cavity occurred, the catheter was removed on 9.9.42, after having been in situ for four months. Her general condition was much improved, cough was less troublesome and her temperature was much more settled. Her weight, which had diminished a little after the introduction of the catheter, increased from 6 sts. 10 lbs. to 6 sts. 12 lbs. For the first fortnight no drainage occurred, but subsequently it amounted to one oz. daily and gradually diminished after one month to 2 drachms daily. It became persistently negative for tubercle bacilli four weeks after the onset of treatment. The sputum gradually diminished from 5 ozs. to 2 ozs. daily, and, apart from occasional positive results, remained negative for tubercle bacilli after aspiration had been carried out for three weeks. Unfortunately, in spite of this temporary improvement, she subsequently developed well established

amyloid disease and died six months later.

Case 10.

E. G. (aet. 29 years) was admitted to hospital on 19.12.41 with a history of cough and spit, lassitude, and loss of weight of two months' duration. Her general condition was fairly good, but her cough was troublesome and she produced 2 - 4 ozs. daily of sputum which contained many tubercle bacilli. Clinical and radiological examination revealed the presence of tuberculous infiltration at both apices with a large right apical cavity containing a fluid level.

A right artificial pneumothorax was induced on 6.4.42 but, as only a little air could be introduced due to gross pleural adhesions, it was abandoned and the lung allowed to re-expand. A Monaldi catheter was inserted on 12.5.42, when a lipiodol cavernogram showed the bronchus to be patent. Seven weeks later the cavity was not visible radiographically, but a subsequent X-ray on 17.7.42 demonstrated that it had re-appeared but was very small. As further reduction in the size of the cavity was considered unlikely, the catheter was removed one week later, after having been in situ for ten weeks. Her cough was much diminished and her general condition was slightly improved, although her weight, which was originally 9 sts. 7 lbs., showed a gradual decrease until 9.7.42, after which it remained stationary at 9 sts. 4 lbs. There was a reduction in the amount of her sputum from 3 ozs. to ¾ oz. daily, and it became repeatedly negative for tubercle bacilli after eight weeks treatment. The drainage, which originally amounted to 2 ozs. daily and contained tubercle bacilli, gradually decreased in amount to a fraction daily and, apart from one occasion on 1.6.42, remained negative for tubercle bacilli. The sinus healed quickly and her general condition continued to improve steadily with further rest in bed. Her sputum, which had increased in amount to 1 oz. daily following removal of the catheter, was found to contain tubercle bacilli, and on 3.8.43 a radiograph revealed re-expansion of the cavity to half its original size. Accordingly, thoracoplasty

PLATE D_{1-4}.

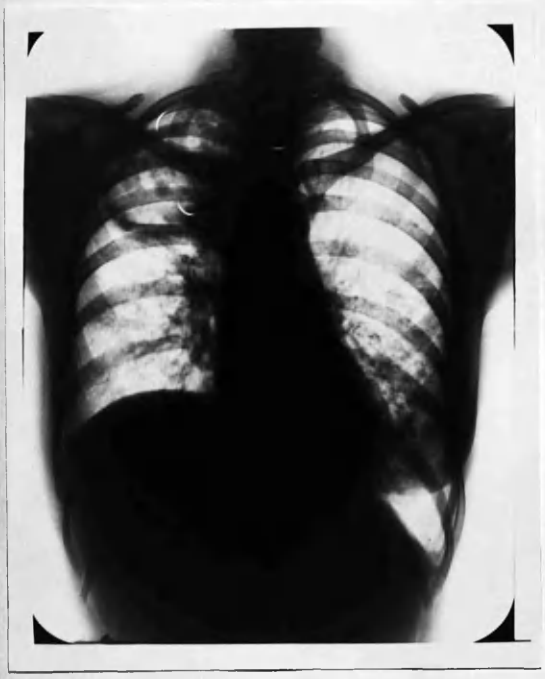


PLATE D_1.

Large right upper lobe cavity before insertion of catheter.

PLATE D_2.

Marked reduction in size of cavity 4 weeks after onset of suction drainage.

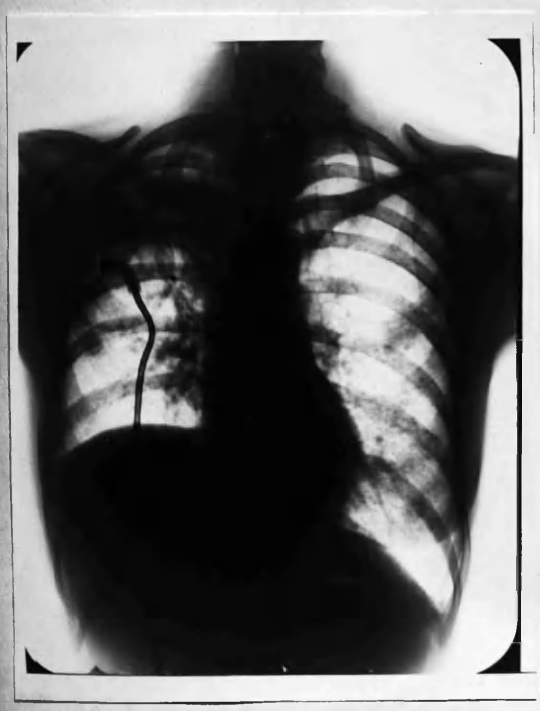


PLATE D_3.

Further reduction in size of cavity 7 weeks later.

PLATE D_4.

Re-expansion of cavity 9 weeks after removal of catheter.

was carried out in two stages on 7.9.43 and 17.9.43. Following the thoracoplasty, a further improvement in her general condition occurred, her sputum was again reduced in amount to a fraction daily and did not contain tubercle bacilli, and her weight increased to 10 sts. 9 lbs. She is now well and will soon be discharged from hospital.

Case 11. (cp. Plate D_{1-4})

M. L. (aet. 50 years) had previously undergone sanatorium treatment for tuberculosis of her right lung from 1934 to 1936 when, after an unsuccessful attempt to induce a right artificial pneumothorax had been carried out, a right phrenic evulsion was performed.

After her discharge she remained well until March 1941, when cough and spit returned and she became easily tired. On admission on 16.8.41, her general condition was fairly good, but her voice was husky and examination of her larynx confirmed the presence of tuberculous laryngitis. A radiograph of her lungs revealed a large well-defined cavity in the right upper lobe with a fluid level, and nodular infiltration of the right upper lobe and of a wide central area of the left lung. Her B.S.R. was 21 mm. per hour, cough was troublesome, and she produced ½ oz. of positive sputum daily. She was treated conservatively, but her cough became aggravated and her sputum increased to 2 ozs. daily. On 15.11.42 a Monaldi catheter was inserted into the cavity, the intracavitary pressures being -2/+4. A subsequent improvement in her general condition was maintained. Her sputum was reduced to ¼ oz. daily and became free from tubercle bacilli, and her cough became proportionately less troublesome. A radiograph of the lungs on 16.12.42 revealed marked reduction in the size of the cavity and, as two months later the cavity as such was no longer visible, the catheter was removed on 26.2.43. The cavity, however, re-enlarged to about half its original size, and the sputum increased to ½ oz. daily, containing tubercle bacilli once more. In spite of this, her general condition remained satisfactory and she regained a loss of 19 lbs. which had occurred prior to the insertion of the Monaldi catheter.

The sinus remained open until 16.10.43 when, as it was considered that she was unlikely to be improved by further sanatorium treatment, she was discharged from the hospital.

Case 12.

R. C. (aet. 18 years) was admitted to hospital on 25.10.41 with a history of lassitude, cough and spit of six months' duration. He was pale and toxic, and his B.S.R. was 74 mm. per hour. Cough was troublesome, and sputum, which contained tubercle bacilli, amounted to 1 oz. daily. X-ray showed tuberculous infiltration of the upper two-thirds of his left lung containing a very large cavity. Left artificial pneumothorax was induced on 14.11.41, but several massive adhesions prevented satisfactory collapse and the pneumothorax was abandoned on 7.1.42. Full re-expansion of the lung occurred, and on 21.5.42 a Monaldi catheter was inserted into the cavity. In spite of this, his general condition continued to deteriorate and there was no reduction in the severity of his cough or in the amount of sputum, which remained persistently positive for tubercle bacilli. The cavity was unaltered in size and on 29.6.42 the catheter was removed, after having been in situ for six weeks. During the first week of treatment, drainage secretions amounted to ½ oz. daily, but latterly they became very scanty; at no time were tubercle bacilli found to be present. His weight, which was 9 sts. 10 lbs. before the onset of treatment, became reduced to 9 sts. 7 lbs. The sinus closed two months after removal of the catheter. A left phrenic crush was performed on 2.7.42 and, following a period of conservative treatment, a first stage thoracoplasty was carried out on the left side on 1.12.43. The second stage of the operation was performed on 5.1.44, and his post-operative condition remained satisfactory until 20.1.44, when he had a profuse haemoptysis and died immediately.

Case 13.

J. S. (aet. 25 years) was admitted to hospital on 10.9.41 with a history of cough and spit of one month's duration, and the occurrence

of a right sided pleurisy two years previously. His general condition was good, but a radiograph revealed the presence of tuberculous infiltration of the right lung with a large right apical cavity. Cough was troublesome, and his sputum amounted to 2 ozs. daily, containing numerous tubercle bacilli.

His condition remained fairly stationary under conservative treatment over a period of eight months. On 11.5.42 a right artificial pneumothorax induction was attempted without success and one week later a right phrenic crush was performed. A Monaldi catheter was inserted into the cavity through the second interspace posteriorly on 9.6.42. Lipiodol cavernography revealed the presence of blockage of the draining bronchus. Drainage from the cavity contained many tubercle bacilli and was very copious, amounting to 5 ozs. during each of the first few days. In one week it was reduced to 1 oz. daily and did not contain tubercle bacilli. The cavity was reduced to two-thirds of its original size when, after one month's treatment, the catheter was removed at the patient's request. His weight fell from 10 sts. 2 lbs. to 9 sts. 10 lbs. during the period of aspiration but his general condition appeared to improve. Cough was less troublesome, and sputum was slightly reduced in amount and rendered negative for tubercle bacilli. The sinus closed eight weeks after removal of the catheter. The improvement in his general condition was maintained and his weight steadily increased to 10 sts. 5 lbs., when X-ray on 5.4.43 showed the cavity to be completely healed. His sputum, which was slightly reduced in amount, remained persistently negative for tubercle bacilli, and he was discharged home on 12.5.43, since when his excellent condition has been maintained.

Case 14. (cp. Plate E_{1-4})

T. A. (aet. 28 years) was admitted to hospital on 14.9.35 suffering from a right sided pleural effusion with underlying tuberculous infiltration. He was dismissed on 11.10.36 as his condition was considered satisfactory, and he remained well until October 1941, when he had a recurrence of cough and spit, with occasional small haemoptyses.

PLATE E_{1-4}.

PLATE E_1.

Film of chest before onset of drainage: large right upper lobe cavity with a second large cavity below.

PLATE E_2.

Upper cavity reduced to half of original size 3 months after onset of drainage. Lower cavity persists as before.

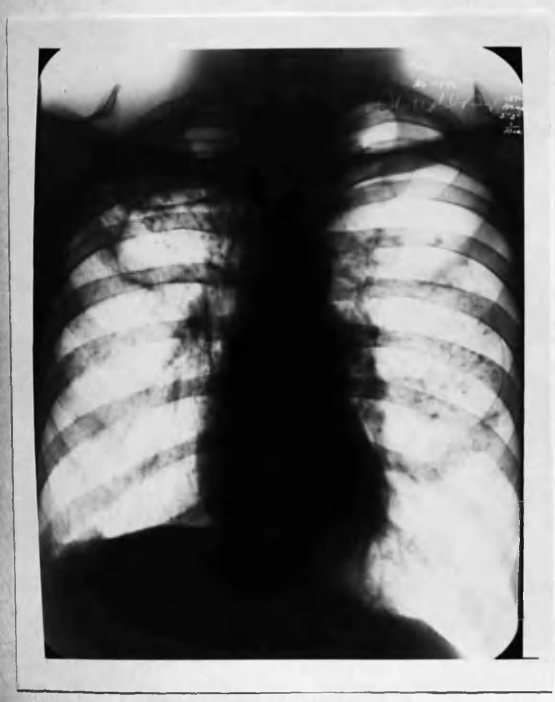


PLATE E_3.

Re-expansion of cavity to original size 8 weeks after removal of catheter.

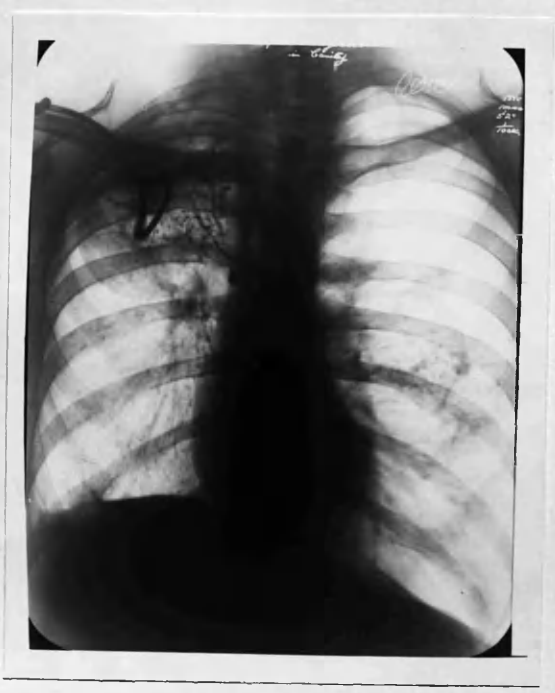


PLATE E_4.

Cavity unchanged after further period of drainage (11 weeks).

He was re-admitted on 7.3.42 in fairly good general condition, although he was mildly febrile and his B.S.R. was 46 mm. per hour. X-ray examination showed the presence of infiltration of the whole of the right lung with a large upper lobe cavity, and infiltration of the upper half of the left lung.

Rest in bed produced little change in his condition and, as a cavity had formed in his left apex, a left artificial pneumothorax was induced on 7.10.42. The collapse was satisfactory, but he continued to expectorate 4 ozs. of sputum containing numerous tubercle bacilli daily, and his general condition gradually deteriorated, with anorexia and slight loss of weight. A radiograph on 24.3.43 revealed the presence of a second large cavity in the right lung just below the initial cavity. On 15.4.43, after an unsuccessful attempt to induce a right artificial pneumothorax, a Monaldi catheter was inserted into the upper cavity, the intracavitary pressures being -4/+6. Immediately following this procedure he slept rather badly and complained of headache, but these symptoms disappeared fourteen days later. One month after insertion of the catheter, the cavity was considerably smaller and the collapse of the left lung was improved, with disappearance of the apical cavity. Although the neighbouring cavity persisted as before, two months later the original cavity was reduced to approximately half its original size, and the catheter was withdrawn on 8.7.43, after having been in situ for 12 weeks. His general condition was a little improved and he had regained a slight initial loss of weight, but his cough was still troublesome and, although his sputum contained only scanty tubercle bacilli, it still amounted to 4 ozs. daily. No further progress in his condition was noted and, as a subsequent radiograph revealed that the cavity had re-enlarged to its original size, the catheter was re-inserted on 7.9.43 when the intracavitary pressures were -3/+3. Little change occurred radiographically or clinically in his condition, and the catheter was removed on 27.11.43. The drainage secretions averaged 2 drachms daily during the first period of aspiration and 1 oz. daily during the second period. In neither case were they found

Case 16.

J. I. (aet 27 years) was admitted to hospital on 9.1.42 with a history of lassitude and morning cough and spit of two months' duration. Her general condition was fairly good, but clinical and radiological examination revealed cavitation in both subclavicular regions with light infiltration of the remainder of both lungs.

Conservative sanatorium treatment, followed by a course of gold therapy, improved her general condition and caused absorption of the disease in both lower zones, but the cavitation persisted in the upper lobes and her cough and spit were unaffected. Left artificial pneumothorax was induced in January 1943, but dense adhesions prevented a satisfactory collapse and the pneumothorax was abandoned. Cough remained troublesome and sputum, which amounted to 1½ ozs. daily, contained numerous tubercle bacilli. On 23.4.43 a Monaldi catheter was inserted into the left upper lobe cavity, which was approximately the size of a tangerine: the intracavitary pressure readings were -8/+2. There was little immediate effect on her cough, and on 14.5.43 a right artificial pneumothorax was induced to control the disease in the right lung. After the catheter had been in situ for four weeks, the cavity was reduced to two-thirds of its original size. On 22.6.43 division of adhesions preventing satisfactory collapse of the right lung was carried out. On 18.8.43 the cavity was found to have further reduced to approximately half of its original size. Two days later, completion of section of the right sided adhesions was carried out, but unfortunately haemorrhage occurred from one of the divided stumps and, in spite of repeated blood transfusions, she died on 2.9.43. Prior to her death, cough was slight and her sputum was reduced in quantity to a fraction daily, containing only scanty tubercle bacilli. Although her weight remained stationary, she looked and felt much better and her appetite was greatly improved. The suction drainage, which initially amounted to ½ oz. daily, latterly measured 3 drachms daily: tubercle bacilli were present throughout.

PLATE F_{1-4}.

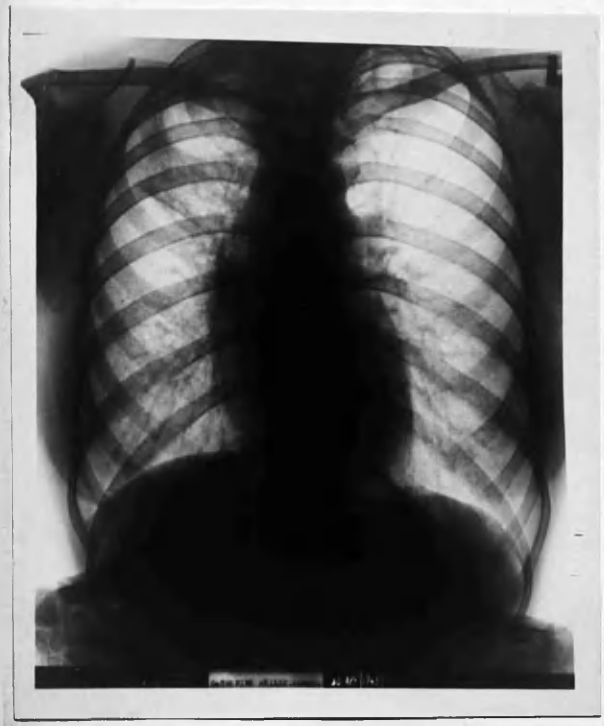


PLATE F_1.

Large right upper lobe cavity before introduction of Monaldi catheter.

PLATE F_2.

Monaldi catheter in position at onset of drainage: patency of draining bronchus.

PLATE F_3.

Moderate dimimution in size of cavity 4 weeks after introduction of catheter.

PLATE F_4.

Thoracoplasty collapse of right upper lobe: cavity as such is not visible.

Case 17. (cp. Plate F_{1-4})

C. R. (aet. 31 years) underwent sanatorium treatment from July 1941 until August 1942, when a right artificial pneumothorax was unsuccessfully attempted. She was re-admitted to hospital in good general condition on 29.4.43 with infiltration of the right upper lobe and a large right apical cavity. Cough was troublesome and her sputum, although scanty, contained numerous tubercle bacilli.

On 4.7.43 a Monaldi catheter was inserted into the cavity, the intracavitary pressure readings being -2/+4. A steady improvement in her general condition was accompanied by a gradual diminution in the size of the cavity. On 15.10.43, when the cavity was reduced in size by half, the catheter was removed with a subsequent view to thoracoplasty. Her B.S.R. had fallen from 75 to 20 mm. per hour, cough, although still troublesome, was improved, and her sputum, which varied from a trace to ½ oz. daily, did not contain tubercle bacilli. Her weight which, at the onset of drainage, was 9 sts. 4½ lbs., increased to 9 sts. 11 lbs. Throughout the entire period of aspiration, there was very little drainage from the cavity and the largest daily quantity was one drachm. As in the case of the sputum, the drainage was converted shortly after the institution of treatment. The sinus healed completely four weeks after removal of the catheter and on 19.11.43 a right apical thoracoplasty was performed, ribs 1 - 5 being resected. Shortly after the thoracoplasty had been performed the sinus broke down, but healed firmly in a few days time. Subsequently however, her general condition deteriorated slightly. Her weight has fallen to its present value of 9 sts. 5 lbs., her sputum has increased to ½ - 1 oz. daily, and once again contains tubercle bacilli.

Case 18.

J. H. (aet. 22 years) was admitted to hospital on 10.5.41 with a history of lassitude, loss of weight, cough and spit of seven months' duration. His general condition was very poor: he was emaciated, sallow and febrile, and his B.S.R. was 43 mm. per hour. X-ray showed gross tuberculous infiltration of both lungs with a

large cavity about the size of a walnut in the left apical region.

Two months later he developed intestinal and laryngeal tuberculosis and his general condition deteriorated rapidly. Left artificial pneumothorax was induced on 14.8.41, but was discontinued on 3.10.41 on account of gross adhesions. Cough became more troublesome, and sputum, which amounted to 1½ ozs. daily on admission, increased to 3 ozs. daily and contained very numerous tubercle bacilli. The cavity increased in size and on 26.2.43 a Monaldi catheter was introduced, the intracavitary pressure readings being -2/+5. After one month, the cavity was appreciably diminished in size and two months later it was not visible radiographically. The cavity drainage, which initially amounted to 2 ozs. daily, gradually decreased and, after 3½ months, had ceased. The catheter was accordingly removed, after having been in situ for fourteen weeks. His condition was greatly improved and his sputum was reduced in amount to ½ - 1 oz. daily, although still containing tubercle bacilli. Following removal of the catheter however, his condition again deteriorated and sputum became more copious. X-ray showed the cavity to have re-enlarged to its original size, and the catheter was re-inserted, the intracavitary pressure readings on this occasion being -3/+6. Once again the cavity became considerably reduced in size, but his general condition remained the same. The intestinal and laryngeal disease persisted as before, his troublesome cough remained, and sputum amounted to 2 ozs. daily, still containing numerous tubercle bacilli. He was transferred to an institution nearer his home on 24.12.43, and the catheter was removed ten weeks later, when the cavity was seen to be about half its original size. His general condition was much improved: cough and sputum were diminished and his B.S.R. had fallen to 10 mm. per hour. The sinus track closed three weeks later.

Case 19. (cp. Plate G_{1-3})

M. H. (aet. 29 years) was admitted to hospital on 3.6.43 with a history of cough, spit and lassitude of seven months' duration. Her general condition was poor, she had a troublesome cough and produced

PLATE G_{1-3}.

PLATE G_1.

Monaldi catheter coiled in huge right upper lobe cavity at onset of drainage.

PLATE G_2.

No change in size of cavity 7 weeks after insertion of catheter.

PLATE G3.

Cavity appearances unchanged following removal of catheter.

3 ozs. daily of sputum containing very numerous tubercle bacilli. A radiograph revealed old tuberculous infiltration of the right upper zone with a large cavity, and active widespread disease throughout the rest of the lung fields.

A right artificial pneumothorax was induced in March 1943, but was abandoned two months later as the collapse was unsatisfactory. On 10.6.43 a Monaldi catheter was inserted into the apical cavity, the intracavitary pressure readings being -2/+8. Two weeks later a left artificial pneumothorax was induced to control the disease in the left lung. After suction aspiration had been in progress for six weeks, there was but little change in her condition. Cough was troublesome and her sputum was still copious and contained many tubercle bacilli. Radiologically the cavity was very slightly reduced in size, but there was an increased opacity in the surrounding parenchyma. Two months later (22.9.43) the catheter was removed as her general condition was gradually deteriorating and no further change was occurring in the size of the cavity. Her weight had fallen from 9 sts. 10 lbs. to 8 sts. 9 lbs., cough remained troublesome, and she still produced 2 ozs. of highly positive sputum daily. The drainage secretions, which had averaged 1 oz. for the first month, latterly became reduced to ½ oz. daily, but tubercle bacilli remained present in large numbers. A Bacillus Proteus infection occurred in the sinus track and, as a result of the persistent discharge, a dermatitis arose in the surrounding skin surface and, in spite of treatment, still persists. Her general condition has further deteriorated; weight has fallen to 7 sts. 10 lbs. and there has been an exacerbation of the disease in the lower zone of her right lung.

Case 20.

M. T. (aet 42 years) was admitted to hospital on 20.4.43 in a very emaciated condition. She was febrile, her B.S.R. was 60 mm. per hour, and cough was frequent and very troublesome. Sputum amounted to 1½ ozs. daily and contained numerous tubercle bacilli. A radiograph revealed the presence of gross bilateral fibrocavernous

tuberculosis, with a large cavity occupying the upper half of the left lung field.

With rest in bed, her general condition improved and weight increased from 5 sts. 7 lbs. to 6 sts. 7 lbs., but there was no change in the lung disease and cough remained very troublesome. A Monaldi catheter was inserted into the left upper lobe cavity on 17.12.43, the intracavitary pressure readings being -1/+1. There was an immediate alleviation of her cough, and sputum, which had amounted to 2½ ozs. prior to the insertion of the catheter, quickly became reduced to 1 oz. daily. Symptomatic improvement continued although radiographically no change in the condition of the cavity was observed. The catheter, which at the onset of treatment drained 1 - 2 ozs. daily of thick mucopus containing numerous tubercle bacilli, latterly drained only a fraction daily. It was removed on 8.2.44, after having been in situ for 7½ weeks. There was no further change in the condition of the cavity, but her general well-being and demeanour were markedly improved and sputum was finally reduced in amount to ¼ oz. daily, still containing numerous tubercle bacilli. Following removal of the catheter, this progress has been maintained, but the sinus is as yet unhealed, ten weeks after cessation of drainage.

Case 21.

M. W. (aet. 22 years) was admitted to hospital on 4.3.43 in very poor condition, with extensive bilateral fibro-cavernous tuberculosis and complete excavation of her left upper lobe. She was emaciated, pale and febrile, and her B.S.R. was 114 mm. per hour. Cough was very troublesome and she produced 1½ ozs. daily of mucopurulent sputum containing numerous tubercle bacilli.

Little change occurred in her condition with conservative treatment and on 17.12.43, after fusion of the pleura had been verified, a Monaldi catheter was inserted into the left upper lobe cavity, the intracavitary pressure readings being -1/+1. At the onset of treatment there was little alteration in her cough, but gradually its severity during the night diminished. There was

PLATE H_{1-4}.

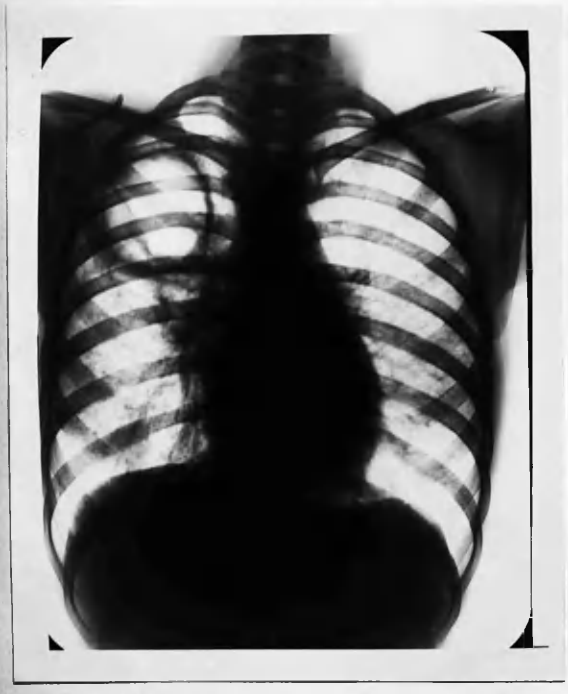


PLATE H_1.

Large right upper lobe cavity prior to introduction of Monaldi catheter.

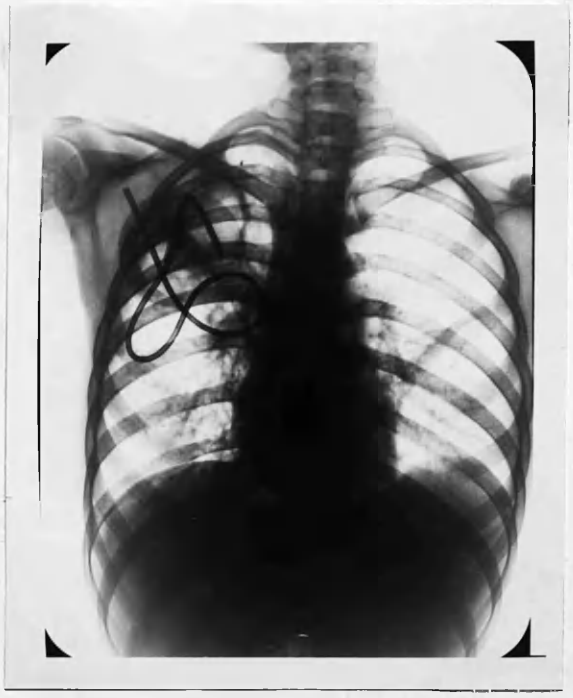


PLATE H_2.

Marked reduction in size of cavity 4 weeks after onset of drainage.

PLATE H_3.

Cavity as such is no longer visible (1.9.43).

PLATE H_4.

Re-expansion of cavity and spread to left lower lobe.

no alteration in the amount of sputum and her general condition gradually deteriorated until, on 10.2.44, oedema of her feet and ankles due to amyloid disease appeared. The oedema rapidly increased, spreading to involve her face, and the catheter was removed on 1.3.44, after having been in situ for ten weeks. Radiologically the disease had advanced in the left lower lobe. The drainage secretions amounted to ½ oz. daily at the onset of treatment, but latterly became reduced to 2 drachms daily; at all times tubercle bacilli were present in large numbers. She was discharged on 3.3.44 at her parents' request and died four days later.

Case 22. (cp. Plate H_{1-4})

H. G. (aet. 15 years), whose mother and sister had died of pulmonary tuberculosis, was admitted to hospital on 15.1.43. She was flushed and cyanosed, and her general condition was very poor. Radiological examination revealed the presence of a large cavity occupying practically the whole of the right upper lobe, with tuberculous infiltration of the greater part of the remaining lung field and of a wide central area of the left lung.

A right artificial pneumothorax was induced on 1.2.43 but, as the entire upper lobe was adherent, it was abandoned on 8.3.43. Her condition further deteriorated and her sputum, which contained numerous tubercle bacilli, increased from ½ oz. to 3½ ozs. daily. A Monaldi catheter was inserted into the cavity on 22.4.43, the intracavitary pressure readings being -4/+5. Following the insertion of the catheter, she had a sharp febrile reaction for one week, due partly to an exacerbation of the disease in the left lung. Drainage from the cavity was intermittent and never amounted to more than 1 drachm daily. A radiograph on 19.5.43 showed that a marked reduction in the size of the cavity had occurred. Drainage ceased and, as further attempts at re-insertion through the sinus failed, the catheter was re-inserted through a fresh stab wound in the region of the original sinus, and drainage re-established. On 1.9.43 the cavity as such was no longer visible, and the catheter was removed on 7.10.43. Her general condition was better than

ever before, and her weight, which had decreased before the onset of drainage, returned to that noted on admission. Cough was less troublesome and sputum, which amounted to ½ oz. daily, did not contain tubercle bacilli. The drainage sinus closed two weeks after removal of the catheter and her progress was maintained until, on 30.11.43, she developed what appeared to be an influenzal cold. This was followed by a return in the severity of her cough, with copious frothy sputum amounting to 4 ozs. daily and containing tubercle bacilli. Clinical and radiological examination revealed that the right upper lobe cavity had re-enlarged to its original size and that an acute spread of the disease had occurred in the left lower lobe. Repeated small haemoptyses occurred, and in an effort to control the latter a first stage thoracoplasty was performed on 3.1.44, but her condition rapidly deteriorated and she died on 8.1.44.

Case 23.

E. B. (aet. 17 years) was admitted to hospital on 12.3.43 with a history of malaise, cough and spit of 5 months' duration. His condition was poor, he was toxic and febrile, and his B.S.R. was 80 mm. per hour. Cough was not troublesome, but he produced 1 oz. daily of sputum which contained numerous tubercle bacilli. Clinical and radiological examination revealed the presence of chronic bilateral tuberculosis with a cavity in the left apical region.

On 3.5.43 attempted induction of a left artificial pneumothorax was carried out, but was unsuccessful on account of dense pleural adhesions. Following a period of six months' conservative treatment, his weight increased from 8 sts. 5 lbs. to 8 sts. 13 lbs., but his cough became more troublesome and sputum increased to 1½ ozs. daily. Extension of the infiltration in the middle zone of the left lung also occurred. On 12.1.44 a Monaldi catheter was inserted into the left apical cavity, the intracavitary pressure readings being -1/+5. A lipiodol cavernogram four days later showed the bronchus to be widely patent. The drainage secretion varied from ½ - 1 oz. daily and contained tubercle bacilli, but it

PLATE I_{1-4}.

PLATE I_1.

Dense disease of right lung with large upper lobe cavity, before onset of drainage.

PLATE I_2.

Lateral view: lipiodol cavernogram showing catheter in smaller cavity which is communicating with larger posterior cavity.

PLATE I_3.

Lateral view: catheter is now in larger cavity.

PLATE I_4.

Cavity unchanged following course of suction drainage.

was almost always blood-stained in spite of reduction in the degree of suction applied and slight alteration in the position of the catheter in the cavity. Suction was discontinued for a few days on several occasions but, on resumption, bleeding occurred each time and the catheter was finally removed on 25.2.44, after having been in situ for 6½ weeks. There was a slight deterioration in his general condition and he lost 3 lbs. in weight. The amount of sputum was unaffected, but cough became more troublesome. Since cessation of drainage he has regained 1 lb. in weight, sputum has diminished to ½ oz. daily, and cough has become less troublesome. The sinus is healing slowly, but still discharges mucopus containing tubercle bacilli.

Case 24 (cp. Plate I_{1-4})

J. N. (aet. 30 years) was admitted to hospital on 26.7.43 with a history of cough and spit, with lassitude and loss of weight, of four months' duration. His general condition was poor, night sweats were severe, and his B.S.R. was 98 mm. per hour. Cough was not troublesome, but he produced 4 ozs. of sputum daily containing numerous tubercle bacilli. X-ray revealed the presence of extensive tuberculous infiltration of the right lung, with a large upper lobe cavity and a smaller cavity antero-inferior to the latter.

A right artificial pneumothorax was induced on 30.8.43, but was abandoned on 23.9.43, as collapse was contraselective and slight enlargement of the upper lobe cavity had occurred. Cough became more troublesome and sputum increased in amount to 6 ozs. daily. Re-expansion of the lung occurred and on 12.1.44 a Monaldi catheter was inserted through an incision in the second interspace anteriorly. The intracavitary pressure readings were -1/+6 and a partial bronchial blockage was demonstrated by the delay in appearance of methylene blue in the sputum after injection through the catheter. Explanation of the latter finding was provided by a lipiodol cavernogram on 13.1.44, when it was demonstrated that the catheter was lying in the small anterior cavity which was communicating with the larger cavity. Drainage secretions amounted to ½ - 2 ozs.

daily, but sputum remained copious and, as neither cavity was altered in size, the catheter was removed on 2.2.44. Six days later it was inserted into the larger cavity through an incision in the first interspace anteriorly, the intracavitary pressure readings being -5/+3. Drainage secretions amounted to $1\frac{1}{2}$ - 2 ozs. daily and sputum was reduced in amount to 4 ozs. daily, but in both instances tubercle bacilli were persistently present. Sharp pain in his right shoulder, which commenced shortly after the onset of the first period of drainage, became very severe and the catheter was accordingly removed on 3.3.44. The cavity was entirely unaffected in size by the suction drainage, and a deterioration in his general condition was accompanied by a reduction in weight from 8 sts. 12 lbs. to 8 sts. 7 lbs. Following removal of the catheter, a course of massage relieved the pain in his shoulder, but cough became more troublesome and his sputum increased to 8 ozs. daily. Both sinuses are unhealed at the time of writing (six weeks after final removal of the catheter).

Case 25.

G. C. (aet. 18 years) was admitted to hospital on 19.7.43 suffering from widespread bilateral tuberculosis, with a large cavity in the right upper lobe. He was toxic and febrile, and in poor general condition. Cough was troublesome and he produced 2 ozs. daily of sputum which contained numerous tubercle bacilli.

After right artificial pneumothorax had been unsuccessfully attempted, a Monaldi catheter was inserted into the right upper lobe cavity on 20.7.43, the intracavitary pressure readings being 0/+6. His condition improved considerably - cough was ameliorated and sputum became reduced in amount to 1 oz. daily and did not contain tubercle bacilli. Two months after insertion of the catheter, a left artificial pneumothorax was induced, and, as satisfactory collapse of the lung was prevented by the presence of an adhesion, the latter was divided on 30.11.43. Subsequently his condition deteriorated steadily and abdominal tuberculosis supervened. Because of the decline in his general condition, the catheter was

removed on 2.1.44, after having been in situ for 5½ months. The cavity was reduced in size by half, but sputum, which was rendered negative for tubercle bacilli shortly after the onset of treatment, again became positive two weeks before his death. Drainage secretions initially amounted to 1 - 2 drachms daily, but latterly increased to ½ oz. daily: tubercle bacilli were present throughout. Death occurred 1 week after removal of the catheter.

CRITICAL REVIEW OF LITERATURE.

In 1939, Monaldi reported his first 100 cases, and later in the same year his co-worker Morelli recorded the results obtained in the first 198 patients treated from August 1938 until November 1939 at the Forlanini Institute. He claimed that in 79 cases the cavity undergoing suction drainage had disappeared. 55 cases were still under observation but showed promising results, and in 64 cases the procedure had to be abandoned for a variety of reasons, such as ineffectiveness, intolerance, deterioration in general condition, haemorrhage from the cavity, and death from intercurrent disease.

In two cases death was considered to be directly due to the treatment, the first being caused by the production of an air embolism at the time of induction, and the other as a result of a convulsive seizure following manipulation of the catheter. The method was attempted, but not carried out owing to inability to enter the cavity or to the persistence of a free pleural space, in seven cases.

In 1939 Weber, reviewing 53 cases in Vienna, claimed that suction drainage was successful, but did not give any statistics. Encouraging results, though on a smaller scale, were reported by Grass (Berlin, 1939), Burnand and Francken (Switzerland, 1939), Schuberth (Davos, 1940), Szule (Hungary, 1940), and Chadbourne and Baudouin (Switzerland, 1940).

In Italy the method was adversely criticized by Parodi, Costantini, and Bocchetti, three prominent phthisiologists. The criticisms of Parodi and Costantini did not appear to be based on any direct personal experience of the treatment as practised at the Forlanini Institute. Bocchetti, however, obtained unsatisfactory results in three cases, two of whom were subsequently treated by Monaldi who claimed cavity closure within a month in each case.

More recently, various authors have published their results of, and expressed their views on, the procedure in American and British literature.

In 1940 Kupka and Bennet reported, from California, a series of 17 cases. At the time of writing, suction drainage had been discontinued in only five cases, in one of whom cavity closure had occurred; in another, the cavity had closed and re-opened. Two cases showed marked diminution in the size of the cavity and the remaining case showed no improvement. Two patients had died, one of tuberculous meningitis, and the other of peritonitis secondary to rupture of a tuberculous ulcer of the ileum. Of the remaining ten cases still undergoing suction drainage, the sputum had been rendered negative for tubercle bacilli in six cases, five of whom showed marked reduction in size of the offending cavity.

In California, during the following year, Goldman, Brunn, and Ackerman attempted transpleural decompression on twenty cavities, in 18 patients, two of whom had bilateral cavitation. In seven instances the treatment was not completed, either because of failure of co-operation on the part of the patient, an aggravation of the existing tuberculosis, or serious complications such as tension pneumothorax and pyopheumothorax. Two patients, in whom preliminary attempts to ensure complete fusion of the pleura had been inaccurate, developed pyopneumothorax and died. A third death was caused by tuberculous pericarditis, apparently unrelated to treatment. Four cavities appeared to be permanently converted into fistulous tracts. The secretions from three other cavities did not contain tubercle bacilli. In one additional case, radiography revealed that the cavity was still present, but the catheter had been removed and the sputum and secretion had remained negative for tubercle bacilli for more than six months. Of the remaining six cases, two patients underwent thoracoplasty after transpleural decompression was discontinued, and in four patients thoracoplasty was carried out prior to transpleural decompression. In the former group, both cavities were still open. In the latter group, one patient was apparently cured, in another the cavity was very small, with secretion negative for tubercle bacilli, and in the third and fourth cases the cavities were smaller, but their secretions still contained tubercle bacilli.

In 1941, Cussen reported three cases from Switzerland, in each of whom he claimed that the cavity had almost completely disappeared, with marked improvement in the patient's general condition.

Roche, writing from Switzerland in the same year, was enthusiastic about the method, although he did not publish any statistics of his own.

In the following year, Des Autels and Hayes recorded their results of intracavitary drainage in three cases, in whom they considered that the results were not wholly satisfactory. All the cavities showed reduction in size and sputum was decreased in quantity, but in two cases it was not persistently negative for tubercle bacilli. In each of the cases cough was reduced and an improvement in general condition, with an increase of weight, occurred.

Two series have so far been recorded in Britain - Holmes Sellors (1942), and Maxwell and Kohnstamn (1943).

Sellors recorded his results in 82 cases in whom he instituted suction drainage. Cavity closure, maintained for at least four months, occurred in twelve cases, and closure, followed by reappearance at a variable interval, occurred in seven cases. In 49 cases a definite reduction in size was obtained, while in 14 cases no appreciable reduction was noticed. Subsequent thoracoplasty was performed in 20 cases.

The main benefit noted by Sellors was the improvement in the patient's general condition which, coupled with diminution in the size of the cavity, enabled the performance of a thoracoplasty which could not otherwise have been satisfactorily undertaken. He stressed the fact that "suction drainage is not an operation to stand by itself except in a very few cases".

The majority of the sinus tracks healed without incident, but a few persisted, especially where cavity closure had not occurred prior to removal of the catheter.

No fatalities occurred during treatment which could be directly attributed to the operation, but in four cases a mild exacerbation of the disease occurred.

Maxwell and Kohnstamn studied the effect of the procedure in in eleven cases. Treatment was terminated in three cases; in one of these the cavity closed, but on withdrawal of the catheter a small cavity remaining stationary in size reappeared soon afterwards. In the two remaining cases the cavity disappeared, and improvement in the patients' general condition permitted the subsequent performance of a thoracoplasty to collapse the diseased lung. At the time of writing, the catheter was still in situ in three cases, in whom its removal resulted in re-enlargement of the cavities. Treatment was abandoned in five cases, in four of whom the cavity was reduced only slightly in size. In the fifth patient, secondary haemorrhage from the chest wall necessitated abandonment of the procedure. In this latter group of cases, all the cavities subsequently re-enlarged.

Maxwell and Kohnstamn did not notice any striking immediate improvement in weight, general condition, or basal sedimentation rate, but they suggested that this might possibly be due to the presence in all their cases of tuberculous foci elsewhere in the lungs.

In a recent general review of collapse therapy in America, several eminent phthisiologists have expressed the following views on the value of cavitary drainage:-

Davidson: "The Monaldi operation, which has taught many of us facts about the pulmonary cavity we never before recognized, at the moment is not being used as a single procedure."

Overholt: "There is a definite place for cavity drainage in the treatment of giant or occluded cavities, but I prefer an open cavernostomy to the Monaldi method."

Matson: "Monaldi procedures seldom effect a cure."

Alexander: "We use the operation occasionally, but are not enthusiastic about it."

COMMENTARY ON PERSONAL CASES TREATED.

The results of the Monaldi procedure as applied in 25 cases are presented.

The duration of intracavitary drainage varied from three weeks to six months, the average period being three months. The degree of suction employed varied from case to case, but was usually in the region of -15 to -20 cm. water. In the majority of cases there was a slight febrile reaction lasting for 7 - 10 days following the insertion of the catheter, the temperature thereafter becoming more settled. In one case, unexplained severe pain in the nearby shoulder occurred during treatment, but disappeared following removal of the catheter.

Permanent and lasting closure of a cavity occurred in two cases only. In neither case was the cavity associated with extensive disease beyond its walls.

Three cases showed radiological evidence of complete closure of the cavity, but re-expansion occurred at a later date - in two instances to the original size, and in the third case to half of the initial size.

In three cases marked reduction, in six cases moderate reduction, and in four cases slight reduction, in the size of the cavity occurred: in this group, four cavities subsequently re-expanded to a degree varying between 30 and 100 per cent of the original size.

In seven cases, no change in the size of the cavity, or in the surrounding disease, was observed.

Varying degrees of improvement in general condition, with amelioration of cough and diminution in amount of sputum, occurred in seventeen cases, and in two cases particularly, such an effect on cough and sputum was very marked. In eight cases of this group, however, the improvement was only temporary, and relapse occurred following termination of treatment.

Deterioration in general condition during the stage of treatment, with little change in cough or sputum, occurred in seven cases.

Disappearance of tubercle bacilli from the sputum was variable, and appeared to depend to a great extent on the degree of pulmonary

disease beyond the confines of the cavity. In twelve cases the sputum remained positive for tubercle bacilli, and in the remaining cases it did not become negative for a period varying between two weeks and five months.

The disappearance of tubercle bacilli from drainage secretions was likewise variable, and on the whole was not directly proportionate to the degree of cavity closure. In eleven cases, tubercle bacilli persisted throughout, and in those cases rendered negative, the period of drainage required varied from one to fourteen weeks. The amount of drainage secretions varied in each individual case, being most marked usually when the cavity was large with a thick irregular wall. During the course of suction drainage, the secretions tended to become more serous in nature and to diminish in quantity, finally ceasing in those cases which were responding well.

The state of the lumen of the draining bronchi varied: bronchial blockage was demonstrated to be present at the onset of treatment in several cases, and later in the course of treatment these bronchi were found to be patent. This occurrence was probably due to removal of a plug of mucus or debris, or the subsidence of an allergic or inflammatory swelling of the bronchial wall.

Complete healing of the sinus track was often long delayed. Although closure occurred in one instance two weeks after removal of the catheter, in the majority of cases a period of between four and eight weeks was required. At the time of writing, one track remains open seven months after removal of the catheter, and the persistent irritation due to the discharge has caused an intractable dermatitis in the neighbourhood of the sinus opening. In two cases the track remains unhealed, ten weeks after cessation of drainage. In three cases re-opening of the track with intermittent discharge occurred after initial closure.

In one instance death was presumed to be due to rupture of an intracavitary vessel during insertion of the catheter. In another case death occurred during treatment as a result of haemorrhage from a divided pleural adhesion on the controlateral side.

Subsequent thoracoplasty was performed in six cases. In one of these the result was satisfactory, but in the second case a slight deterioration in condition occurred. In a third case death occurred suddenly from an intracavitary haemorrhage, and in the fourth case death resulted from myocardial failure after the first stage of the operation had been performed. Both remaining cases in this group died from toxic absorption following infection of the thoracoplasty wound.

In the other cases no active surgical intervention was undertaken. One patient developed a tuberculous meningitis five months after cessation of drainage. Another case died following a massive haemoptysis from a neighbouring cavity, and four patients subsequently succumbed to amyloid disease.

CONCLUSIONS.

Continuous suction drainage of a large cavity with flexible walls leads to reduction in its size if the suction over the period of treatment is greater than the air entry into the cavity from the draining bronchus or bronchi.

Final and permanent cavity closure is unusual, and is probably conditioned by the complete occlusion of the draining bronchus or bronchi and the re-expansion of pericavital atelectatic tissue. Closure is therefore rare in old-standing thick-walled cavities with little surrounding atelectasis. It is more likely to occur in recently formed tension cavities.

Intracavitary drainage should not be carried out without a preliminary attempt to close the cavity by simple relaxation measures such as artificial pneumothorax or phrenic paralysis.

As a preliminary measure to thoracoplasty, intracavitary drainage possesses the advantages that it frequently brings about a reduction in the size of the cavity and an improvement in the patient's general condition. Unfortunately, the delay in healing of the sinus may be such that re-expansion of the cavity may occur before thoracoplasty can be undertaken. Further, during the performance of the thoracoplasty, the tissues in the vicinity of the sinus track may be

reopened, with the risk of contamination of the wound. Such infection may occur even when anterior drainage has been employed, but is obviously more liable to do so when the posterior route has been used.

In a recent personal communication, Holmes Sellors describes a method whereby this difficulty may be overcome. As a preliminary to the insertion of the catheter, the costal cartilages and portions of the upper ribs are removed, and thus the need to intrude in the field of drainage during a subsequent thoracoplasty is minimised.

However, the writer is of the opinion that intracavitary drainage should not be attempted as a preliminary measure to thoracoplasty, even in those cases where tension cavities exist. Rather should mobilization of the apex of the lung be carried out during the performance of a thoracoplasty in such cases.

Probably the greatest indication for intracavitary drainage is as a palliative measure in those cases, otherwise untreatable, where severe cough and copious sputum are distressing features. In certain instances, the amelioration of cough and sputum so produced is indeed marked.

SUMMARY.

1. The aetiology of the formation of tuberculous cavities in the lung is reviewed.

2. The history of the practice of cavity drainage and its rationale are discussed.

3. The technical features of the method associated with the names of Monaldi and Morelli are described.

4. The results in 25 cases treated personally are analysed and recorded.

5. The scope and value of the method are discussed critically.

ACKNOWLEDGEMENTS.

I wish to express my grateful thanks to Mr. Bruce Dick and Dr. Charles Cameron for permission to record these cases, the majority of which were investigated at the Thoracic Unit, Hairmyres Hospital, and East Fortune Sanatorium. I am indebted to Dr. D. C. Orr for his encouragement and help, and to my friend Dr. N. R. Cowan for executing the drawings which illustrate the thesis.

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