FIG. IV.—Direct, straight X-Ray mitral stenosis appearance.

FIG. V.—200 cc. of air in the anterior mediastinum (m. 1.50 distance of tube) sub-mediastinal pleura pulled out by adhesion. Mitral stenotic appearance explained. Air line round lower border of the heart.
ARTIFICIAL ANTERIOR PNEUMOMEDIASTINUM.

By ELIO MONTUSCHI, M.D.

(Clinical Assistant at Queen Mary's Hospital for the East End.)

Since Carson, in 1822, first introduced air into the pleural cavities, and Forlanini put artificial pneumothorax on a firm footing as a practical procedure in the therapy of pulmonary tuberculosis, the practice of introducing air into the body cavities has been greatly extended, both for diagnostic and therapeutic purposes. Air has been introduced into the peritoneal cavity, into the cerebral ventricles, into the joint spaces, and into the retroperitoneal tissues.

In cases where artificial pneumothorax is impossible because of the adherence of the pleura, and where other "collapse" methods are considered unsuitable, air has recently been introduced surgically outside the pleura—extra-pleural pneumothorax. This method, however, necessitates an operation and its results are not always satisfactory, so that it is unlikely that it will come into such universal use as the other methods.

There is also another approach to the lungs and pleuræ, that is, medially, via the mediastinum. Although this approach is extremely easy, as we shall see, it appears that the risks of infection, of cellulitis of the mediastinal tissues, have made the medical profession reluctant to follow this path.

Danelius, it is true, injected abrodil in the mediastinum, but to the inconvenience that only a small amount of information could be obtained by using an opaque contrast medium, there was added the very real danger of chemical irritation to the delicate lax mediastinal connective tissues with consequent sclerosis and retraction.

In 1936, Professor Condorelli, of the University of Bari, published a series of articles on artificial pneumomediastinum, with the idea of serving a double purpose, first, to obtain a clearer view by X-rays of normal and pathological structures in the mediastinum, and, secondly, to obtain in selected cases a limited collapse of the medial part of the anterior aspect of the lung.

It must be mentioned that Condorelli described an anterior and a posterior artificial pneumomediastinum. I will limit myself in this paper to the consideration of anterior pneumomediastinum: of the posterior I have no personal experience, and, to my knowledge, no further work has yet been published on it.

According to Condorelli, who made extensive preliminary anatomical investigations, the mediastinum appears to be sharply divided in an anterior and a posterior portion by a fibrous septum: air, or liquids, such as solutions of prussian blue and of carmine red* do not diffuse from one side of this septum to the other. An expansion of the deep layer of the middle cervical fascia constitutes the superior portion of the dividing septum, and the posterior aspect of the fibrous pericardial sac constitutes its inferior portion: these two portions are soldered together at the level of the cranial border of the posterior wall of the fibrous pericardial sac. It may be added that where the vessels perforate the dividing septum in passing from the anterior to the posterior mediastinum, they are strictly adherent to it.

*These solutions were used only for anatomical investigations in the dissecting-room.
In the anterior mediastinum are contained the thymus gland or its remains, the right and left innominate veins, the extra-pericardial tract of the superior vena cava, the arch of the azygos vein, and the phrenic nerves. The arch of the aorta perforates the septum in an oblique line from right to left, before giving rise to the innominate artery and the left carotid, etc. The heart is also, of course, contained in the anterior mediastinum.

A liquid or gas injected under moderate pressure in the anterior mediastinum, infiltrates the lax connective tissues and easily diffuses, so that 4—500 c.cs. can easily be introduced. The gas penetrates into the thymic lodge, and infiltrates downwards through the retrosternal tissues, separating the vascular peduncle and the heart from the sternum. The limits of the distribution of the gas, anteriorly, are shown in Fig. I.

From Fig. II an idea can be gained as to how the gas distributes itself in the mediastinum, and finds its way between the pleurae and the pericardium, up to its right and left border (pulmonary ligaments). It also separates the anterior third of the superior mediastinal pleurae. The pericardium and the vascular peduncle are, therefore, immersed in a gaseous atmosphere.

The presence and distribution of the gas in the anterior mediastinum can clearly be demonstrated by X-ray. The most striking changes are to be found in the lateral skiagrams: the vascular peduncle and the pericardium are seen to be separated from the sternum by a large air-bubble. Very characteristic changes, however, are seen in the antero-posterior view: the shadow of the heart and of the vascular peduncle are seen to be surrounded by a well-defined air-line. This characteristic appearance is always found in normal cases; when in doubt, a slightly oblique exposure (rotation of 10 per cent.) on both sides will afford a clearer evidence of the existing condition (Catalano, 1936).
Technique.

A needle 4 inches long and of 1 mm. bore, curved at its distal third at an angle of $120^\circ$, and an artificial pneumothorax apparatus, are the only instruments required.

The patient lies on his back, with the head in slight hyper-extension. The needle is introduced (after disinfection of the skin, with alcohol and after local infiltration with novocaine), one inch above the suprasternal notch, in the mid-line. The index finger of the left hand guides the direction of the needle, and this is made to slide under the manubrium sterni for one-and-three-quarter inches.

Figure III.
Needle in situ, for induction of artificial anterior pneumcmediastinum:
- a. Deep layer of the middle cervical fascia;
- b. Superficial layer of the middle cervical fascia;
- c. Superficial cervical fascia;
- d. Left innominate vein.

If the needle is introduced in the mid-line, and kept close to the posterior aspect of the sternum, for not more than two inches, it is impossible to perforate the left innominate vein (the only vessel of some importance likely to be injured) or the pericardium or right pleura which sometimes crosses the middle line at a lower level.

Before introducing air, it is always wise to draw from the needle with a syringe; if blood is drawn—a rare occurrence in my experience—it is advisable to withdraw the needle, and postpone the procedure to the following day.

Air is introduced with the aid of an artificial pneumothorax apparatus, a total of 200—500 c.cs. according to plan. The flow is stopped after every 50 c.cs., or if the patient complains of a feeling of tightness in the chest, and readings are taken on the manometer while the pressures fall. It will be found in normal cases that the initial pressure is 0, or slightly negative, sometimes with a small pleural swing. During the induction of the air the pressure rises to about $+25$, and sometimes a double oscillation is recorded, a larger one in connection with the respiration and a smaller one synchronous with the pulse: it will often be observed that the needle itself oscillates with the pulse-wave. On stopping the air entry, the pressure soon falls to 0 as the gas diffuses, and in the great majority of cases, the final pressure is 0, occasionally, even in normals, a final pressure of $+2 +5$ is observed.

As previously mentioned, the patient often experiences a feeling of tightness under the sternum, occasionally radiating to the back between the shoulders. No
anginal symptoms have been observed, as often found in cases of traumatic or spontaneous mediastinal emphysema (Scott, 1937), and on cutting off the air entry the discomfort disappears as the pressures fall. There is no marked modification in the pulse rate, arterial and venous blood pressures, and in the three normal leads of the electrocardiogram; in lead IV, however, a diminution of voltage of the R wave is frequently observed, clearly due to the interposition of air between the sternal electrode and the heart (Francaviglia, 1936).

It is not rare to observe some subcutaneous emphysema in the neck, but this is never very marked or extensive.

During the introduction of the first 100 c.c.s. of air, some fine crepitations are frequently heard over the sternum, and occasionally sounds simulating a pleuro-pericardial rub. After introduction of 250—400 c.c.s. of air, a hyperresonant note is obtained anteriorly over an area corresponding to that shown in Fig. I, and the apex beat becomes more distant and at times is no longer palpable. It is easy to imagine the genesis of these phenomena.

Artificial pneumomediastinum has been performed in patients with congestive heart failure, with hypertension, with bilateral pleural effusion with artificial pneumothorax: even extensive cardio-vascular and respiratory embarrassment does not, therefore, constitute a contra-indication to this procedure.

Discussion.

As previously mentioned, artificial anterior pneumomediastinum is thought to serve two purposes, diagnostic and therapeutic. Condorelli himself initially laid a greater stress on its diagnostic value, especially to the cardiologist, and I will therefore consider this aspect first.

In Relation to Diagnosis. Keeping in mind the anatomical correlations and the radiological appearances of the normal mediastinum after introduction of air, it is easy to foresee and explain the modifications induced by extensive pericardio-sternal and pleuro-pericardial adhesions.

In the presence of the first, it will occasionally be possible (Francaviglia) to visualise directly a single pericardio-sternal adhesion by a lateral X-ray; in the majority of cases, however, the lateral skiagrams will show the heart to be strictly adherent to the sternum with no air bubble in between.

It must be mentioned that it is possible to obtain some information as to the presence of extensive mediastinal adhesions and of the frequently co-existing pulmonary sclerosis, previous to the X-ray examination. It will be found, in such cases, that only a small quantity of air can be introduced; at high pressures, and that the pressures do not fall, or very slowly, on discontinuing the air entry. A fairly accurate estimation of the degree of sclerosis and retraction can thus be obtained.

In the presence of pleuro-pericardial adhesions, as the air will not have penetrated between the pericardium and the mediastinal pleura, the bright line surrounding the heart will not be observed on the affected side in the antero-posterior X-ray. It will also be possible to differentiate this condition from others in which pleural shadows proximal to the heart might have led to a suspicion of its presence.

Artificial anterior pneumomediastinum is also of great value in differentiating the shadows, often so difficult of correct interpretation, of the superior mediastinum (aorta pulmonary arteries, left auricle); this both in the A.P. and in the lateral
skiagrams. A very interesting example is shown in Figs. IV and V, where it is seen that the convex curve of the left upper border of the heart shadow, with a typical appearance of mitral stenosis (Fig. IV, Plate II), is in reality due to the mediastinal pleura pulled out by an adhesion (Fig. V, Plate II); this after induction of 200 c.c.s. of air in the anterior mediastinum.

It is presumed that not much additional information will be forthcoming from artificial pneumomediastinum in the diagnosis of mediastinal tumours, as the lymphatic glands, the greater part of the arch, and all the thoracic aorta, lie in the posterior mediastinum. In presence of large aneurisms, of thymic and other retrosternal tumours, the introduction of the air is likely to be either too dangerous or impossible.

If the greater accuracy in the diagnosis of the conditions of the mediastinum will certainly prove to be of great value to the clinician, and more especially to the cardiologist, I venture to believe that the practice of artificial pneumomediastinum will render still greater services to the surgeon, before he attempts an operation to free the heart from embarrassing adhesions and constrictions.

In Relation to Therapeusis. While the diagnostic value of artificial pneumomediastinum can be said to be established beyond any reasonable doubt, the same cannot yet be stated as regards its therapeutic application. The study of this is still in its initial stages, but I would like to emphasize the first three points that seem to me of the greatest importance, (1) that it is a very safe procedure, (2) that the technique is quite easy, being much simpler than that of artificial pneumothorax, (3) that it does not intend to substitute artificial pneumothorax, which remains the procedure of election in "collapse therapy," and should therefore always be performed whenever possible.

The first therapeutic application was, as shown by Caputi (1936), in the possibility of reducing recent mediastinal herniae, following artificial pneumothorax; in long-standing cases, when the pleural pressures are decidedly positive, and when the mediastinal hernia is due to retraction of the lung on the homologous side, the attempt to reduce the hernia by introducing air in the mediastinum is doomed to failure. This practice, however, in appropriate cases, will save the application of a contralateral pneumothorax.

Pennetti (1937) first demonstrated the possibility of obtaining a partial mediastinal collapse of the lung by artificial pneumomediastinum in two cases of pulmonary tuberculosis.

De Tullio (1937) then showed in four cases that the "collapse" of the lung obtained by this procedure tends to be selective, the air accumulating in correspondence to the lesion.

Vercesi (1937) has produced X-ray evidence of a remarkable degree of "mediastinal collapse" of the left lung, in one case. This author also conceived the idea of using pneumomediastinum as a haemostatic in cases of haemoptysis due to pulmonary tuberculosis. The lesion is often, in these cases, situated in the vicinity of the paramedian and anterior aspect of the upper lobes, where it is most likely to benefit from the partial collapse induced by pneumomediastinum. To the seven successful cases published, should be added many more, whose charts and X-rays I was very kindly shown by Professor Vercesi at the Forlanini Institute for Tuberculosis in Rome, last January.

The evidence produced impressed me very favourably.

My personal experience of pneumomediastinum as a therapeutic agent is still very limited, and it cannot be said to be conclusive. In three cases of pulmonary tuberculosis there has been some evidence of "splinting of the lung," and the impression has been gained that the patients have done better than could have been expected without such therapy. (It must be remembered that pneumomediastinum
was resorted to only after repeated failure to induce an artificial pneumothorax.) One of these cases was reported at a clinical meeting of the Royal Society of Medicine; in the X-rays then produced, it can be noticed that some confirmation has been obtained of the selectivity of the collapse (right upper lobe), as described by De Tullio.

I have purposely used the word "splinting" of the lung in reference to my cases; it is, in fact, my impression that a real medial collapse of the lung as in Vercesi's case will be found to be only a very rare and fortunate occurrence. This simple process of "splinting" the lung has, however, proved itself to be of sufficient importance in pulmonary mechanics to stop the bleeding from tuberculous cavitations.

One noticeable disadvantage artificial pneumomediastinum has over the other forms of "collapse therapy" is that it appears that it cannot be maintained indefinitely. After 15 or 20 weekly refills, the experience is that increasing difficulty is encountered in the introduction of air; this is interpreted as being due to some sclerosis of the retrosternal connective tissues from the repeated trauma of the needle.

I am personally inclined to think that apart from the indication shown by Caputi and Vercesi, pneumomediastinum will find its principal therapeutic application in pulmonary tuberculosis, as an aid to tide over a case in preparation for a more complete collapse of the lung to be obtained by surgery, when it is required by the seriousness of operation that the patient should be at the optimum compatible with his disease.

As already stated, research and clinical trial are yet in the initial stages. What little has been done seems however to be of sufficient interest to warrant an extensive application of this procedure, which combines a great simplicity of technique with a remarkable safety from complications and untoward effects.

**Summary.**

A description of Condorelli's artificial anterior pneumomediastinum is given, and the technique and X-ray appearances are described. Condorelli's anatomical investigations, showing that a fibrous septum divides the mediastinum in an anterior and posterior portion, are also mentioned.

The significance of artificial pneumomediastinum in the diagnosis of pericardio-sternal and pleuro-pericardial adhesions and of other cardiological conditions, is discussed.

The possible value of pneumomediastinum as a therapeutic agent in pulmonary tuberculosis, by producing a medial "splinting" of the lung, its value as a hæmostatic in hæmoptysis and as a means to reduce recent mediastinal hernia consecutive to artificial pneumothorax, are also discussed.

While the importance of pneumomediastinum in diagnosis is established, it is remembered that its therapeutic aspect has hardly yet been explored. The simplicity of the technique and the almost absolute lack of danger are emphasized, as warranting more extensive research.

This work has been carried out in the Out-patient Department and wards of Queen Mary's Hospital for the East End and I have to express my appreciation of the facilities afforded me.

I should also like to express my thanks to Professor Condorelli, Dr. Vercesi and Dr. Capua for the help they have given me, and to Dr. Capua for kindly allowing me to reproduce two plates.

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