COLLAPSE THERAPY IN THE TREATMENT OF PULMONARY TUBERCULOSIS.

A REVIEW OF ITS DEVELOPMENT AND ACTION.

James Allan Crocket.

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 – 1346

I wish to acknowledge my gratitude to Dr Charles Cameron, Medical Superintendent of East Fortune Sanatorium, for granting access to case records, and for the constant encouragement he gave during the composition of this thesis.

COLLAPSE THERAPY IN THE TREATMENT OF PULMONARY TUBERCULOSIS: A REVIEW OF ITS DEVELOPMENT AND ACTION.

This thesis has been compiled on the following basis:-

SECTION I. The development of collapse therapy, particular attention being given to the evolution of artificial pneumo-:thorax, as this aspect of the subject is to a large extent neglected in literature dealing with the subject.

SECTION II. The anatomy and physiology of the res-:piratory system, considered from those aspects necessary in comprehend-:ing theories of the action of artifi-:cially produced collapse therapy.

SECTION III. The pathology of the collapsed lung with special reference to the relation-:ship between atelectatic collapse of the lung and the closure of cavities.

SECTION IV. A review of cases treated at East Fortune Sanatorium by three types of collapse therapy - artificial pneumo-:thorax, phrenic paralysis, and thor-:acoplasty. An analysis has been made in an endeavour to elucidate those factors most favourable or inimical to a successful result.

SECTION V. An attempt to correlate briefly certain facts elicited by the investigations into the results of treatment with anatomical, physiological and patho-:logical knowledge.

SECTION I.

THE DEVELOPMENT OF COLLAPSE THERAPY.

1. Artificial Pneumothorax.

The use of artificial pneumothorax in the treatment of pulmonary tuberculosis has become established in the physician's armamentarium only within comparatively recent years. Although from time to time during the nineteenth century, reference is made by various writers to the improvement which not infrequently is seen in a phthisical subject after a spontaneous pneumothorax has occurred, it was not until the end of that century that the artificial production of a pneumothorax was brought into the realm of accomplished fact and found of value in treating pulmonary tuberculosis.

When one considers the difficulties which beset the earlier protagonists of artificial pneumothorax, the delay in its introduction cannot be considered surprising. Ignorance of the causes of sepsis and its frequent occurrence as a complication of spontaneous pneumothorax, the presence of extensive pleural adhesions, commonly found in cases with advanced disease, and the difficulty of devising and procuring suitable apparatus and needles, all played their part in prolonging its introduction. The first of these was probably the greatest barrier, and, indeed/

indeed, it was only a few years after Pasteur's dis-:covery of microbic infection as the cause of sepsis that Potain induced the first successful therapeutic pneumothorax.

The first reference to what was essentially artificial pneumothorax would appear to occur in the writings of the Hippocratic school of the fourth cen-:tury B.C. (Krause: 62). Under the title of "The lung inclining against the side," is the following passage:- "When the lung inclines against the side, the patient has a cough and is orthopnoeic: the expectoration is colourless: and he has pain in the breast and back. The lung is thrust outward, pressed closely to the side. The sick man feels as though a weight were in his chest . . . . . If this affection results from a wound or, as sometimes happens, from an incision for empyema, one should attach a pipe to a bladder, fill the bladder with air and send the air into the inter-:ior of the chest. And one should insert a solid pewter sound and push it forward. It is by this method that you will get the very best results." Krause thinks that the sound was used as a means of pushing the lung away from the chest wall so as to permit the inflow of air.

The idea of the artificial production of a pneumothorax was not heard of again until the latter half/

half of the eighteenth century, although references to surgical treatment in cases with gross cavitation are numerous. Among these may be mentioned the names of Schenk in the sixteenth century, Willis and Baglinini in the seventeenth, and Barry of Dublin and Poteau and David in the eighteenth. The treatment usually consisted in draining the cavity through an incision of the chest wall and the lung substance, and, while a few brilliant cures seem to have followed the operation, the outcome was nearly always fatal. In one case described by Bligney in 1670, and quoted by Murphy, cure of phthisis followed accidental puncture of the chest by a sword: it is possible that cures such as this were due to the beneficial results of a traumatic pneumothorax rather than to incision of lung parenchyma.

The only direct reference to the possible use of pneumothorax that one can find during this period is that of a French writer, Bourru, in 1770. He writes:- (Sinding-Larsen: 96) "On sait que sitot que l'air est introduit dans une des cavites de la poitrine ou sont loges les poumons, le lobe de ce cote s'affaise sur-le-champ et n'a plus de jeu: l'autre lobe alors fait seul l'office de la respiration. On entretienderait cette communication de l'aire exterieur avec la cavite de la poitrine ou git la maladie jusqu'a ce que la nature aidee par des remedes internes, eut pu procurer/

procurer la cicatrice de l'ulcere, ce qui ne soit pas fort long, suppose toujours, que le vice fut local et non habituel, ou repandu par toute l'habitude du corps."

Meanwhile the practice of the Hippocratic school was not forgotten entirely. It was recalled by Thomas Young of London in 1815 (103). His comment on the method was, "however extraordinary the practice appears, it is not impossible that it might be beneficial where the adhesion was not such as to prevent the collapse of the lungs, allowing the wounded parts to reunite more readily than in the natural process of respirat-:ion, since they would be more intimately in contact with each other, though not more at rest."

James Carson of Liverpool, established beyond doubt the feasibility of artificial pneumothorax, though his work did not receive the recognition it deserved and fell into comparative oblivion till brought to light by Daus in 1909. His first paper (15) was read before the Literary and Philosophical Society of Liverpool in November 1821, and published, along with the results of other experiments, in the following year. The communication was very complete: he summarised his experimental work on rabbits and then in the peroration stated:- "There can be no doubt, however, that one of the lungs of an animal may be reduced to a state of collapse with perfect immunity. This/

This was a priori indeed to be presumed, as in all other cases in which animals are supplied with double organs, one of these organs may be removed or rendered unfit for the discharge of its functions without destroying or materially injuring the animal . . . . . In the case of the collapse of a single lung the impunity is no doubt secured by the tenseness of the mediastinum, or membrane which is placed vertically in the middle of the chest, between the lungs: and which, after the collapsing of one lung, by the admission of the external air into contact with its surface, secures to the other lung nearly its own proportion of the cavity of the chest, and protects it from being materially impeded in the performance of its functions." He next gave his views on the causes of the rarity of healing of tuberculous lesions, and, after pointing out that the mobility of the lung cannot be the sole cause of this difficulty, concluded that, "The chief cause of the peculiar obstinacy observed in the healing of injuries of the lungs arises, in my opinion, from the state in which the substance of these organs is held in the living system. It has been proved that the substance of the lungs is powerfully elastic, and that in the living system it is at all times on the stretch. When a lesion from any cause occurs in the lungs, the sides of the divided substance recede in opposite directions: and a power equal to the elastic spring of the fibres, tends/

tends, not only to prevent the approach of the sides of the divided parts, but still farther to increase the breach."

Carson assumed that the tuberculous lesion could be cured in a very short time by simply collaps-:ing the lung: apart from this misconception there is very little in his argument that has not been found to be correct.

When he attempted to put the method into prac-:tice he chose, as is so often done when testing any new form of treatment, two patients who were suffering from advanced tuberculosis. In each case the presence of adhesions rendered a pneumothorax impossible, and the patients died within a month of the attempts being made. These were made in 1822, but the results were not published till 1833 (16), and Carson does not appear to have persevered further in his efforts to procure collapse by artificial pneumothorax.

Krimer in 1830 (8), and Ramadge (.x.) in 1839 are said to have performed thoracentesis, but apparent-:ly they did so without any clear idea underlying the practice, and without much success attending their efforts./

(.x.) References are given by several authors (Bal-:boni, Murphy, etc.) to a paper by Ramadge, but it has not been possible to trace this from the references, which are not all identi-:cal, given by these authors. Riviere states he was unable to trace this paper.

efforts.

Up till 1819 when Laennec published his book, "De l'Auscultation mediate," the condition of pneumo-:thorax had not been recognised generally as a separ-:ate entity. A few isolated examples "very imperfect-:ly described," and a short treatise published by Itard in 1803, of five cases, only three of which had been observed by himself, represented all the refer-:ences to the subject which Laennec could find in the literature. He himself gave a very full description of the physical signs of the condition, and recognised its gravity.

In the first edition of his book (63) he stat-:ed (Vol.II, p.262) he had never seen a case recover, but in the second published in 1827, he expresses a more modified opinion, although still holding that in the majority of cases death ensues within a short per-:iod, if not immediately. Laennec's work led to the more frequent recognition and diagnosis of pneumothorax, and during the next fifty years references are more frequent to the improvement which may occur in a tuber-:culous patient after a spontaneous pneumothorax. Houghton (53) in 1832 gave a detailed description of a man in whom pneumothorax had been present for a year, and in whom the disease - which was bilateral - was so greatly lessened in activity as to permit him to resume his/

his work. In 1837, Stokes (97) was able to record that "In several instances, I have observed (with pneumothorax) a complete change in the character of the cough, and a cessation of expectoration. The latter symptom seems peculiar to those cases in which the expectoration had been furnished by the lung which was subsequently perforated. I have seen a case in which the expectoration, being previously copious ceased on the occurrence of fistula, and only returned when tubercular ulceration had invaded the opposite lung." "In many cases, where the disease (pneumothor-:ax) becomes chronic, we may observe a singular suspen-:sion of the usual symptoms of phthisis. The phthis-:ical countenance disappears: the sweats cease: the pulse I have known in some cases to become quiet, and the patient may gain flesh and strength to a surpris-:ing degree, and be only troubled with dyspnoea on exercise, and with the sound of fluctuation in the chest." "I have long thought that the suspension of hectic under these circumstances, was to be explained on the same principle that we account for it after the removal of an external disease, such as white swelling. I have before stated my conviction that the hectic of phthisis is more a measure of the irritation than the suppuration of the lung: and when we reflect on the collapse of, and the pressure on, the effected lung: the/

the obliteration of its blood vessels and the atrophy thereby induced, we must admit that it is placed in a condition unfavourable to the progress of irritation or of tubercle."

The next contribution of importance to the literature on pneumothorax was made by Toussaint in 1880. He collected particulars of twentyfour cases of spontaneous pneumothorax where improvement in the patient's condition had taken place after the pneumo-:thorax. This thesis was one of the articles which attracted Forlanini's attention to the subject, and in 1882 he published (40) a long dissertation in which he analysed in detail the literature dealing with the treatment of tuberculosis by the injection of fluids into the lung or its cavities, by surgical removal of the diseased tissue, and by collapse of the lung, or rather the beneficial results that sometimes follow spontaneous collapse. He considered the last method the most logical line of treatment, mainly because it produced rest of the lung. He concluded his article thus:- "I see the proposition of artificial pneumo-:thorax in phthisis supported, moreover, as a necessary, logical, obvious offspring of clinical facts, the worth of which cannot be doubted for one part, and of the most elementary ideas of physiology and physics for the other part. It has, to my mind, requisites worthy/

worthy of consideration. It would certainly seem rash to me today to attempt it now directly on a consumptive. But when by experimentation of animals it will have been demonstrated that the physician can quantify with precision artificial pneumothorax and always control its volume, and the absolute harmlessness of proper gases, brought into contact with the pleura, will also have been demonstrated, then this operative procedure should seem logical and legitimate."

Before Forlanini could put his theory to the test certain other important contributions appeared. Already Parker (82) in 1882 had read a paper (which Forlanini quoted in his article of 1882) before the Royal Medical and Chirurgical Society of London advising that in the treatment of cases of empyema where, owing to the non-expansion of the lung, difficulty was experienced in aspirating the fluid, replacement of the fluid by sterilised air should be practised. Parker makes no mention of repeating the air injection and apparently had no notion of the possibility of inducing pneumothorax in other conditions.

Three years later, in 1885, Cayley (18) reported to the Clinical Society of London the case of a man with severe and recurring haemoptyses whom he treated by inducing pneumothorax by open operation. The haemorrhage was largely arrested, but the patient died rather/

rather suddenly six days later. At autopsy, adhes-:ions were found limiting the extent of the collapse, and there was miliary disease of the opposite lung. Cayley thought that the collapse of the lung would arrest the haemorrhage by lessening the circulation in the lung, and "moreover, probably check, at any rate for a time, the development of tubercle in this lung, supposing such to be in progress."

During the discussion which took place after Cayley's paper had been read, Ewart stated (35) that Dr Douglas Powell "some years ago" had made use of artificial pneumothorax to combat a large cavernous upper lobe affection. The patient died, but at post mortem examination the lung was found to be well col-:lapsed and the cavity practically completely obliter-:ated.

In 1887 a letter appeared in the Lancet from an Irish practitioner, F.E. Adams (1), describing the improvement following the development of a spontaneous pneumothorax in a case of tuberculosis, and suggesting artificial pneumothorax as a logical method of treat-:ing tuberculosis, and also haemoptysis due to tuber-:culosis. It excited no interest.

The following year Potain (84) read a very com-:prehensive paper before the Academie de Medecine de-:scribing three cases of spontaneous pneumothorax com-:plicated/

complicated by pleural effusion. The first had occurred in 1884, and in all three cases treatment had consisted of aspiration of the fluid at intervals of one to two months and replacement with sterile air. One case - an old man with advanced bilateral disease - died within a short time, but in the other two the pneumothorax was maintained for six and a half and eight months respectively, the first patient being alive and well two years from the onset, while in the second tubercle bacilli could not be found in the spu-:tum when the pneumothorax was terminated. Potain described in detail his apparatus, which did not differ greatly from that of present day usage, and in-:cluded a mercury manometer: he recommended that the pressure after a refill should be in the neighbourhood of -7mm. of mercury, that being considered the normal intrapleural pressure. Although his original reason for maintaining the pneumothorax was to prevent re-:opening of the pleuro-pulmonary fistula, he concluded that "this mode of treatment favours the cicatrisation and healing of tubercular (parenchymatous) lesions."

Forlanini's second communication (41) was pre-:sented before the eleventh International Medical Con-:gress in Rome in 1894. After recording the improve-:ment which resulted from spontaneous pneumothorax in two phthisical patients, he gave a detailed description of/

of the technique for the induction and maintainance of a pneumothorax. He advised using either air or nitro-:gen, and giving small quantities - 200 to 250 c.c. - at a time. His attempts had not then been crowned with success, but this was not surprising, for as he says, "I have to limit myself for the time to treat in this manner some subjects in whom the extent, gravity and, above all, the bilateral lesions removed any hope: and my purpose could not be more than that of studying the tolerance of the patient for the pneumothorax in-:duced systematically; and of finding the best oper-:ative technique. In short, to prepare the soil for the future. This purpose I have achieved."

He reported his first successful case the fol-:lowing year (68) to the sixth Congress of Internation-:al Medecine in Rome. It was that of a girl, aged 17, in whom a pneumothorax had been induced in October 1894 and who in July 1895 was clinically cured.

Murphy of Chicago (77) in 1898, independently of Forlanini, arrived at a similar method of treating pulmonary tuberculosis. He attempted to induce a pnaumothorax in seven patients and was successful in five of them. Murphy's interest in the subject had been aroused by observing the progressive contraction of the chest wall which took place in chronic phthisis, the repair of primary lung lesions which sometimes followed/

followed compression of the lung by an effusion, and the healing of tuberculous lesions after being collapsed by the radical operation for obliteration of empyema cavities. He used a trocar to puncture the chest wall and introduced 70 - 200 cubic inches of nitrogen, depending on the symptoms produced. Although the injection was repeated only in one case he advised repetition in six to ten weeks' time if indicated, and considered three to six months a reasonable time in which to obtain cure.

It is interesting to compare his article (which was illustrated with radiographic reproductions) with those of Forlanini. While each was attracted by the idea of "immobilisation and physiologic rest of the lung" (Murphy), the similarity between the two ends there. Forlanini's progress was slow and every detail was subjected to the closest scrutiny and examination before being put into practice: His first paper was published in 1882, and particulars of his first successful case thirteen years later. Murphy published his paper less than three months after he induced his first pneumothorax, and a number of his conclusions were mere guesswork without any foundation on experience. His interest did not last long, and by 1902 he had abandoned the method. (Tice: 99). Murphy should, however, receive recognition for the use/

use he made of radiography, which had been discovered by Roentgen, a mere three years previously, in 1895, in his pneumothorax work. He showed a proper apprec-:iation of its value when he said:- " . . the x-ray is of undeniable value in studying the pathologic pro-:cesses of the lung, particularly in the localisation of cavities."

Although the success of artificial pneumothor-:ax was thus demonstrated by Forlanini and, to a lesser extent, by Murphy, the growth of its use as a method of treating phthisis has been slow, and it is only since the Great War that the method has become widespread. The only important modifications that have been made to it are the introduction of the water manometer by Saug-mann, thoracotomy and adhesion cutting by Jacobaeus in 1905, and low pressure and bilateral pneumothorax by Ascoli in 1912. Its development has been coincidental with other methods of producing collapse of the lung, notably extrapleural thoracoplasty and phrenic nerve interruption.

2. Phrenic Paralysis.

The earliest reference to operation on the phrenic nerve is that of Sir Astley Cooper (19) in 1836. He states that in a rabbit - "I divided the phrenic nerves one after the other, in immediate succession." Respiration became "excessively laborious" and the ani-:mal/

animal died in twenty minutes. Similar results were obtained with dogs. His work appears to have influ-:enced surgical thought for almost seventy years, and was not disproved until 1902 when Schroeder and Green (93) published an account of a man with a tumour of the neck in which the phrenic nerve was cut, without any ill effect, during operation for the removal of the tumour. Subsequently they carried out a series of experiments on dogs which proved that in these ani-:mals one or both phrenic nerves could be divided with impunity.

The operation of phrenicotomy was proposed first by Stuertz in 1911 for unilateral tuberculosis of the lower lobe. Sauerbruch, working independently, published in 1913 an account of 5 cases, and Ochlecker, in the same year, published an account of 3 cases, the first of which had been operated on in 1911. Several series of results were published during the next few years, but it was found generally that diaphragmatic function returned in up to 50 per cent of cases, and the operation fell into disuse. In 1922 anatomical investigations by Felix (39) showed as the reason, the frequency with which additional branches reach the phrenic nerve below the usual site of section in the neck. Not uncommonly the nerve is duplicated, and it may receive branches from the sympathetic, the nerve to/

to the subclavius, hypoglossal, spinal accessory, vagus and suprascapular nerves. Section in the neck leaves these accessory branches intact. (7, 66). To overcome the difficulty caused by accessory sources of supply, Felix proposed and carried out the operation of phrenic evulsion.

Later it was found that several accidents such as injury to the thoracic duct or subclavian vessels may occur during the operation. To overcome these risks Goetze (74) devised the operation of radical phrenicotomy. In this operation the nerve is dis-:sected out and cut low down in the neck below its anastomosis with the inferior cervical ganglion. Accidents are very rare, and in the majority of cases evulsion is without risk; should the nerve prove ad-:herent it is a simple matter to enlarge the incision and carry out the radical operation.

In recent years increasing use has been made of temporary phrenic paralysis. The main nerve is iso-:lated, either injected with alcohol or crushed, and all accessory branches divided. Return of function takes place in from four to six months. Should fur-:ther paralysis be desired the operation can be re-:peated, or a permanent paralysis produced.

3. Thoracoplasty.

A limited rib resection over the site of a tuberculous/

tuberculous cavity, performed with the idea of collapsing the cavity, appears to have been performed first by De Cerenville (27) with only limited success.

In 1888 Quinke and Spengler (92) proposed a more extensive resection, which was, however, still to be limited to the area immediately overlying the cavity. Attempts made by Bier and v. Mikulicz to carry out this operation did not yield any measure of success, and it was not until 1907 that the next step in the evolution of thoracoplasty occurred, when Brauer (81) proposed the operation of complete extrapleural thoracoplasty. It was performed by Friedrich, but, while the first patient made a perfect recovery, the operative mortality proved to be over 25 per cent, and the operation somewhat naturally fell into disuse.

It was in 1913, when Sauerbruch published the results obtained with paravertebral extrapleural thoracoplasty, an operation which he had devised, that the procedure became of practical importance as a method of treatment. In this country its adoption was very slow, and only since the War has it been used to any extent.

The great drawback of the Sauerbruch operation was that it produced collapse mainly from the side: this tended to be incomplete and to collapse cavities only in one plane, leaving them as stretched-out slits between/

between the apex and root area. Several surgeons attempted to devise some form of apical apicolysis whereby the collapse might be enhanced. Generally the technique evolved was difficult, and not justified by the results obtained, until 1935 when Semb (94) published his method of performing extrapleural apic-:olysis: this operation or some modification of it has now largely displaced, in most cases where thoraco-:plasty is indicated, the older Sauerbruch procedure. The immediate results of the operation are extremely good (95): the mortality within two months is about 3 per cent, and over 90 per cent of the survivors loose their sputum.

SECTION II:

ANATOMY AND PHYSIOLOGY OF THE RESPIRATORY SYSTEM;

Anatomical aspects of the lungs and bronchi.

Nelson (78) has demonstrated that, although the right lung has three lobes and the left two, the internal structural relations are symmetrical on the two sides. Each lung can be regarded as consisting of four principal and anatomically separate areas, the upper, the middle (ventral), the dorsal and the lower. On the right side the upper and middle (ventral) areas correspond to the upper and middle lobes, while the lower lobe composes two areas, the dorsal corresponding to the upper portion of the lobe, and the lower lying below and anteriorly; occasionally the division between these two areas is marked by a fissure which may be partial or complete. On the left side the upper lobe is divided into two areas, that portion of the upper lobe situated below the plane of the fourth costal cartilage being equivalent to the middle (ventral) area: the arrangement in the lower lobe is similar to that of the right lower lobe. In the left upper lobe a fissure, as in the lower lobes, is sometimes found separating these areas. Each area is supplied by either a main bronchus or a branch bronchus resulting from the first division of a main bronchus. These/

These areas are of importance when one considers the relationship of atelectasis to the healing of tuber-:culous lesions, as massive collapse may occur in one such area alone, that is it may affect only a portion of a lobe.

The structure of the bronchi (Miller:75) is at first similar to that of the trachea, but distally the cartilagineous elements disappear in bronchi be-:tween .6 and .7 mm. in diameter. The bronchial muscle (muscle of Reisseisen) forms a geodesic network about the air channels. As stretched elastic cords along such a network of lines form a force which is wholly normal to the wall, it is the ideal arrangement to withstand, or produce, pressure within the apace enclosed by the surface, without any tendency for the bands to slip along the surface. This muscle is arranged in circular bands, which interlace in every way, and, at points where branches are given off, they have a tendency to a triangular formation. At the distal end of the ductus alveolus the muscle forms a sphincter about the openings leading into the atria. Distal to the sphincter no muscle is found. The muscle is proportionately thicker in the smaller ducts, and in a bronchiolus 1 mm. in diameter it is approximately five times as strong as in one 10mm. in diameter.

The ciliated epithelium disappears in bronchi-:oli/

bronchioli about the point of their final division as bronchioli and is replaced by cubical epithelium, which in the ducti alveoli gives way to simple squamous epithelium, similar to that found in the alveoli. Miller states that when the alveoli are collapsed there is reason to believe that this epithelium has then the same cuboidal appearance as that lining the respiratory bronchioli.

In the bronchi, bronchioli, and ducti alveo-:lares the elastic fibres run parallel to the long axes of the air passages. Branches are given off which pass to the bands of smooth muscle in the walls, surround them with a network of fibres, and then take part in the formation of the outer fibrous tissue. In the atria, the sacculi alveolares and the alveoli, the elastic fibres form an intricate network. About the openings leading from the ductuli alveolares into the atria, from the atria into the sacculi alveolares, and from the sacculi alveolares into the alveoli they are arranged in an encircling band of interlacing fibres. From these bands individual fibres are given off which branch and anastomose to form a network of fibres, which are derived, in the case of the atria from the fibres of the ductuli alveolares, in the case of the sacculi alveolares from the fibres of the atria, and in the case of the alveoli from the sacculi alveolares. Thus if the alveoli, sacculi alveolares, and atria are considered/

considered as distensible bladders enclosed by an elas-:tic network of such a nature, it will be obvious that, as they are distended with air, the elastic fibres in the bronchioli and ducti alveolares are put on the stretch in a longtitudinal direction, but in the case of the walls of the atria, alveolar sacs and alveoli, also put on the stretch and distended in all their dia-:meters, their relative shape is preserved by the en-:circling network of fibres. In the bronchioli and ductuli alveolares the bands of smooth muscle serve to prevent overdistension. Macklin (70) has proved that practically the entire elastic recoil of lung tissue is due to the elastic tissue in the bronchi, more par-:ticularly to that found in the tunica propria of the larger bronchi. He dissected out, as far as was poss-:ible, this elastic membrane and found that when stretched and allowed to snap back it acted much as an elastic band, while in the remnant of the trachea and bronchi, which before dissection had shown normal elastic recoil, there was virtually no elasticity. He has also described (72) the interstitial muscle of the lung: it occurs in three situations, viz; the muscle fibres of the interlobar septa, those of the bronchial and vascular sheaths, and those of the vis-:ceral pleura. It forms a fenestrated membrane in these areas and may possibly play some part in dimin-:ishing lung volume.

A/

A consideration of the development of the dia-:phragm helps to elucidate certain points connected with its action. Early in embryonic life it is situated towards the head, but it migrates caudally until it forms a septum dividing the coelome into the thor-:acic and the abdominal cavities. In the human em-:bryo of the third week two narrow short passages ly-:ing opposite the fourth and fifth cervical segments and leading from the pericardium to the peritoneum re-:present the potential pleural cavities, (Keith: 59). Keith pointed out that "the pleural cavities are sim-:ilar in many respects to the tunicae vaginales; both are extrusions or extensions of the primary coelomic cavity, but whereas the testicles have extruded in front of them all three primary layers from the hind gut, the lungs perforate only the inner of the three layers of the fore end of the cavity and, instead of being extruded in the neck, push down the inner layer to form the diaphragm. The lungs as they develop thus become lodged, as it were, in the abdominal wall, as one might conceive happening of an imperfectly des-:cended testicle at the groin." The points at which the right and left lung escape from the primitive ab-:dominal cavity through the diaphragm are termed the pleuroperitoneal openings. They are situated one on either side and divide each half of the diaphragm into a dorsal portion, arising from the spine and arcuate ligaments,/

ligaments, and a ventro-lateral portion arising from the ribs and sternum. The pleuroperitoneal openings ultimately close, but it will be seen that the dia-:phragm consists of two dorsal and two ventro-lateral portions, the central tendon situated between the four, forming the fifth morphological element.

The central tendon is developed from the septum transversum; the dorsal portions are formed from that portion of the body wall which forms the subvertebral musculature, and gains an insertion anteriorly into the pericardium and septum transversum. The ventro-:lateral parts are derived from the ventral longtitud-:inal muscular sheets which give rise to the rectus abdominalis and depressors of the hyoid, the develop-:ment of the lung separating from the chest wall the deepest part of the rectus sheath to form the ventro-:lateral part of the diaphragm. The ribs are formed in the chest wall, and to the posterior six this part ultimately obtains an origin: it is continuous at its insertion with the septum transversum. One would thus expect the diaphragm, from its origin, to be com-:posed of two parts differing in function, and this is, in fact, the case; the spinal part acts on the heart and pericardium, elongating the thorax, and the sterno-:costal part on the lower six ribs.

Physiological aspects of respiration:

Movements of the bronchi:

Rhythmical/

Rhythmical dilatation and contraction of the bronchi during inspiration and expiration was first noted by Ingals (54) in 1905 while performing bronchoscopy. The movements were more marked in children than in adults, and he confirmed their presence by experiments on dogs. He stated that in quiet inspiration the smaller tubes dilated to four times their size in expiration, when they were almost closed. This movement has been verified frequently since then, particularly by Chevalier Jackson who stated (55) that "respiratory and pulsatory movements are in many planes, but the chief movements noticed by the bronchoscopist in all cases of foreign bodies in the larger bronchi is the to and fro motion towards and from the bronchoscope, chiefly in the bronchoscopic axis." Similar movement of the bronchi, although less marked than the up and down motion due to the action of the diaphragm, was noted by the radiologist who examined the cases. Studies made on the bronchial movements after the injection of opaque substances (Bullowa & Gottlieb: 14. Macklin: 71.) yielded similar information. In addition Bullowa and Gottlieb claimed to be able to detect a long peristaltic wave of small amplitude, passing up the bronchi, but subsequent investigators have been unable to confirm this.

Although the vagus contains broncho-constrictor fibres (Dixon & Brodie: 28), it is unlikely that they/

they play any part in bringing about this rhythmic di-:latation and contraction, as this takes place even if the vagal and sympathetic fibres running to the lung are cut. Ellis: (31, 32) explained the expansion and contraction as being due to mechanical effects produc-:ed by the suction of the chest. He found no evidence in support of the view that it is an intrinsic function of the bronchial muscle, which is concerned entirely in maintaining a moderate force and thus leaving a lumen in the smaller bronchi which otherwise might be com-:pletely excluded during expiration.

The intercostal muscles: Hoover: (52) after a very careful investigation of the functions of the intercos-:tal muscles, concluded that, contrary to the belief that inspiration and expiration are determined by the alternate action of the two sets of intercostals, the muscles act synergically with each other and with the accessory muscles of respiration. Whether their con-traction result in inspiration or expiration depends on the group of accessory muscles with which the intercos-:tals are integrated: if the scaleni and the serratus posticus superior, then inspiration follows, if the triangularis sterni and serratus posticus inferior, then expiration. The function of the intercostals is to aid either expiration or inspiration. Normally, the external intercostals only are employed during in-:spiration, and neither the external nor the internal during/

during expiration. If, however, the abdominal mus-:cles are used in forced expiration, then the external intercostals also are brought into play, while in hyperpnoea where there is resistance to the entrance of air the internal intercostals are employed along with the external during inspiration.

The mechanics of respiration: Much of the pioneer work on this subject was done by Sir Arthur Keith (57, 58, 59, 60, 61), and his views will be summarised in the following paragraphs.

The lungs are composed of elements of varying degrees of extensibility, hence the expansion of their parts is unequal during respiration. They may be con-:sidered as being composed of three parts; 1. the root zone, which is inexpansile: 2. the intermediate zone, which is partly expansile: 3. the expansile outer zone, extending to a depths of 25 - 30 mm. Dis-:tensibility of any part of the lung depends on the number of primary lobules it contains.

The lungs do not expand equally in all direc-:tions. Of the five areas one may distinguish on the surface of the human lung, three are in contact with stationary, or almost stationary parts, of the pleural cavity; these are the mediastinal, the dorsal and the apical; the two parts which can be expanded directly are the diaphragmatic and the sterno-costal.

In man the manubrium sterni, the first pair of ribs/

ribs and their cartilages, with Sibson's fascia, form a functional lid (the thoracic operculum) to the thor-:ax, and move as if they formed one piece. The lid is hinged to the vertebral column at the first costo-:vertebral articulation; its moveable or swinging end is attached to the anterior wall of the thorax at the sterno-manubrial joint.

At the apex of the lung there is no inspir:-:atory expansion of the ribs in a backward direction, but a bucket handle action of the first five ribs which provides effective ventilation of the anterior parts of the upper lobes. These ribs resemble arcs, the bows of which are represented by axes joining the spinal and sternal extremities. The movement is peculiar to the upper five ribs and does not apply to the lower group (ribs seven to twelve, rib six being intermediate in its action).

The basal parts of the lungs are expanded directly by a compound motion of the diaphragm and the lower ribs. During complete inspiration the whole lung is moved downwards, forwards and outwards, the roots sharing in this movement. Macklin (73) has from radiographic studies on normal persons esti-:mated the vertical excursion of the carina as 21 mm. during full respiration.

The diaphragm thus plays a complex action dur-:ing/

during inspiration. It acts as a true piston, expand-:ing the basal areas of the lung directly and through them the apical parts; through the muscular crura, which forms one-third of the muscle, it acts on the pericardium and so has a direct influence on the lung roots; it raises the anterior portions of the ribs to which it is attached, i.e: the lower six, which, acting through their costal cartilages on the fifth and sixth chondo-sternal facets, elevate the body of the sternum, and in so doing produce a bending at the manubriosternal articulation.

Normally these two types of respiration, the costo-sternal and the costo-diaphragmatic are always present in varying degree; the former mechanism is almost peculiar to man and is only slightly developed in the higher primates.

The great fissure of the lung is of functional significance as it permits the anterior parts of the upper lobe to be swept forward and upward without hin-:drance from the lower lobe. In post-mortem speci-:mens the marks of the first four ribs only can be seen, and these are not visible posteriorly, thus proving that both the lower lobe and the posterior part of the upper must glide over the chest wall.

The importance of free root movement in the ventilation of the supra-retro-radicular area is stressed/

stressed both by Macklin and by Keith. The former defined this area as the keel-like region bounded inwardly by the vertebral bodies and adjacent mediastinal wall, posteriorly by the medial ends of the ribs, and above by the cupola of the pleura, while Keith says:- "The supraradicular parts of the lung can be thoroughly aerated only if the roots of the lungs participate in the respiratory movements of the diaphragm. For the proper aeration of the apical part of man's lungs diaphragmatic movements are essential."

Clinical proof of the above findings was supplied by an International Congress of Radiologists in Vienna (Roche: 86). There Delheim and Bonte reported their findings after injecting lipiodol into the middle lobe bronchus and studying the movements of the bronchus by radiokymography. The displacement of the bronchus was exactly parallel to that of the diaphragm suggesting that the middle lobe is directly influenced by the diaphragm. Weber with the kymograph investigated the movements of the ribs. The greatest motion was that of the third, fourth and fifth ribs. Lower down the amplitude lessened and was subservient to the diaphragm. He thought the function of the fissure was to allow one lobe to slide over the other, and that if the fissure was free from adhesions it was not possible to rest the upper lobe by phrenic nerve interruption./

interruption. In health the movements of the upper lobe bronchi were directly opposed to the movements of the diaphragm, but in disease they were directly related, i.e: they tended to be pulled down by the action of the diaphragm.

The findings of other physiologists are usually in agreement with those of Keith. Briscoe:(11) varies from him only in detail. On studying cases of post/operative collapse of the lungs, of supposed postdiphtheritic paralysis and of high spinal paraplegia, he noticed that inspiration was associated with retraction of the sternum, recession of the epigastrium and eversion of the lower ribs. On examining these patients radioscopically, the diaphragm was seen to move poorly. He then made pressure over the lower thorax and lateral abdomen, and found that normal diaphragmatic motion appeared, and that the epigastric recession changed into propulsion. He thought that in these cases the costal portion of the diaphragm was in abeyance, but that it could be made to contract if required. He thought the crura the essential portion of the diaphragm, and considered that it acted continually in all types of respiration, but that its action was relatively greater and almost exclusive in the thoracic type, while it was relatively less in the abdominal type, the costal portion of the diaphragm playing/

playing a larger part in the latter. He considered that the action of the diaphragm took place in two dir-:ections - through the pericardial ligament on the root of the lung expanding the part of the lung above that level, especially when erect, and at the base of the sternum through the trefoil tendon and the seventh and adjacent ribs, bending the sternum and so expanding the area which lies above the second rib, especially when supine.

His view, that the diaphragm caused retraction of the sternum was opposed to that of Keith, but was supported by the work of Hoover: (51), who considered the diaphragm as antagonistic to the scaleni and inter-:costals, which tended to widen the anteroposterior and transverse diameters of the thorax and to lessen the vertical length of the thorax. The motions of the lower end of the sternum and the subcostal angle resulting from this antagonism depended on the position of the diaphragm; when it was pushed up it was placed at a mechanical disadvantage in approximating the parts of its origin, i.e: the central tendon, the sternum, and the costal border, while when it was pushed down it was at a mechanical advantage. He found that if the diaphragm was clamped to the chest wall above the thoracic margin in approximately a straight line from the central tendon, then marked inspiratory retraction occurred./

occurred. Clinically such a position is seen after an empyema or fluid effusion, while the opposite, where there is a mechanical disadvantage, is seen in emphysema. From the careful observation of thirty two cases of phrenic evulsion at East Fortune Sanator-:ium, Anderson (5) found that in fifty per cent there was quite definite increased freedom of movement of the lower ribs and widening of the subcostal angle after phrenic nerve interruption. In the remainder the change was not detected, but in the majority of the latter there was extensive lung disease with fair-:ly marked contraction and fixation of the lung. These findings of Anderson's lend support to Hoover's explanation.

Section III./

SECTION III.

THE PATHOLOGY OF THE COLLAPSED LUNG.

Among the signs indicative of a good prognosis in a patient with phthisis are the disappearance of tubercle bacilli from spit in which previously they were present, and the healing of any cavities which may have been present. A positive sputum is practi-:cally always found in the presence of open cavitation, and, while the reverse is not true, namely, that the closure of a cavity is accompanied by a vanishing of tubercle bacilli from the spit, it happens sufficient-:ly frequently to render the closure of cavities the ultimate aim in treating pulmonary tuberculosis.

"Natural" healing in pulmonary tuberculosis.

Healing of cavities occurs frequently without any active treatment. According to Pinner (4) "spon-:taneous" healing - closure of the cavity without col-:lapse measures - occurs in from 10 to 30 per cent of cases with cavitation. Heise (48) states that 27 per cent of one hundred and forty patients admitted to Trudeau Sanatorium after 1919, and treated by bed rest alone had no cavity after six months' residence. The majority of the cavities which closed were of recent origin, did not have thick walls and were under 4 cm. in diameter. Fales and Beaudet supply very detailed statistics/

statistics relating to "natural" disease of cavities. In their first paper (36) they found that cavities van-:ished in 40 per cent of one hundred and twenty cases. The ability to heal depended largely upon the size of the cavity, the amount of pulmonary involvement, and, more especially, on the absence of bilateral cavita-:tion. It should, however, be noted that these cases were observed under better conditions than is the rule in Sanatoria in this country, while patients who had any collapse therapy were excluded, an exclusion which, naturally, raised the proportion of successful results. Observation was continued for at least one year and often for eighteen months, and bed rest was strict, at least twenty hours and frequently twenty-four hours per diem being spent in bed. In their second series (37) they found that healing occurred in 46.7 per cent of ninety cases. Again, this series was composed largely of cases which favoured a high percentage of satisfactory results, and bed rest was prolonged.

McMahon and Kerper (69) had in their series two hundred and ninety six cases which were observed for a minimum period of three months and an average period of thirteen months. Excluding sixty two cases which received collapse therapy within two months of admission to hospital, in 28 per cent of the remaining two hundred and thirty one cases the cavities closed spontaneously,/

spontaneously, while in another 17 per cent they con-:tracted a size less than 1 cm. by 1 cm. These auth-:ors make the interesting observation that the period which elapsed before a cavity closed was almost the same whether the patient was treated by bed rest or by collapse measures, namely, between five and six months. This observation, however, has not been confirmed and De Bloeme's figures (26) may be quoted. He found that the sputum became tubercle free in 74.6 per cent of one hundred and sixty six cases of unilateral tubercu-:losis. This percentage was almost constant whether the cases were treated conservatively or by artificial pneumothorax (74.2 per cent of one hundred and one cases treated conservatively, and 75.3 per cent of sixty five cases treated by artificial pneumothorax), but while with conservative treatment the average per-:iod which elapsed before spontaneous healing took place was fourteen months, in collapse cases sputum conversion and cavity closure occurred within a few months of the induction.

Healing by Collapse Therapy.

It may be accepted that while spontaneous heal-:ing will take place in between 20 and 40 per cent of cases, in the remaining 60 to 80 per cent the patient, while his condition may improve and the disease area become less active and extensive, will remain infected with/

with active tuberculosis, be liable to spread of the disease at any time, and be potentially capable of con-:veying his infection to persons with whom he may come in contact. In a proportion of these 60 to 80 per cent of cases, arrest of the disease, and often perma-:nent cure, can be procured by collapse therapy.

Although there has been much experimental work on the etiology of the healing process, the exact method by which it occurs is still obscure. Reports on the post mortem appearances of lungs which contain healed cavities are scanty and not very helpful. Pinner (4) considers that anatomical healing should imply complete obliteration of the cavum and disappear-:ance - by resorption or fibrous substitution - of all tuberculous tissue alterations in the constituent parts of the cavity; mere apposition of the walls without fibrous bridging may simulate healing both clinically and radiographically, but such disease can not be con-:sidered healed. Neither may epithelialisation of the cavum wall. He gives a short description of two cases which conformed to the above standards and states he was able to find only one other description of a healed cavum in the literature - that of Gilbert (43). In each of these three cases the cavum was represented by a small star-shaped mass of whitish fibrous tissue with no evidence of residual cavitation, caseation or calcification./

calcification.

In addition to those cases with anatomical healing, there are cavities which clinically and radio-:graphically appear healed, yet at post mortem are found to contain small residual cavities buried in scar tissue. Such a case, in which the lung had been collapsed for four years prior to death, is described in Gilbert's paper on the subject. It contained two cavities, the one the size of a lentil and the other of a small pea. Both were encapsulated in fibrous tissue; one contained caseous masses with calcified deposits, while in the other, which lay in atelectatic parenchyma, there were no signs of a tuberculous char-:acter save one or two giant cells in the fibrous walls.

The pathology of the lung under collapse meas-:ures has been described repeatedly (Rolland: 87. Gard-:ner: 42. Caussade & Isidor: 17. Lindblom: 67. Sweany: 98. Pinner: 4.). The outstanding change produced by collapse is the development of fibrous tissue, which in a pneumothorax of a few months' standing may be equivalent to that seen in chronic phthisis of many years' duration. This fibrosis is not generalised, but localised and nodular, and very dense. It tends to be well-marked in certain areas - peribron;-:chial, periarterial (but detached from the vessels), about caseous masses, subpleural, and along the inter-:lobar/

interlobar and interlobular septa. The increase in the preformed tissue (peribronchial, periarterial and septal) is most marked in the immediate neighbourhood of tuberculous lesions. Lindblom found that if a pleural effusion should develop, there is a marked in-:crease of the preformed and subpleural fibrosis, the latter area being one in which fibrosis is not other-:wise great.

There are numerous theories as to the actual mode of healing of cavities. If theories which lack any pathological support, such as that of Doubrow (discussion, Gilbert (43)) - who considered healing to be accomplished by granulation tissue growing into the cavity and filling it completely after which it was replaced by actual regeneration of lung tissue - are left out of account, then the remainder are based on one of the following two arguments.

There is, first, what was for long the gener-:ally accepted method. According to this theory a cavity resulted from interruption of lung parenchyma and was constantly being enlarged by the natural elas-:ticity of the lung which tended to pull it out. The natural tissue reaction to the pathological lesions was the formation of fibrous tissue, which surrounded the lesion and more particularly, the cavity. This fibrous tissue had a natural tendency to contract as it/

it grew older and eventually it would manage to produce obliteration of the space. Collapse aided healing by reducing the elastic tension in the lung and enabling the fibrous tissue to contract more easily and close the cavity. There is no histological evidence that this process alone is in fact what takes place. Hebert (46) had pointed out that fibrosis in the wall of a cavity will render it less collapsible while fi-:brotic contraction of the area in which the cavity is situated tends to reduce it in size. Again fibrous tissue tends to be more exuberant the older the lesion is; one would thus expect a higher percentage of cav-:ities to close in chronic phthisis, whereas in this condition one obtains the smallest percentage of spon-:taneous cures. This conclusion is possibly not true as, in marked fibrosis there is widespread pleural adhesion which will tend to prevent retraction, as will the fact that there is relatively little healthy parenchyma to compensate for any contraction which takes place. Pinner advances an ingenious theory when he stated that round any cavity there are two sets of fibres, the one, arranged concentrically, acts as constrictors, and the other, which radiates from the cavity and may be anchored distally to the pleura or interlobar septa, acts as dilators; the latter predominate in chronic cavities and tend to keep/

keep them from closing, while in recent cavities the constrictor fibres are more numerous and may lead to closure of the cavity. There is no histological proof that this is the case and the theory is contra-:dicted by the fact that a cavity in a lung collapsed by pneumothorax, in which case there is no anchorage for the "dilator" fibres, may increase in size. One might also mention Parodi's work (83). He believes that the weight of the lung is the primary factor both in deciding the site of the lesion - usually apical - and in the healing of the lesion whether this is by collapse or by conservative measures. His argument is involved, but if one substitutes the term "elasti-:city" for, "the weight of the lung" it does not differ materially from the views given above.

Atelectasis and Tuberculosis.

During recent years, Coryllos and his co-work-:ers have advanced the theory that tubercular cavities close and heal only as a result of atelectasis subse-:quent to occlusion of the bronchus supplying the dis-:eased part of the lung. As early as 1909 Klieb had noted that "scar tissue in the lungs may compress the bronchi so that areas of alveoli collapse" (Holcomb & Weber: 30.). One finds similar statements not infrequently in the literature, but it was not until Coryllos published his various papers on the subject (Coryllos:/

(Coryllos: 20. 21. 22. Coryllos & Birnbaum: 23.) Coryllos, Kanterwitz & Levine: 24.) that attention was drawn to the association between atelectasis and the healing of tuberculous lesions. Briefly, his theory may be stated thus:- A cavity is formed as a result of evacuation of caseous matter from an early lesion. This hole in the lung does not collapse as the pressure inside it is greater (one atmosphere) than the pressure about it (less than one atmosphere). As the pressure of the surrounding tissue is more or less uniform it assumes a spherical shape. If air is entrapped in any tissue in the body it is absorbed; this applies equally to air entrapped in the lungs. When a cavity is first formed the bronchus draining it is in communication with the atmosphere and with the cavity. Three things may happen to the bronchus. If it remains open there is free drainage of the cavity, unhampered growth of tubercle bacilli, progression of the lesion and absorption of toxic products by the lymph stream. If the bronchus is narrowed so as to allow free ingress of air during inspiration but no egress during expiration, emphysema of the lung tissue distal to the narrowing is produced and any cavity present in this tissue will increase in size - the so-called "check-valve" cavity. Should the bronchus become completely blocked, then there will be absorption of the entrapped air in the/

the distal part of the lung with the production of ate-
:lectasis and closure of the cavity. In this last eventuality certain other biological factors aid heal-
:ing of the lesion. The tubercle bacillus is a strict aerobe, and in the presence of atelectasis is placed in an environment much more unsuitable for its survival than is the open cavity. In addition, atelectasis leads to diminished blood flow through the affected lung tissue and consequently lessened toxic absorption. Another effect of the coincident reduction of circul-
:ation which occurs is tissue anoxaemia, which, if pro-
:longed and sufficiently pronounced, gives rise to a fibrosis analagous to that seen in Volkmann's ischaemic paralysis.

Coryllos has advanced some very substantial arguments in favour of his theory. He has analysed samples of gas withdrawn from cavities through the chest wall. In cavities connected with open bronchi the oxygen percentage was 16-19, the carbon dioxide under 1, while the pressure was atmospheric with an oscillation between minus one and plus one mm. of mercury. In check valve cavities the oxygen percent-
:age was 10-17, the carbon dioxide 2-3, and the pres-
:sure lay between plus two and plus four mm. with no, or only weak, inspiratory oscillation; while in clos-
:ed cavities the oxygen fell within a few hours to under/

under 1 per cent, or even disappeared; the carbon di-:oxide was above 5 per cent, pressures were negative and no oscillations could be detected.

That atelectasis is capable of producing pres-:sures sufficiently high to close the vast majority of cavities has been shown by Habliston (Lee Lander: 64. Jenning: 56.) who found intrapleural pressures in the presence of widespread atelectasis as low as -432 mm. of water, the normal intrapleural pressure being - 40 to -80 mm. This figure is in the region of the lowest which theoretically is possible since the blood can absorb air only to a pressure of about 400 mm. of water, (Trocme: 101).

Sanes and Smith (91), and Eloesser (34), have made very complete studies of bronchial obstruction, and they show that complete obstruction may be produc-:ed by many causes other than tuberculous bronchitis, which Coryllos mentions as the commonest. Among the causes they list are enlarged lymph nodes, bronchitis, rest in bed in the supine position, immobilisation of the chest and diminution of the cough reflex by seda-:tives.

Concerning experimental work related to the cure of tuberculous lesions in atelectatic lung tissue, two papers may be quoted. Adams (2) has found that in dogs in which massive atelectasis was produced through/

through stenosing the main bronchus to one lung by cauterising the mucous membrane with a 35 per cent solution of silver nitrate, tuberculous lesions healed more rapidly in the atelectatic lung than in the in-:flated lobes. In a very interesting paper Brooks (12) has published the case of a patient with a lower lobe infiltration with cavity formation; she was treated by pneumothorax, but the cavity was still pres-:ent after nine weeks, despite a partial selective col-:lapse. Bronchial occlusion was then produced by placing a collapsed balloon in the lower lobe bronchus through a bronchoscope, inflating the balloon with water and leaving it in position. Massive collapse of the lower lobe took place in six hours' time and the balloon was withdrawn. Complete obliteration of the cavity resulted despite the presence of unsuspected adhesions, and no inflation of the lobe resulted during the next four months, artificial pneumothorax being continued. The appearances of the lower lobe were identical with those seen in what Lee Lander & Davidson (65) have called the "black lobe." This phenomenon is often seen in pneumothorax when a diseased lobe rapidly decreases in size and comes to lie around the root. This collapse has been shown by these authors to be due to atelectasis.

Coryllos's theory offers a satisfactory ex-:planation/

explanation of those appearances not infrequently seen in serial radiographs of tuberculous patients, with or without a pneumothorax, in whom a cavity will show frequent alterations in size, a phenomenon not hitherto explained satisfactorily. One can assume in such cases that there has been only temporary bronchial occlusion, producing contraction of the cavity, which is succeeded by partial occlusion or no occlusion, when the cavity will again dilate.

Massive lung collapse may possibly be an etiological factor in the production of cases of chronic phthisis or fibrothorax (Trocme: 101. Sanes & Smith: 91.) In such cases the occlusion is assumed to have given rise to traction in the bronchi sufficiently strong to cause a compensatory bronchiectasis.

There are, however, certain arguments against atelectasis as a beneficial factor in pulmonary tuberculosis. If Van Allen's inter-alveolar pores exist they will prevent atelectasis taking place should blockage occur in a small bronchus or in a bronchiolus, as air would then be able to enter the tissue affected through the pores. Miller (75) has demonstrated that their presence is doubtful, and if they occur it is probably only as the result of pathological lesions, most commonly lobar pneumonia. In this respect Warner & Graham (102) have published a report on a patient with/

with atelectasis in whom the bronchi were clear, but in whom there was a marked inflammation of the distal bronchioli.

Salkin, Cadder & McIndoe (89. 90) have examined by post mortem bronchography and post mortem dissection of lungs a large number of cavities, and state that in blocked cavities (cavities into which the radio-opaque substance did not enter), no matter whether the blockage was intracavitary, extra-bronchial, or intra-bronchial, the walls of the cavities showed gross and miscroscopic evidence of tuberculous activity with numerous areas of caseation necrosis. As they stand these results argue against Coryllos's theory, but it is possible that either the blockage was of too recent a date to show any effect on the cavity, that although radio-opaque substance could not enter the cavity, yet air could, or that the cavity wall was too thick to allow air absorption to take place.

It is frequently stated that the retention of cavity secretions is dangerous and toxic to the patient, as cavities are usually secondarily infected, and while closure of the cavity may hinder the growth of tubercle bacilli, it will have no effect on pyogenic organisms. Adams (2) found that pyogenic abscesses healed more slowly in atelectatic lung tissue than when collapse was not produced, and Farage (38) has isolated from the blood/

blood anti-bodies against the haeomotoxin and toxin of B. Welchii in 42 per cent of cases with tuberculosis with cavity formation. In addition he was able to isolate the organism from 12 per cent of the sputa.

It is difficult to agree with Coryllos that all cavities heal only by the presence of atelectasis or air absorption, and the post mortem reports so far published are insufficient to prove his theory. The argument is, however, very attractive and calls for further inquiry.

Certain actions of the different methods of collapse therapy will now be considered:-

Artificial Pneumothorax.

It will readily be realised from the description of the distribution of the elastic tissue and muscle in the lung that the arrangement is ideally suited for spontaneous and simultaneous retraction of all healthy parts of the lung, and that as the major lines of force generated by the elastic tissue lie in the direction of the bronchial tree, the healthy lung tends to retract round the root. In a lung the seat of a tuberculous lesion the natural elasticity of the lung in the diseased area is destroyed. Parry Morgan (76) was the first to describe how only the healthy portions can be inflated freely without undue increase of/

of tension. Thus in the presence of a pneumothorax the healthy areas expand freely with inspiration and in so doing displace air which finds lodgment over the less expansile or non-expansile diseased parts of the lung. Such a process leads to the so-called sel-:ective collapse of the diseased area, but this col-:lapse is not due to increased elasticity of the di-:seased area, as is often stated, but to the inertia of the area to expand. Frequently this type of sel-:ective collapse is not immediate but takes a varying period of time to develop and can be studied on serial radiographs (Hennel & Stivelman: 49.). It is slow in appearing when the lesion is of a bronchopneumonic type, in which the elastic fibres of the lung have not been destroyed, and will appear more rapidly when the lesions are already the seat of fibrous tissue forma-:tion, the speed of its appearance being governed, after the initial contraction, by the rate at which the fibrous tissue contracts. If there is a consider-:able quantity of fibrous tissue in the lesion before the pneumothorax is induced, then one may see a selec-:tive collapse develop almost immediately after induc-:tion, and this may also be the case when atelectasis has occurred prior to the induction, or when it takes place shortly after induction (Ellison: 33.).

Healthy lung tissue is little affected by

pneumothorax/

pneumothorax collapse, provided no pleural effusion forms. Rolland (87) found that even if collapse was maintained for years, on terminating the pneumothorax the healthy lung tissue re-expanded rapidly and at post mortem was of normal appearance.

On the other hand, in the presence of a fluid effusion the preformed fibrous tissue in the lung tends to increase, particularly in the diseased areas, Lindblom (67), and this clinically appears to exert a limiting influence on the lung when the pneumothorax is abandoned. Trocme (100) has shown that if the pleural thickening is at all marked its effect is to limit the respiration of the collapsed healthy lobes, as can be seen clinically by the relative immobilisation of the chest on the affected side and the large manometer swing which then occurs.

When a pneumothorax which has not been complicated by effusion is abandoned then the healthy lobes will expand to a far greater extent than will those which are diseased. An extreme case has been published by Rossel (88), the final radiograph of his patient being undistinguishable from that of a normal lung. In such extreme instances probably a degree of true hypertrophy of the lung occurs. That this is possible has been suggested by Addis (3), who found in rats after a left pneumonectomy, the right lung increased/

increased in mass by more than forty per cent of its original weight.

Parodi (83) has stressed the importance of the part played by the weight of the lung in pneumothorax, when the support of the lung is different from that in the intact chest. In patients with apical adhesions when the remainder of the lung is free, a large part of the weight of the lung, the proportion varying with the position of the patient, will be borne by way of the diseased area to the apex; any cavities in the area are under tension from above and from below, and may well increase in size.

Phrenic Evulsion.

The question as to whether diaphragmatic paralysis has any effect on upper lobe tuberculosis has been widely debated. Some authorities such as Gravesen (45) claim that it has no action, but this view is not supported by the anatomical facts. Morriston Davies (25) quotes Orsos as using an ingenious device for demonstrating the effect of the diaphragm on the apex. He fixed the apex of a triangular piece of thick rubber. This rubber is perforated by a series of rows of circular holes of equal diameter and spacing. On drawing down the base and fixing that, he demonstrated conclusively that whilst the downward displacement of the lower rows of holes is much greater/

greater than that of the upper, yet the upper are much more elongated than the lower. Orsos concluded that the fixation of the apex of the lung (as frequently occurs in apical disease) in the upper thoracic open-:ing is of great importance in relationship to the influence of the diaphragm on the whole lung, and by analogy from the above experiment, that the diaphragm exerts a greater displacement on the lower part of the lung, but has a greater influence on the alveoli of the apex. Bigger & Cox (9) experimenting with ani-:mals, measured the changes in length and angles of deviation of the bronchi and calculated from these figures the actual lengths. They obtained an aver-:age lengthening of the bronchi during stimulation of the phrenic nerve of 21 per cent for the upper lobe and 34 per cent for the lower lobe. If the change in bronchial length is taken as an indication of the change in respired air, contraction of the diaphragm produces a slightly greater effect on the lower lobe than on the upper, but the difference is so slight during normal respiration that it is of no practical importance.

Despite Gravesen's experience clinically, there is little doubt on theoretical grounds that the disphragm plays an important part in aerating the upper lobe.

The/

The presence of adhesions limits the effects of diaphragmatic paralysis, and if these adhesions are very widespread then the results of phrenic evulsion will be scanty. Matson (74) found that the results are more dependent on the rise of the diaphragm and on the degree of collapse of diseased tissue taking place than on the immobility produced. He also points out that the rise is progressive and may continue for two years. In evaluating clinical results both Trocme (100), and Parodi (83) state that, if the diaphragm rises "en bloc," then it is likely to be free from adhesions, whereas, if it ascends "en arc," i.e: if the central portion alone arises, it is likely that extensive adhesions exist and will prevent much col-:lapse taking place.

Thoracoplasty.

In the old Sauerbruch paravertebral type of operation, as has been stated, collapse was obtained mainly in a lateral direction. In addition, partic-:ularly when the transverse processes were removed and the "paravertebral gutter" abolished, there was a par-:tial degree of antero-posterior compression. The lung, however, remained uninfluenced in the vertical axis and it was not uncommon in such cases to experi-:ence merely an alteration in size of the cavity or even only its displacement downwards in an unaltered state./

In distinction from the collapse produced by a pneumothorax, some cavities which heal after thoracoplasty do so as a result of actual compression of their walls, the vertical axis of such cavities being sufficiently lax to allow apposition of the walls of the cavity. On the other hand, it is not at all improbable that healing by atelectasis is of frequent occurrence. Robinson (85) at the Papworth Settlement in a series of twelve cases in which thoracoplasty had been performed was able by bronchography to diagnose bronchiectasis of the collapsed lung in five of these cases. He suggests that the bronchiectasis existed before the operation; it is also possible that the complication developed after the operation and as a result of atelectasis taking place, particularly as two of the bronchiectatic patients had a persistently negative spit. Overholt & Betts (80) also have published two cases in which, after a thoracoplasty collapse of the upper lobe, lobectomy was required for bronchiectasis in the lower lobe. The history, in one of the cases at least, suggests that the bronchiectasis may have been a post-operative complication due to massive collapse of the lower lobe.

With the adoption of apical mobilisation the collapse of the upper lobe obtained by thoracoplasty is much more complete. The lung is free to collapse in/

in all directions and a collapse not unlike that in a complete pneumothorax is possible.

SECTION IV:

A REVIEW OF COLLAPSE TREATMENT:

carried out at

EAST FORTUNE SANATORIUM.

At East Fortune Sanatorium, between the years 1924 and 1937, collapse therapy has been carried out on two hundred and thirty five patients. The Institu-:tion was opened in 1922, and the number of beds has been increased from time to time, particularly during the first decade of its existence. It is, however, only since 1931 that collapse therapy has been used extensively.

During the period under review artificial pneumothorax was induced in one hundred and forty four patients, phrenic paralysis produced in one hundred and thirty five, and thoracoplasty performed on thirty three patients. These numbers are too small to permit of drawing any conclusions. They have, however, been analysed in detail, and will serve to demonstrate cer-:tain points mentioned in the preceeding review.

The three types of collapse - artificial pneu-:mothorax, phrenic paralysis and thoracoplasty - have each been considered separately. The adoption and development of each method from 1924 onward is demon-:strated, then is given a resume of the general indic-:ations/

indications for its use, which is succeeded by an analysis of the factors most likely to affect the treatment, and finally, the results obtained are detailed and the mortality computed. A detailed list of indications for the different types of collapse is not given as these do not differ from those generally accepted.

The classification laid down by the Ministry of Health has been adopted to describe the extent of disease. It is stated thus:-

Group A.

Cases in which tubercle bacilli have never been demonstrated in the sputum, pleural fluid, faeces, etc.

Group B.

Cases in which tubercle bacilli have at any time been found. It should be noted that a patient originally in Group A. must be transferred to Group B. at any stage in the course of treatment if and when tubercle bacilli are found, while on the other hand, a patient who is once placed in Group B. can never be included in Group A. Group B. should be further subdivided into three groups as follows:-

Group 1. (B.1.)

Cases with slight constitutional disturbance, if any: e.g: there should not be marked acceleration of pulse, nor elevation of temperature except of very transient duration; gastro-intestinal disturbance or emaciation, if present, should not be excessive. The obvious physical signs should be of a very limited extent, as follows:-

Either/

Either present in one lobe only and, in the case of an apical lesion of one upper lobe, not extending below the second rib in front or not exceeding an equivalent area in any one lobe; or where these physical signs are present in more than one lobe, they should be limited to the apices of the upper lobes, and should not extend below the clavicle and the spine of the scapula. No complications (tub-:berculous or other) of prognostic gravity should be present. A small area of dry pleurisy should not exclude a case from this group.

Group 3. (B.3.)

Cases with profound systemic disturbance or constitutional deterioration, with marked impairment of function, either local or general, and with little or no prospect of recovery. All cases with grave complications (e.g: diabetes, tuberculosis of intestine, etc.), whether those complications are tuberculous or not, should be classified in this group.

Group 2. (B.2.)

All cases which cannot be placed in Groups 1 and 3.

Artificial Pneumothorax./

ARTIFICIAL PNEUMOTHORAX.

Artificial pneumothorax has been induced on one hundred and fifty five occasions in one hundred and forty four patients at East Fortune Sanatorium. In one case suffering from bronchiectasis pneumothorax was produced as a preliminary to the operation of lobec-:tomy; this case will be left out of the series now under review. All the remaining patients suffered from pulmonary tuberculosis.

NUMBER OF A. P. INDUCTIONS PERFORMED IN CONSECUTIVE YEARS.

TABLE I.

Year	Males	Females	Total
1924	-	1	1
1925	-	1	1
1926	-	1	1
1927	-	2	2
1928	1	2	3
1929	-	1	1
1930	4	5	9
1931	10	9	19
1932	6	8	14
1933	5	16	21
1934	6	14	20
1935	2	12	14
1936	7	12	19
1937	13	16	29
Total	54	100	154

While the first pneumothorax was induced in 1924, it was not until six years later that this treatment was used in any considerable proportion of patients. This was largely due to lack of proper facilities./

facilities. Since 1931 approximately one-fifth to one-quarter of the pulmonary cases in the Sanatorium have received pneumothorax treatment, exclusive of those cases in which induction proved impossible owing to the presence of adhesions. The actual number of inductions in consecutive years is given in Table I.

Although the number of male cases admitted to the Sanatorium was about ten to fifteen per cent greater than the female admissions yet the incidence of pneumothorax inductions in female patients is almost double that of the male patients. Several factors lie behind this, the most important of which is the higher proportion of male patients with advanced disease.

NUMBER OF PNEUMOTHORAX INDUCTIONS IN VARIOUS AGE GROUPS.

TABLE II.

Age in years.	Males. Number.	Per cent.	Females. Number.	Per cent.	Total
0-15	-	-	8	8.5	8
16-20	19	38.7	30	31.9	49
21-25	11	22.4	25	26.6	36
26-30	8	16.3	21	22.3	29
31-35	7	14.3	5	5.3	12
36-40	1	2.0	5	5.3	6
41-45	1	2.0	-	-	1
46-50	2	4.1	-	-	2
Total	49	-	94	-	143

The proportion of pneumothorax inductions in the/

the various age groups was approximately the same for the two sexes. About 60 per cent were performed in patients of between sixteen and twenty five years of age, and more than half of these between the ages of sixteen and twenty.

The youngest patient was an infant of twenty-two months with pulmonary tuberculosis, in whom pneumothorax was induced as a last resort. A collapse which was promising was obtained, but the child did not improve, symptoms of meningitis appeared, and the pneumothorax was discontinued. The remaining cases in the age group, 0-15 were between the ages of ten and fifteen years. A successful collapse, with clinical improvement, was obtained in a child of ten years of age.

Stage/

STAGE OF DISEASE AT TIME OF PNEUMOTHORAX INDUCTION.

TABLE IIIa.

Year	Stage. A.	B.1.	B.2.	B.3.	Total
1924	-	-	1	-	1
1925	-	-	-	1	1
1926	-	-	1	-	1
1927	-	-	1	1	2
1928	-	-	2	1	3
1929	-	-	-	1	1
1930	-	-	5	4	9
1931	-	-	10	9	19
1932	-	-	9	5	14
1933	-	3	9	8	20
1934	-	2	9	8	19
1935	1	-	5	5	11
1936	-	1	15	1	17
1937	-	2	16	7	25
Total	1	8	83	51	143
Still attending on 31-9-38	1	2	21	3	27
Completed before 31-9-38	-	6	62	48	116

TABLE IIIb.

Year	Stage. A.	B.1.	B.2.	B.3.	Total	Per cent in Group B.3.
1924-31	-	-	20	17	37	45.9
1932-34	-	5	27	21	53	39.6
1935-37	1	3	36	13	53	24.5

In the early years of pneumothorax treatment the proportion of inductions in patients with advanced disease was high. It has fallen steadily and the relative increase in number of patients with disease not far advanced who now receive pneumothorax is shown in/

in the second part of Table III. This increase is certainly not due to any decrease in the number of patients with advanced disease admitted to the Sana-:torium, but probably indicates the wider adaption of pneumothorax which follows on experience of the results obtained by its use.

INDICATIONS FOR TREATMENT.

Cases have been divided into three Groups as below:-

Group 1.

Cases.

Pneumothorax performed as the method of choice- 102

Group 2.

Pneumothorax combined with phrenic paralysis - 33

Group 3.

Pneumothorax performed after phrenic paralysis had failed to produce clinical improvement - 8

1. Pneumothorax as a primary mode of treatment.

Pneumothorax was induced as the treatment of choice in one hundred and two cases. At present (September 1938) eighteen patients are still receiving refills, in sixty the pneumothorax has been completed, and twenty four patients have required further col-:lapse measures owing to the failure of the pneumo-:thorax to produce a satisfactory result.

The patients still undergoing treatment in-:clude a high proportion in whom sputum alteration has occurred as a result of the treatment; in sixteen the sputum either has disappeared or does not contain tub-:bercle/

tubercle bacilli, and two remain with positive spit.

Of the eighty-four cases in which pneumothorax has been completed, nineteen cases, as a result of treatment, had conversion of the sputum, and sixty-five remained with a positive spit. All the cases with sputum conversion had at least nine months treatment, but of those cases remaining with a positive spit, thirty-two were abandoned within six months. The cases included in this section are those in which pneumothorax was used in preference to any other form of collapse therapy, and they include a large proportion of cases done in the early days, in which a pneumothorax would not now be attempted.

SUPPLEMENTARY METHODS OF COLLAPSE USED AFTER THE FAILURE OF PNEUMOTHORAX.

	++	+-	--	Total
Thoracoplasty	1	6	2	9
Phrenicectomy & Thoracoplasty	-	2	-	2
Phrenicectomy	3	3	-	6
Contralateral Pneumothorax	4	3	-	7

(The signs, ++ +- --, refer to the sputum. ++ signifies a case in which the sputum was positive both before and after treatment, +- one in which the sputum became negative for tubercle bacilli, or which disappeared, as a result of treatment, and -- one in which the sputum was either absent, or tubercle free both before and after treatment).

It/

It will be seen that thoracoplasty was performed on two patients in whom the sputum was tubercle free before operation; these were cases with a chronic tuberculous empyema. Supplementary collapse treatment was indicated in the other twenty-two cases for persistence of bacilli in the sputum. These cases include ten in which the pneumothorax was maintained for less than six months.

2. Pneumothorax supplemented by diaphragmatic paralysis.

There were thirty-three patients in this group. In fourteen a satisfactory result was obtained and nineteen remained with a positive spit after treatment. Of the latter, five received further collapse measures, in three a pneumothorax of the contralateral lung and in two a thoracoplasty; four as a result became free from tubercle bacilli and one died of intestinal disease.

3. Pneumothorax as a secondary measure.

This group comprises eight patients in whom a diaphragmatic paralysis had been produced with unsatisfactory result. They are segregated separately since it was thought that the diaphragmatic paralysis might cause some difference in the effect of the pneumothorax; this, however, is not evident owing to the paucity of the/

the figures. Four cases became tubercle free and four remained with a positive spit, but these include three in which the pneumothorax comprised merely a small pocket.

RESULTS OBTAINED FROM TREATMENT.

TABLE IV.

	Primary A.P.	A.P. & phrenic paralysis	Secondary A.P.	Total	Per cent
Number still requiring refills	18	8	1	27	-
--	1	-	-	1	-
+-	15	4	1	20	-
++	2	4	-	6	-
Completed cases	84	25	7	116	-
+-	19	10	3	32	-
++	65	15	4	84	-
All cases	102	33	8	143	-
--	1	-	-	1	.7
+-	34	14	4	52	36.4
++	67	19	4	90	62.9
All cases with A.P. of at least six months duration	70	32	6	108	-
--	1	-	-	1	.9
+-	34	14	4	52	48.5
++	35	18	2	55	50.9

This Table largely amplifies the figures given above and presents them in a more comprehensive form.

As/

As a result of treatment just over one third of cases exhibit sputum alteration, but if one excludes the thirty-five cases in which pneumothorax was aban-:doned within six months, then the figure is raised to almost one-half. This change is due almost entirely to cases composing the first group, thirty-two of the thirty-five cases which lasted less than six months being included in this group.

FACTORS INFLUENCING THE RESULTS OF ARTIFICIAL PNEUMO-:THORAX THERAPY.

DURATION OF COLLAPSE IN CASES WITH COMPLETED PNEUMOTHORAX.

TABLE V.

Age in years.

Sputum	0-½	½-1	1-2	2-3	3-4	4-5	5-6	Total
++	35	20	16	8	4	1	-	84
+-	-	5	8	7	9	2	1	32

Cases which terminated satisfactorily, as was to be expected, had a considerably longer period of collapse. The average duration of collapse in those cases was 2.87 years as compared with 1.04 years in those with persistently positive spit. These figures possibly are more the consequences of other factors than themselves factors which were the cause of suc-:cess or failure. When pneumothorax was successful in collapsing the diseased area, an endeavour was made to maintain the collapse for at least three years; if the/

the patient was then without symptoms and had been free from spit for at least two years, the pneumothor-:ax generally was abandoned. If, however, as happen-:ed in a few instances, spit or symptoms recurred on ceasing to refill the pneumothorax space, the collapse was maintained. In those cases in which the sputum remained positive even with collapse the pneumothorax was usually stopped after about three years as being of no further service. Generally, if a pneumothorax in anyway satisfactory was stopped in less than from two and a half to three years it was abandoned involun-:tarily.

RELATIONSHIP OF SPUTUM ALTERATION TO THE STAGE OF DISEASE.

TABLE VI.

All cases: A.P. alone.	+-	++	Per cent ++
Group B.1.	7	1	12.5
Group B.2.	39	44	53.0
Group B.3.	6	45	88.2
Total	52	90	64.1

A large proportion of successful results was obtained in the earlier cases, again a result to be expected.

Of the Group B.3. cases, 88.2 per cent remained with a positive spit, while of the Groups B.1. and B.2. 49.5 per cent remained positive.

Relationship /

RELATIONSHIP OF DEGREE OF PNEUMOTHORAX COLLAPSE TO SPUTUM ALTERATION.

TABLE VII.

Collapse	+-	++
Complete	5	1
Selective	32	16
Partially-selective	5	32
Irregular	-	41
Total	52	90

It is difficult, particularly when one has to rely on past records and radiographs, to define the degree of collapse. An anatomical scale might appear the best, but this leaves out of account such factors as the occurrence of atelectasis in a lobe, even although the rest of the lung is adherent. Again, to estimate the result by the clinical improvement which is effected in the patient is obviously unsatisfactory. The following arbitrary scale, based on the examination of radiographs and screening notes, has been used:-

Complete collapse. The lung is quite free with no visible cause to prevent a complete collapse about the root.

Selective collapse. Collapse occurs in the diseased area; the presence of adhesions, if they do not interfere with the collapse, are not considered.

Partially selective collapse. Comprises those groups where/

where selective collapse tends to occur, but is hinder-:ed by the presence of adhesions. Some degree of col-:lapse must have taken place, and the diseased area be more condensed.

Incomplete. Collapse is irregular and with no obvious selective effect on the diseased area.

Applying those standards to all cases the re-:sults obtained are shown in Table VII.

71.1 per cent of the cases showing sputum alter-:ation had a satisfactory collapse as compared with 18.9 per cent of the cases with a persistently positive spit, while none of the patients with an irregular col-:lapse showed sputum alteration.

RELATIONSHIP BETWEEN DISEASE IN THE CONTRA-:LATERAL LUNG AND SPUTUM ALTERATION.

TABLE VIII.

Extent of disease	+-	++
Unilateral	21	34
Bilateral:-		
Slight	20	21
Moderate	9	25
Extensive	2	10
Total	52	90

The extent of disease on the contralateral lung has to be taken into account. The following degrees of disease were recognised:-

Unilateral /

Unilateral. No evidence of disease in the contralateral lung other than Ghon's foci.

Bilateral. 1. Slight - Healed, quiescent or light infiltration of not more than one lobe. 2. Moderate - Definitely active disease, or disease with cavitation, of not more than one lobe. Quiescent disease of more than one lobe. 3. Extensive - Active disease of more than one lobe.

21.1 per cent of the cases with sputum alteration had moderate or extensive disease in the contralateral lung as compared with 38.9 per cent of cases in the group with persistently positive spit.

EFFECTS OF ANCILLARY TREATMENT.

TABLE IX.

Indications	Number	Result Success	Failure
Prevent symphisis	1	-	1
Bronchopleural fistula	3	1	2
Lax mediastinum	5	1	4
Empyema	6	4	2

Oleothorax was carried out on fifteen occasions in fourteen patients. With the exception of the group suffering from tuberculous empyema, the results, which are given in Table IX were unsatisfactory.

Thoracoscopy was employed in eight patients who had a cavity held out by adhesions which were at least partially/

partially divisible. A few, who on examination with the thoracoscope were found to be inoperable cases, have not been included. Two patients had the operation performed on both sides. The complete results were as follows:-

Successful (+-)	4 cases
Some success (++)	3 cases
Failed (lung expanded)	2 cases
Empyema	1 case

Gold Therapy was frequently employed, particularly in the presence of disease of the contralateral lung. While in many instances this appeared to be of undoubted help to the patient, on the whole it was very difficult to evaluate and approportion the results which might be due to the gold. In several instances diarrhoea proved intractable and of a tuberculous nature leading to death.

FACTORS LEADING TO CESSATION OF PNEUMOTHORAX.

TABLE X.

Reason for termination of A.P.	++	+-
Still attending	5	22
Voluntary cessation	2	13
Symphisis of the lung	2	5
Inefficient collapse	25	2
Empyema	4	7
Effusion	1	2
Contralateral spread	26	-
Contralateral spread & enteritis	10	-
Enteritis	4	-
Amyloid disease	2	-
Broncho-pleural fistula	3	-
Spontaneous pneumothorax	2	-
Spontaneous pneumothorax - of contralateral lung	1	-
Meningitis	2	-
Mediastinitis	1	-
Ceased attending	-	2
Total	90	53

This Table shows that inefficient collapse or spread of the disease in contralateral lung accounted for cessation of the pneumothorax in two-thirds of the cases with positive sputum.

After /

AFTER HISTORY OF PATIENTS

TABLE XI.

Years after commenc-ing A.P.	++ Cases		-- & +- Cases		All Cases	
	Died	Alive	Died	Alive	Died	Alive
0-1	30	2	-	3	30	5
1-2	6	7	-	9	6	16
2-3	4	3	1	6	5	9
3-4	2	2	-	6	2	8
4-5	1	1	1	8	2	9
5-6	2	2	-	8	2	10
6-7	-	1	1	2	1	3
7-8	-	-	-	3	-	3
8-9	-	-	-	1	-	1
9-10	-	-	-	-	-	-
10-11	-	-	-	-	-	-
11-12	-	-	-	1	-	1
12-13	-	-	-	-	-	-
13-14	-	-	-	1	-	1
Total	45	18	3	48	48	66

The above Table indicates the number of deaths occurring each year after the commencement of treatment, and also gives the number of patients who were alive when last heard of in the appropriate year after com-:mencing treatment.

With three exceptions all the patients were traced for varying periods after leaving the Sanator-:ium, over ninety per cent up to the time of their deaths, or until September 1938. Of the three who were untraced, two left to reside in areas outside the South Eastern Counties and did not reply to circular letter. In both these cases the pneumothorax had been completed./

completed. One patient left to go home to Donegal before the pneumothorax had been terminated. It has not been possible to obtain any information concerning this patient, and she has been included among these still under treatment, the pneumothorax being presumed to have been maintained only for the period she was under our care. Cases which received later treatment such as phrenicectomy and thoracoplasty are not included here; they are placed under the appropriate headings below. The mean period which elapsed between instituting collapse and death, or the time when last heard of, in patients receiving pneumothorax treatment, was 31.2 months. The corresponding figure for those cases dying and those alive when last heard of was -

Positive cases.	21	months
Average period till death	13.4	months
Average period last heard of	36	months
Negative cases.	50.6	months
Average period till death	51	months
Average period last heard of	50	months

The mortality for both groups combined was 42.1 per cent, but for the persistently positive group it was 71.4 per cent, and for the group showing sputum conversion, as low as 5.9 per cent.

Phrenic /

PHRENIC PARALYSIS.

Phrenicectomy was performed on one hundred and thirty-four occasions between 1926 and the end of 1937, but only since 1931 has it been employed systematically.

NUMBER OF PHRENICECTOMIES PERFORMED EACH YEAR.

TABLE XII.

Year	Males	Females	Total
1926	-	2	2
1929	2	3	5
1930	3	4	7
1931	6	13	19
1932	9	13	22
1933	9	9	18
1934	8	10	18
1935	2	12	14
1936	2	6	8
1937	10	11	21
Total	51	83	134

The same disparity between the number of operations performed on males and females as was noted in the pneumothorax cases is again apparent.

INDICATIONS.

1. **Preliminary to thoracoplasty.** On nine occasions between 1929 and 1932 the operation was performed as a routine measure preliminary to thoracoplasty. Usually the thoracoplasty was performed two or three weeks later, which period was not sufficient to permit/

permit any clinical improvement to occur.

2. Symptomatic. As a palliative measure the operation was performed on sixteen occasions. The majority of the patients were in a hopeless state and no improvement in their general state was expected. The indications were -

Shoulder pain due to peaking of the diaphragm from old pleurisy -	1 case
Severe cough -	9 cases
Haemoptysis -	5 cases
Dyspneoa due to traction on heart and mediastinum -	1 case

The operation failed to stop bleeding in one of the cases of haemoptysis and was only partly successful in another case, but in all other cases it fulfilled the reason for its performance.

3. Phrenic paralysis combined with artificial pneumothorax.

This group has already been considered with the pneumothorax cases. Of the thirty-three patients composing it, one had a negative sputum before operation, in nineteen the sputum remained positive and in thirteen it altered from positive to negative.

4. Phrenic paralysis after the failure of other collapse measures.

Of the seven cases in this group, six had a phrenic paralysis produced after an unsatisfactory pneumothorax collapse had been abandoned, and one was performed on a thoracoplasty patient who had experienced an acute postoperative spread into the lower lobe. In three of the patients in this group, sputum/

sputum alteration resulted from the operation while in four no change was produced.

5. Phrenic evulsion as the primary method of treatment.

Phrenic evulsion was performed as the method of choice in bringing about collapse in sixty-nine cases. One patient was admitted to the Sanatorium with a pleurisy and a very restricted sub-apical infiltration of a fibrotic type. He produced no sputum, but felt pain in the shoulder and along the insertion of the diaphragm of a severity sufficient to interfere with his everyday life; after the phrenic paralysis was produced pain disappeared and his general condition showed a marked improvement, which was coincidental with a contraction of the diseased area in the lung. Of the remaining sixty-:eight cases, sixteen became sputum negative, and fifty-two remained with a positive spit. Of the fifty-two patients in the latter group, additional collapse measures were instituted in eighteen, arti-:ficial pneumothorax in eight, and thoracoplasty in ten; these measures led to sputum alteration in eight cases.

RESULTS.

As in the first two groups phrenic evulsion had no active influence on the course of the disease, these groups and group three which was included with the/

the pneumothorax cases, will be omitted, leaving seven-:ty-six patients in whom phrenic paralysis was induced as an independent therapeutic measure. Of these one was a group A. case with negative sputum who was great-:ly helped by the operation, nineteen became sputum negative for tubercle bacilli, and fifty-six remained with a positive spit, eighteen of the latter patients having additional collapse treatment as detailed above. Thus, of seventy-five patients who before operation had a positive spit, nineteen or 25.3 per cent showed spu-:tum alteration as a result of treatment; as a result of further collapse measures in those suitable, eight more became negative or 36 per cent of the seventy-:five cases, while 64 per cent remained positive.

FACTORS INFLUENCING THE RESULTS OF TREATMENT.

NUMBER OF PATIENTS IN VARIOUS AGE GROUPS HAVING PHRENIC PARALYSIS.

TABLE XIII.

Age in years.	Males Number.	Per cent.	Females Number.	Per cent.	Total.
10-15	-	-	3	6.4	3
16-20	2	6.9	6	12.8	8
21-25	5	17.2	14	29.8	29
26-30	4	13.8	8	17.0	12
31-35	6	20.7	7	14.9	13
36-40	4	13.8	4	8.5	8
41-45	1	3.4	3	6.4	4
46-50	3	10.3	1	2.1	4
51-55	4	13.6	1	2.1	5
Total	29	-	47	-	76

The age distribution of the operation is markedly different between the two sexes. In male patients the operation was performed at a later age than in women; the age group with the greatest number of inductions is, in men 31-35, and in women 21-25.

STAGE OF DISEASE IN PATIENTS HAVING PHRENIC PARALYSIS INDUCED.

TABLE XIVa.

Year	A.	B.1.	B.2.	B.3.	Total
1926	-	-	-	2	2
1929	-	-	-	2	2
1930	-	-	1	-	1
1931	-	-	6	7	13
1932	-	-	8	4	12
1933	-	1	12	3	16
1934	1	1	3	5	10
1935	-	1	3	3	7
1936	-	-	4	2	6
1937	-	-	6	1	7
Total	1	3	43	29	76

TABLE XIVb.

	A.	B.1.	B.2.	B.3.	Total	Per cent in B.3.
1926-31	-	-	7	11	18	63.6
1931-34	1	2	23	12	38	31.6
1935-37	-	1	13	6	20	30.0
Total	1	3	43	29	76	-

The stage of disease at the time phrenicectomy was performed is given in Table III. A high proportion/

proportion of the cases had advanced disease, more than was the case with artificial pneumothorax patients. This is not surprising as the operation is frequently performed on patients unsuited by reason of pleural adhesion or too extensive disease for artificial pneumothorax, and as it is a relatively benign procedure, as a last line of attack on patients who are very ill.

It is interesting to note that as with artificial pneumothorax when the operation was first introduced it was used in a large proportion of Group B.3. patients, but that as experience was gained a higher proportion of patients with less advanced disease had the operation carried out.

The cases were analysed with a view to determining whether an adherent pleura, as shown to exist by failure to establish pneumothorax, had any effect on the effect of phrenic paralysis. The figures were, however, too small to be of any value. Certain other factors which exert a definite influence are given below:-

INFLUENCE OF STAGE OF DISEASE ON SPUTUM ALTERATION.

TABLE XV.

Group	Sputum			
	+-		++	
	Number	Per cent	Number	Per cent
Group B.1.	1	33.3	2	66.7
Group B.2.	14	32.5	29	67.5
Group B.3.	4	13.8	25	86.4

The/

The number of cases which became sputum negative after operation in each group, and the percentage they represent is given above. It will be seen that two and a half times as many patients in Groups B.1. and B.2. became sputum negative as in Group B.3.

EFFECT OF PHRENIC PARALYSIS ON DISEASE IN DIFFERENT AREAS IN THE LUNG.

TABLE XVIa.

Site of disease	+- Number	+- Per cent	++ Number	++ Per cent	Total
Mainly upper	16	31.4	35	68.6	81
Mainly basal	-	-	12	100.0	12
Diffuse	3	25.0	9	75.0	12

TABLE XVIb.

	Disease mainly:- Upper	Basal	Diffuse
Cases with ++ spit	35	12	9
Worse after evulsion	3	2	-
No improvement after evulsion	9	3	1
Slight improvement after evulsion	5	3	2
Moderate improvement after evulsion	13	2	4
Marked improvement after evulsion	5	2	2
Total showing moderate, or marked improvement	18	4	6
Per cent -do-	51.4	33.3	66.7

Cases have been grouped according as to whether the disease on the side operated on was confined chiefly to the upper or basal areas, or was diffuse. The figures are given in Table XVIa. The failure of the paralysis to produce sputum alteration in basal disease is very striking. That this is not due to

the/

the paucity of the cases is shown when one analyses further (Table XVIb.) cases with a persistently positive sputum, and finds that only 33.3 per cent of cases of basal disease showed moderate or marked improvement, as compared with over 50 per cent in the other two Groups.

INFLUENCE OF THE EXTENT OF DISEASE IN THE CONTRALATERAL LUNG ON RESULTS.

TABLE XVII.

	+-	++
Unilateral	8	16
Bilateral -		
Slight	5	20
Moderate	5	17
Extensive	1	3
Total	19	56

Table XVII indicates the extent of the disease. The standards described in the section dealing with artificial pneumothorax have been used in estimating the extent of disease in the contralateral lung. The effect of the extent of the disease is less marked than was the case with the artificial pneumothorax patients. 68.4 per cent of the cases with sputum alteration had unilateral or only slight contralateral disease, as compared with 64.2 per cent of the persistently positive cases.

Number /

NUMBER OF CASES SURVIVING AND DYING EACH YEAR AFTER OPERATION.

TABLE XVIII.

Years since Operation	++ Cases Died	++ Cases Alive	-- & +- Cases Died	-- & +- Cases Alive	All Cases Died	All Cases Alive
0-1	12	-	1	-	13	-
1-2	10	3	1	3	11	6
2-3	6	2	3	1	9	3
3-4	1	-	2	3	3	3
4-5	1	-	-	1	1	1
5-6	1	-	-	4	1	4
6-7	-	-	-	-	-	-
7-8	1	1	-	1	1	2
Total	32	6	7	12	39	19

It will be noted that only thirty-eight of the fifty-six patients with a persistently positive spit are included in Table XVIII. The remaining eighteen patients received later some other form of collapse therapy, such as artificial pneumothorax or thoracop-:lasty, and have been included with the cases treated by these means.

Cases treated by phrenic paralysis were traced for a mean period of 28.9 months. The average time elapsing between the operation and time of death or per-:iod when last heard of was:-

Positive cases.	23.4 months
Average period till death	21.4 months
Average period till last heard of	34 months
Negative cases.	40.1 months
Average period till death	34.2 months
Average period till last heard of	47 months

The/

The mortality for all cases was 67.2 per cent, for the group without sputum alteration, 84.2 per cent, and for the group with negative sputum at the conclus-:ion of treatment it was 35 per cent.

Thoracoplasty /

THORACOPLASTY.

Thirty-three patients have had performed the operation of thoracoplasty. The cases included here are those cases in which, at least, the first stage of the operation was performed prior to the end of 1937. The earlier cases were operated on by the Sauerbruch technique, commencing with the lower ribs and working upwards. Later, the removal of the transverse pro-:cesses was introduced, the operation was begun with removal of the upper ribs, and was performed in two or more stages. Of the thirty-three cases only the last two had extrafascial mobilisation of the apex carried out. In addition to these two cases there have been done sixteen thoracoplasties this year using Semb's technique. These cases are not included here, but it may be mentioned that they have been carried out without operative mortality and appear to give better results, while postoperative shock is greatly dimin-:ished.

NUMBER OF OPERATIONS PERFORMED EACH YEAR.

TABLE XIX.

	Males	Females	Total
1926	1	-	1
1929	1	2	3
1930	2	3	5
1931	-	1	1
1932	-	1	1
1933	-	1	1
1934	3	2	5
1935	3	5	8
1936	3	2	5
1937	1	2	3
Total	14	19	33

Previous treatment.

In nine of the early cases a preliminary phren-:ic evulsion was performed as a routine measure, and in one it was performed after thoracoplasty in a pat-:ient who developed an acute infection of the lower lobe. Six patients had had pneumothorax treatment, nine a phrenic paralysis, and three a combination of these.

Indications.	Cases.
Bronchiectasis;chronic tuberculosis	1
Pyopneumothorax	3
Bronchopleural fistula	2
Tuberculosis - Stage B.2. 17) Stage B.3. 10)	27

Age and Sex.

The number of patients in the various age Groups was as follows:-

Age /

Age in years	0-15	-20	-25	-30	-35	-40	-45
Males	-	2	4	2	3	1	2
Females	2	4	4	4	4	1	-
Total	2	6	8	6	7	2	2

RESULTS.

Operative Mortality.

There were five deaths within the first three months after operation. All occurred in patients operated on before 1935. The causes of death were -

Spontaneous pneumothorax (a case of pyopneumothorax in which (the original fistula re-opened)	First day
Pneumonia	Fourth day
Pneumonia	Fifth day
Cardiac failure (due to mediastinal flap)	Tenth day
Unexplained sudden death	Twenty-second day

Bronchiectasis.

The radiographic appearancesin this case were those of old tuberculous mischief with a super-added bronchiectatic condition, which was the cause of the symptoms for which he was admitted to the Sanatorium. After the first stage of the thoracoplasty operation he became much worse, further operative treatment was not possible, and he died four months later.

Pyopneumothorax.

One patient died postoperatively. Supplement-

:ary/

Supplementary plastic operations were required in the other two patients. One patient has died of amyloid disease, and the other is still convalescent from a supplementary plastic operation.

Bronchopleural fistula.

One patient died postoperatively, and the other case died from meningitis five months after operation.

Tuberculosis.

Three patients died postoperatively. Of the twenty-four surviving cases, seven remained with a positive sputum, while in seventeen the sputum has disappeared or become tubercle free. Further operative treatment carried out in the cases with a persistent positive sputum included plombage on one case with a residual cavity, phrenic evulsion in a patient who had experienced an acute postoperative spread of disease into the lower lobe, and an anterior removal of ribs in two cases with residual cavities. In no case did this supplementary treatment lead to disappearance of tubercle bacilli from the sputum.

NUMBER OF CASES SURVIVING AND DYING EACH YEAR AFTER OPERATION.

TABLE XX.

Years since Operation	++ Cases		+- Cases		All Cases	
	Died	Alive	Died	Alive	Died	Alive
0-1	1	1	-	-	1	1
1-2	2	-	-	4	2	4
2-3	-	-	-	3	-	3
3-4	-	1	2	4	2	5
4-5	1	1	-	-	1	1
5-6	-	-	-	1	-	1
6-7	-	-	1	-	1	-
7-8	-	-	-	-	-	-
8-9	-	-	-	-	-	-
9-10	-	-	-	-	-	-
10-11	-	-	-	1	-	1
11-12	-	-	-	1	-	1
Total	4	3	3	14	7	17

Cases treated by thoracoplasty were traced for mean period of 42.5 months. The average period elapsing between the operation and the time when last heard of was -

Positive cases.	28.3 months
Average period till death	16.8 months
Average period till last heard of	38.4 months
Negative cases.	48.4 months
Average period till death	39.6 months
Average period till last heard of	57.6 months

The mortality for the whole Group was 29.2 per cent, for the cases with persistently positive sputum 57.1 per cent, and for those with no, or negative sputum 17.6 per cent.

Results /

RESULTS OF TREATMENT IN ALL CASES.

TABLE XXI.

Years since institution of treatment	++ Cases		-- & +- Cases		All Cases	
	Died	Alive	Died	Alive	Died	Alive
0-1	43	3	1	3	44	6
1-2	18	10	1	16	19	26
2-3	10	5	4	10	14	15
3-4	3	3	4	13	7	16
4-5	3	2	1	9	4	11
5-6	3	2	-	13	3	15
6-7	-	1	2	2	2	3
7-8	1	1	-	4	1	5
8-9	-	-	-	1	-	1
9-10	-	-	-	-	-	-
10-11	-	-	-	1	-	1
11-12	-	-	-	2	-	2
12-13	-	-	-	-	-	-
13-14	-	-	-	1	-	1
Total	81	27	13	75	94	102

Two hundred and thirty-five patients have been treated at East Fortune Sanatorium by some form or combination of forms of collapse therapy. Thirty-nine patients were either treated on symptomatic grounds, died postoperatively, or have this year received some additional collapse treatment. The results obtained from treatment in the remaining one hundred and ninety-six patients are summarised in Table XXI. The cases were traced for a mean period of 33.4 months. The average period elapsing between the institution of treatment and the time when last heard of was -

Positive /

Positive cases.	21.7 months
Average period till death	18 months
Average period till last heard of	32.4 months
Negative cases.	47.3 months
Average period till death	40.2 months
Average period till last heard of	47.7 months

The mortality in the entire series is 48 per cent, in the group with persistent positive sputum 75 per cent, and in the group with negative sputum at the termination of treatment, 14.2 per cent.

Section /

SECTION V.

DISCUSSION.

The figures of the preceeding section permit little comment. They yield results which have been demonstrated frequently, particularly as regards the beneficial effect which sputum alteration has on the patient's expectation of life. Certain points, however, may be emphasised.

Artificial pneumothorax.

The occurrence of what Lee Lander has titled the "black lobe" during a pneumothorax, due to atelectasis taking place in the lobe is a well-known phenomenon, but it has not been possible, from a study of the radiographs of patients in this series, to demonstrate this occurrence in any new way. The appearances are not seen in all cases of pneumothorax which have a successful outcome, nor even in a majority of such cases. That this is so, is probably due to the anatomical division of the lobes into separate areas, in which collapse may occur quite independently. On examining the patient by fluoroscopy or by a radiograph taken in the usual antero-posterior position this collapse may not be seen. In some cases this is because the collapsed lung is overshadowed by lung which/

which remains inflated, and in such cases the black collapsed lobe can usually be seen on rotating the pat-:ient.

The difference found in the results obtained in the three groups of pneumothorax patients is note-:worthy. The figures are given in Table IV. on page 68. The difference between the results obtained by artificial pneumothorax alone and artificial pneumo-:thorax combined with phrenic paralysis, is similar to, but not so marked as, that found in larger series of cases, such as those referred to below. If however, one omits from consideration those cases in which pneu-:mothorax was abandoned within six months then the dif-:ference in the immediate results in the two groups of cases is largely removed. Provided the paucity of the cases does not nullify this result, it indicates that in a certain proportion of cases where collapse is in-:complete, if a diaphragmatic paralysis is added then the collapse is made effective. In the present series phrenic evulsion was performed only if it appeared from the radiograph of the patient that a paralysis of the diaphragm would increase the collapse; the most com-:mon indication was a lung strung out between the apex and the diaphragm and adherent to both.

Larger series of results have been published by Harper (46), Edwards and Stevens (30), and Edwards (29)./

(29). Harper's figures refer to only 45 cases in which sputum had remained persistently positive after pneumothorax, but in which a large proportion had become negative after a paralysis was added. Edwards and Stevens analysed the after histories of one thousand cases in which phrenic paralysis had been produced two to twelve years previously. They concluded that while phrenicectomy was of definite value as a sole collapse measure, its greatest value was in conjunction with pneumothorax. Of two hundred and eighty-two patients treated by phrenicectomy, sputum alteration was obtained in 30.4 per cent, while of six hundred and forty-seven treated by a combination of artificial pneumothorax and phrenic paralysis the sputum became negative in 49.9 per cent. The figures for artificial pneumothorax treatment alone are not given in this paper, but in the Annual Report of the Cheshire Joint Sanatorium (the Institution in which the above series of cases was treated), Edwards gives a series of tables dealing with results obtained from collapse therapy. In those cases with a satisfactory pneumothorax collapse, 61.81 per cent were alive four years later, while for similar cases in which pneumothorax had been supplemented by phrenic evulsion, the figure was 83.57 per cent. The corresponding figures for cases in which a partial pneumothorax collapse was obtained/

obtained were 24.4 per cent and 63.92 per cent respectively.

The most important of the factors influencing the course of a pneumothorax is the extent of the disease in the contralateral lung. 9.1 per cent of all successful pneumothorax cases had moderate or extensive disease of the contralateral lung - the corresponding figure for those remaining with a positive sputum was 41.7 per cent. These figures suggest that in a high proportion collapse was probably effective on the collapsed side, but that the contralateral lung remained with active disease. They would indicate that greater use should be made of bilateral pneumothorax.

Table IIIb. on page 64, is of interest as it indicates the marked fall which has taken place in cases with advanced disease receiving collapse therapy. Taken in conjunction with Table VI. on page 70, which shows only 10.5 per cent of B.3. cases with sputum alteration after treatment as compared with 39.7 per cent of B.1. and B.2. cases, it suggests that greater use is now being made of pneumothorax in earlier cases. The classification which has been used is not satisfactory in considering these cases in so far as it groups together as B.3., and to a less extent as B.2. cases which have a different pathological basis. B.3. cases include those with advanced chronic disease for which/

which no treatment is of avail, and cases with acute illness and wasting who do have a reasonable chance of improvement by pneumothorax. To a less extent the same argument holds good for B.2. cases. A pathological basis for grading cases was, however, impracticable. It is of interest to note that the greatest proportion of pneumothorax inductions was in the period 16-20 years of age when chronic disease is rare.

Finally, one may present a point which arises from clinical observation and cannot be reduced to statistics in small series of cases. Repeatedly one has seen a pneumothorax induced in a toxic and ill patient. Although incomplete collapse results, great improvement may take place, the temperature falling, sputum diminishing and weight increasing, but the sputum remains positive and the diseased area uncollapsed. This improvement is due to diminution in the blood supply to the affected lung and consequent diminished toxic absorption. Although such a pneumothorax is a failure as far as its curative effect is concerned, it does allow such a patient to improve and to become stabilised in a less acute stage, probably because there is a greater formation of fibrous tissue than would be the case in the absence of a pneumothorax, and in the course of a few months he may be able to undergo a major collapse procedure which otherwise would have been out of the question. Usually the improvement/

improvement seen in such a case is only temporary, the patient after a short period again going down-hill. In some other cases a condition of stalemate is reach-:ed, the patient remaining tolerably well and able to get up and about while the pneumothorax is maintained, but relapsing if it is abandoned. Such cases would appear to approximate to what Lawrason Brown and H.L. Sampson (13) have described as the "good chronic" case, and which they define thus:- "A cavity 2 cm. in dia-:meter or larger must be present. The general condi-:tion must be favourable. The temperature and pulse must be normal during the period of observation of several months. The appetite and strength must be good, and the patient must sleep well. Expectoration may be present, but must not be excessive. He is usually able to take some exercise. The number of tubercle bacilli in the sputum is not taken into con-:sideration." Of 205 such "good chronics" 80 per cent were alive after five years, and 66 per cent at the end of ten years, while of 131 bad chronics, only 37 per cent and 25 per cent were alive after five and ten years respectively. Brieger (10) in his survey of the rehabilitation of sanatorium patients makes mention of a similar group. In some patients, it appears clin-:ically that a pneumothorax may play a part in convert-:ing them into, at least, a chronic case, and sometimes even into a "good chronic" case. It is not an un-:reasonable/

unreasonable supposition when one considers the in-:crease of fibrous tissue which results from collapse of the lung.

Phrenic paralysis.

The results obtained by this form of collapse therapy are, as shown by the survival figures on Page 86, not so good as those obtained by other collapse methods. This is not surprising since, from a consid-:eration of the muscular action of the diaphragm, one would expect paralysis of this muscle to be beneficial chiefly in so far as it abolishes the concertina-like pumping action of the muscle and lessens the respir-:atory motion of the upper lobe. This is borne out by the fact that only 25 per cent of cases in which the operation is carried out for curative purposes show sputum alteration, although it must be noted that these cases include a higher proportion with advanced disease than is the case with other modes of collapse treatment.

Gravesen has already been quoted as of the opin-:ion that paralysis of the diaphragm has little effect in disease of the upper lobe. He found (44) propor-:tionally basal or middle lobe affections in three times as many of the successful cases as of the cases with negative results. Altogether his results from the/

the operation were disappointing save in localised les-:ions.

In the cases operated on at East Fortune Sana-:torium, the least successful results were obtained in basal disease. Not only did none of the twelve cases show sputum alteration, but in only one-third was there any material gain as a result of the operation. Better results were obtained both in cases of upper lobe disease, and in cases with diffuse disease. As has been described in Sections II, and III, one would certainly expect paralysis of the diaphragm to exert some influence on the upper lobe. One aspect of this subject, however, does not appear to have received adequate attention from experimental workers. It has not been determined in what way interlobar adhesions alter the action of the diaphragm. In Roche's paper (86), it is stated that if adhesions are present, then on screening the patient after bronchography, or by kymoradiography, the upper lobe bronchus is pulled downwards with inspiration instead of merely increasing in its own axis as is normally the case. On theoret-:ical grounds one would expect that a diaphragmatic paralysis would have a greater effect in lessening respiratory movements of the upper lobe in cases with interlobar adhesions than in those where they are absent. An analysis of the East Fortune figures to discover/

discover whether pleural adhesions, as determined to exist through the failure to induce a pneumothorax, exerted any influence on the effectiveness of a dia-:phragmatic paralysis was of no value owing to the few cases available. Edwards' figures may be quoted. He found that when a pneumothorax was impracticable only 25.62 per cent of cases were alive four years later, but if a phrenic paralysis was produced in such cases then 49.44 per cent were alive four years later.

Two factors brought out in an analysis of the factors effecting the results suggest that the oper-:ation acts more in a general way by resting the lung than by allowing collapse to take place in it. These are, the lessened effect which the stage of disease exerts than is the case with artificial pneumothorax cases, (only one-third of cases not far advanced showed sputum alteration as compared with 50 per cent of the pneumothorax cases at a corresponding stage), and the fact that disease in the contralateral lung appears to exert very little influence, approximately the same proportion of cases showing sputum alteration as remain with a positive spit. These findings sug-:gest that a phrenic paralysis acts more by increasing the chances of natural recovery through lessening the respiratory motion of the lung than by relaxing the lung sufficiently to allow collapse of the diseased area/

area to occur in the way it does with a pneumothorax. The frequency with which a phrenic paralysis is induc-:ed after failure to induce a pneumothorax, and the fact that this failure does not appear to limit the effects of the paralysis support this argument.

Thoracoplasty.

The results in this group suggest that a high-:er proportion of successful results in suitable cases are obtained from thoracoplasty than from other coll-:apse measures; 70.8 per cent of the patients showed alteration of sputum. The number of operative deaths is high, but these occurred mostly in the earlier cases. The results obtained from the more recent operation, where thoracoplasty is combined with mobilisation of the apex are much more promising. As has been stated, this is because it permits a much better collapse of the lung about the root, particularly of the upper lobe, whereas, with the older type of operation a cavity was not infrequently only reduced in size or altered in position. Sembs' figures for his immediate results have already been quoted, they are very satisfactory. Overholt (79), has obtained similar good results. His figures refer to two hundred and fifty-three patients. One hundred and forty-seven cases were operated on without apical mobilisation between June 1932 and February 1935. From February 1935 till June 1936 he/

he performed thoracoplasty with apical mobilisation on 106 cases. Of the former group, 15 per cent had act-:ive bilateral disease, and the total mortality was 6.4 per cent. In the latter group 28 per cent had active bilateral disease, and the total mortality was 5.6 per cent. Surveyed in the spring of 1937, a sat-:isfactory collapse in the first group was found in 95 of 133 patients, i.e: 71 per cent: in the second, in 86 of 93 patients, i.e: 92 per cent. Contralateral spread had taken place in the first group in 11 pat-:ients, in the second, in 7 patients. Operative re-:vision was required in 20 cases in the first group and in only one, in the second.

Reference has already been made (page 56) to occurrence of bronchiectasis in cases which have had thoracoplasty performed, as was demonstrated by Robin-:son at Papworth, and Overholt and Betts in America, and its probable relationship to massive collapse of the lung mentioned.

This complication developed in one of the cas-:es treated at East Fortune.

Case History.

J.B. aged 18 years - admitted to the Sanatorium on 22-9-28 with diffuse active disease of a relatively chronic type, in the left lung. The right lung appeared healthy. The sputum contained tubercle bacilli and his gen-eral condition permitted classification as/

as a Group B.2. case. Commencing on the 7-11-28 he had series of small haemoptyses for which on 3-12-28 an artificial pneumothorax was induced. Collapse was incomplete. The upper part of the lung, containing at least three fair sized cavities, was adherent. He improved considerably and the pneumothorax was maintained until 30-11-29; when abandoned, a symphisis was taking place after the occurrence of a small tuberculous empyema. Symptoms returned and, after a preliminary phrenic evulsion had been performed, complete extrapleural thoracoplasty was carried out in two stages on 13-2-30 and 3-3-30. Convalescence was normal and he was discharged on 24-7-30 free from cough and spit.

He remained well for some months, but on 18-3-31 was re-admitted with a history of a slight haemoptysis and with slight cough and spit. Collapse appeared satisfactory, but a lipiodol examination showed appearances very suggestive of bronchiectasis on the collapsed side, no lipiodol passing into the collapsed lung parenchyma. Tubercle bacilli were not recovered from the sputum in the course of twelve examinations. He recovered rapidly and was discharged on 20-6-31, again sputum free.

Apart from a short period in the Sanatorium from 22-2-33, till12-6-33, more of a prophylectic measure than for active treatment, he kept well until early in 1936, when a cough and spit resumed and rapidly became profuse. Re-admitted on 28-3-36 with symptoms of amyloid disease, he went downhill and died on 23-7-36, apparently from that condition. Sputum was very abundant, but examination on 19 occasions had failed to reveal tubercle bacilli. Post mortem examination was refused.

The terminal development of amyloid disease is interesting, and was probably a complication of the bronchiectasis. The association of these conditions had/

had been referred to by Aufses (6), who states - they are of not uncommon occurrence as a sequel to thoraco-:plasty, although he does not give details of any cases.

Conclusions./

CONCLUSIONS.

1. The development of collapse therapy has been traced from early times. A summary of the physiology of respiration as related to collapse therapy is given and theories as to the mode of action of collapse therapy discussed.

2. Cases treated at East Fortune Sanatorium have been analysed with a view to determining what factors influence the results of collapse therapy.

3. Pneumothorax has been found of proved value. It is now being used in cases in a relatively early stage, and its use in such cases is increasing. The more frequent addition of a phrenic paralysis is indicated, particularly in cases with unsatisfactory collapse. A more extensive use of bilateral artificial pneumothorax is also indicated. Further investigation into a small group of cases approximating to what has been called the "good chronic" type of case is called for.

4. Phrenic evulsion yields permanent results less satisfactory than those from either artificial pneumothorax or thoracoplasty. It has been of little value as the sole method of collapse in cases with basal disease. The effect which interlobar adhesion exert on a diaphragmatic paralysis calls for further investigation./

investigation.

5. Thoracoplasty in suitable cases yields the highest proportion of successful results. Its use could pro-:bably, with advantage, be extended.

References./

REFERENCES.

1. Adams, F.E. (1887) Lancet. i, 799.

2. Adams, W.E. (1932) Proc. Soc. Exper. Biol. & Med. xxix, 537.

3. Addis, T. (1928) J. Exper. Med. xlvii, 51.

4. Alexander, J. (1938) The Collapse Therapy of Pul-:monary Tuberculosis. London.

5. Anderson, B.W. (1934) Quart. J. Med., New Series. iii, 15.

6. Aufses, A.H. (1937) Amer. Rev. Tub. xxxv, 464.

7. Aycock, T.B. & Habliston, C.C. (1930) Amer. Rev. Tub. xxii, 757.

8. Balboni, G.M. (1935) New England J. Med. ccxii, 1020.

9. Bigger, I.A. & Cox, B. (1931) Arch. Surg. xxiii, 1041.

10. Brieger, E. (1937) Brit. J. Tub. xxxi. Supp.

11. Briscoe, J.C. (1920) Quart. J. Med. xiii, 293.

12. Brooks, W.D.W. (1938) Brit. J. Tub. xxxii, 14.

13. Brown, L. & Sampson, H.L. (1934) Trans. Nat. Tub. Ass.

14. Bullowa, J.G.M. & Gottlieb, C. (1920) Amer. J. Med. Sc. clx, 98.

15. Carson, J. (1822) Essays Physiological and Practi-:cal, Liverpool.

16. _____ (1833) An Inquiry into the Causes of Respi-:ration, Etc. London. Second Edition.

17. Caussade, G. & Isidor, P. (1930) Bull. et Mem. Soc. Hop. Paris. liv, 1062.

18. Cayley, W. (1885) Trans. Clinical Soc. London. xviii.

19./

19. Cooper, Sir A. (1836) Guy's Hospital Reports. i, 457.

20. Coryllos, P.N. (1933) Amer. Rev. Tub. xxviii, 1.

21. _____ (1933) J. Amer. Med. Assoc. c, 480.

22. _____ (1936) Amer. Rev. Tub. xxxiii, 639.

23. _____ & Birnbaum, G.L. (1932) Amer. J. Med. Sc. clxxxiii, 317.

24. _____ Konterwitz, H. & Levine, E.R. (1932) Amer. Rev. Tub. xxvi, 153.

25. Davies, H.M. (1928) Tubercle. ix, 206.

26. De Bloeme, P.J.L. (1937) Tubercle. xix, 120.

27. De Cerenville. (1886) Rev. Med. de la Suisse Rom. June-August.

28. Dixon, W.E. & Brodie, T.C. (1903) J. Phys. xxix, 97.

29. Edwards, P.W. (1938) Annual Report of Cheshire Joint Sanatorium.

30. _____ & Stevens, J.S.T. (1938) Tubercle xix, 252.

31. Ellis, M. (1936) J. Phys. lii, 298.

32. _____ (1936) Proc. Royal Soc. Med. xxix, 527.

33. Ellison, R.T. (1937) Amer. Rev. Tub. xxxv, 484.

34. Eloesser, L. (1934) Amer. Rev. Tub. xxx, 123.

35. Ewart. (1885) Lancet i, 893.

36. Fales, L.H. & Beaudet, E.A. (1931) Amer. Rev. Tub. xxiii, 690.

37. _____ (1934) Amer. Rev. Tub. xxx, 225.

38. Farage, F.C. (1935) Amer. Rev. Tub. xxxix, 452.

39. Fishberg, M. (1932) Pulmonary Tuberculosis. London. Fourth Edition.

40./

40. Forlanini, C. (1882) Gazetta degli Ospedali e delle Cliniche di Milano. iii, 537, 585, 601, 609, 617, 625, 641, 657, 665, 689, 705. (Translation by S. Lojanco in Tubercle, 1934. xvi, 61)

41. _____ (1894) Gazetta Medica di Torino. lxv, 381, 401. (Translation by S. Lojanco in Tubercle 1934, xvi, 121)

42. Gardner, L.U. (1925) Amer. Rev. Tuber. x, 501.

43. Gilbert, M. (1931) Revue de la Tub. 3me. serie. xii, 979.

44. Gravesen, J. (1935) Brit. J. Tub. xxix, 12.

45. _____ (1936) Brit. Med. J. ii, 270.

46. Harper, F.R. (1937) Amer. Rev. Tub. xxxv, 475.

47. Hebert, G.T. (1936) Brit. Med. J. ii, 272.

48. Heise, F.H. (1932) Forty-eighth Annual Report of Trudeau Sanatorium.

49. Hennel, H. & Stivelman, B.P. (1923) Amer. Rev. Tub. vii, 291.

50. Holcomb, F.W. & Weber, G.W. (1934) Amer. Rev. Tub. xxx, 299.

51. Hoover, C.F. (1913) Arch. Int. Med. xii, 214.

52. _____ (1922) Arch. Int. Med. xxx, 1.

53. Houghton, J. (1832) Dublin Med. J. i, 313.

54. Ingals, E.F. (1905) J. Amer. Med. Ass. xlv, 1302.

55. Jackson, C. (1917) J. Amer. Med. Ass. lxviii, 245.

56. Jennings, G.H. (1937) Brit. Med. J. ii, 963.

57. Keith, Sir A. (1903) J. Anat. & Phys. xxxvii, 51.

58. _____ (1909) Further Advances in Physiology. London. Edited by Leonard Hill.

59. _____ (1910) Brit. Med. J. ii, 1297.

60./

60. Keith, Sir A. (1923) Brit. Med. J. i, 545.

61. _____ (1933) Human Embryology and Morpho-:logy. London. Fifth Edition.

62. Krause, A.K. (1922) Amer. Rev. Tub. vi, 327.

63. Laennec, R.T.H. (1819) De l'Auscultation Mediate. Paris.

64. Lander, F.P.L. (1936) Proc. Royal Soc. Med. xxix, 1383.

65. _____ & Davidson, M. (1937) Brit. J. Radiol.65.

66. Lemon, W.S. (1930) Amer. Rev. Tub. xxii, 685.

67. Lindblom, A.F. (1930) Acta Med. Scand. lxxiii, 493.

68. Lojanco, S. (1934) Tubercle. xvi, 54.

69. McMahon, B.T. & Kerper, E.H. (1933) Amer. J. Med. Sc. clxxxvi, 170.

70. Macklin, C.C. (1922) Anat. Rec. xxiv, 119.

71. _____ (1925) Amer. J. Anat. xxxv, 303.

72. _____ (1929) Phys. Rev. ix, 1.

73. _____ (1932) Amer. Rev. Tub. xxv, 393.

74. Matson, R.W. (1930) Amer. Rev. Tub. xxii, 1.

75. Miller, W.S. (1937) The Lung. London.

76. Morgan, P. (1917) Quart. J. Med. xi, 1.

77. Murphy, J.B. (1898) J. Amer. Med. Ass. xxxi, 151, 208, 281, 341.

78. Nelson, H.B. (1934) Brompton Hospital Reports. iii, 108.

79. Overholt, R.H. (1937) Amer. Rev. Tub. xxxv, 411.

80. _____ & Betts (1938) Amer. Rev. Tub. xxxviii, 392.

81. Parfitt, C.D. (1922) Trans. Nat. Tuber. Ass. 197.

82./

82. Parker, R.W. (1882) Lancet. i, 689.

83. Parodi, F. (1933) La Mecanique Pulmonaire. Paris.

84. Potain. (1881) Le Bulletin Medical. i, 555

85. Robinson, H.J. (1937) Tubercle. xix, 1.

86. Roche, H. (1937) Tubercle. xviii, 25.

87. Rolland, J. (1925) Annal. de Medec. xvii, 327.

88. Rossel, G. (1931) Schweiz. Med. Wochen. xii, 793.

89. Salkin, D., Cadden, A.V. & McIncoe, R.B. (1936) Tubercle. xviii, 71.

90. _____ (1936) Amer. Rev. Tub. xxxiv, 634, 649.

91. Sanes, S. & Smith, W.S. (1937) Amer. Rev. Tub. xxxvi, 727.

92. Sauerbruch, F. & O'Shoughnessy, L. (1937) Thoracic Surgery. London.

93. Schroeder, W.E. & Green, F.R. (1902) Amer. J. Med. Sc. cxxiii, 196.

94. Semb, C. (1935) Acta Chir. Scand. lxxvi, Supp.

95. _____ (1937) Brit. Med. J. ii, 650.

96. Sinding-Larsen, Chr. M.F. (1937) Acta Med. Scand. lxxx, Supp.

97. Stokes, W. (1837) A Treatise on the Diagnosis and Treatment of Diseases of the Chest. Dublin.

98. Sweany, H.C. (1935) Amer. Rev. Tub. xxxii, 544.

99. Tice, F. (1931) City of Chicago Municipal Tuber-:culosis Sanitarium Bulletin. xi, 10.

100. Trocme, C. (1934) Pneumothorax et Respiration. Paris.

101. _____ (1936) Annal. de Med. xl, ii, 106.

102. Warner, W.P. & Graham, D. (1933) Arch. Int. Med. lii, 888.

103. Young, T. (1815) Treatise on Consumptive Diseases. London.