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DECORTICATION OF THE LUNG IN TUBERCULOUS DISEASE

A STUDY IN 43 CASES

BY

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Constrictive pleuritis is a not uncommon complication of pulmonary tuberculosis. It may occur as an effect of primary tuberculosis or, less commonly, of tuberculosis at any stage, or as a complication, unhappily frequent, of artificial pneumothorax treatment. Once established, this condition gives rise to considerable loss of respiratory function, to danger from an unobliterated pleural space which, if not already infected, is liable to become so, and, occasionally, to symptoms from a displaced mediastinum.

Established methods, other than decortication, of treating such a chronic condition are far from satisfactory. Frequent aspiration provides no answer; simple drainage means a permanent "tube life"; an oleothorax as a rule becomes infected. Thoracoplasty may further reduce function, and though it may apparently obliterate the pleural space an empyema may lie quiescent under it only to discharge itself through a bronchus or on to the skin years later. Operations of the Schede type are both mutilating and function-destroying.

Decortication of the lung is obviously a most attractive form of treatment, combining a removal of this thickened pleura and empyema with an opportunity for improving the respiratory function, allowing the mediastinum to return to the normal position, and permitting resection of the diseased segments of the lung if this is indicated.

Decortication has been and is practised in many centres, but with varying results. These have been reported by many workers, including Waterman and Domm (1951), Weinberg and Davis (1949a and b), and Riley and Kaunitz (1951), who deal with the unexpanded artificial pneumothorax, and Gurd (1947), O'Rourke, O'Brien, and Tuttle (1949), Quinlan, Schaffner, and Hiltz (1952), Lam (1948), and Stead, Eichenholz, and Stauss (1955), who deal with the general problem of tuberculous pleurisy. In these reports of series of cases the historical aspects of the subject and the details of the operations used are fully covered.

The main reasons for the indifferent results have been summarized in an annotation in the *Lancet* (1954). These are the presence of old foci of tuberculous disease and fibrosis in the lung, bronchostenosis, and difficulty in removing the "peel" from the tuberculous lung, giving rise to many air leaks which make subsequent expansion of the lung difficult and sometimes impossible. Thoracoplasty was not infrequently needed to obliterate persistent post-operative air spaces (Ellis, Hedberg, and Krueger, 1953). Another cause of failure is the collection of blood and fluid in the unobliterated pleural space with the eventual formation of another cowl over the lung.

A number of instances of thickened pleura and empyema are seen in cases of complicated primary tuberculosis where the pulmonary parenchymal element of the complex is very small and healed and the rest of the lung perfectly healthy, or in cases where an artificial pneumothorax induced for localized disease in one or two segments of lung has given rise to pleural complications. Again, most of the lung is perfectly healthy, and there is certainly initially no generalized pulmonary fibrosis which would prevent expansion of the lung. Stenosis of a major bronchus is relatively rare, but its presence would certainly contraindicate decortication alone.

We consider that, provided disease is not scattered widely through the lung, failure to expand the lung after decortication is due to inability to deal with the air leaks and fluid collecting in the pleural space in the early post-operative

days. Such failure will inevitably lead to the lack of improvement, or even deterioration in lung function frequently reported in tuberculous cases (Wright, Yee, Filley, and Stranahan, 1949; Carroll, McClement, Himmelstein, and Cournand, 1951; Falk, Pearson, and Martin, 1952), and leading to the conclusion that functional considerations should not be taken as a prime indication for operation.

While agreeing that these points must be considered, we feel that the cases reported here show that such objections are far from absolute, and that, when the post-operative care is carried out as herein described, the end-result is good: the lung is fully expanded, and the patient has not only lost a potential source of danger to his health but has gained an improvement in functioning lung tissue.

In this hospital, where the indications for resection in pulmonary tuberculosis are wide and many operations are carried out, minor decortications are often necessary in the course of resection of tuberculous segments of lung. However, in this paper it is intended to confine the study to a series in which thoracotomy was carried out primarily for the thickened pleura, with or without empyema.

Indications and Contraindications for Operation

Forty-three cases were operated upon, the first in September, 1950, and the last (of this series) in November, 1954.

INDICATIONS.—(1) Tuberculous empyema with either no detectable disease in the underlying lung, or disease treatable by chemotherapy, partial resection, or thoracoplasty; (2) thickened pleura giving rise to appreciable loss of respiratory function, the conditions as regards parenchymal disease applying as in indication (1).

CONTRAINDICATIONS.—(1) Stenosis of a main bronchus, though decortication plus a lobectomy in a lobar bronchostenosis is possible; (2) severe uncontrolled disease in the underlying lung, e.g., destroyed lung; here, pleuropneumonectomy would be indicated, provided the contralateral lung were satisfactory; (3) severe contralateral disease making an operation on the side with the thickened pleura functionally impossible. However, in lesser degrees of contralateral disease decortication is often indicated in order to allow later surgical treatment of the contralateral lesion.

It has been suggested that a mixed infection type of empyema is a contraindication, but in this series there were two such cases (Case 1 and Case 3) and in both the outcome of operation was successful. Modern antibiotics undoubtedly play an important part in the success of these operations. Though there are no such cases in this series, we would not consider the presence of a bronchopleural or even a bronchopleurocutaneous fistula a contraindication to operation.

Details of Cause of the Condition Requiring Operation

Primary tuberculous effusion and complicated artificial pneumothorax were the causes in an almost equal number of cases. Spontaneous rupture of a cavity in a free pleura was the cause in one case. Table I shows causes of empyema and thickened pleura.

TABLE I

CAUSES OF EMPYEMA AND THICKENED PLEURA

Primary tuberculous pleurisy and effusion	20
Pleurisy and effusion complicating artificial pneumothorax	22
Spontaneous rupture of cavity in a free pleura	1
Total	43

Bacteriology of the pleural fluid was as in Table II.

TABLE II

RESULTS OF CULTURE FOR *M. TUBERCULOSIS*

Fluid positive	26
„ sterile	17
Total	43

Of those in which the fluid was positive for *M. tuberculosis*, a mixed infection was present in two cases, introduced, presumably, during the multiple aspirations that were carried out.

Age of Patients

The age range was from 8 to 53 years. The oldest was Case 30, a man in whom the result was clinically, radiologically, and functionally satisfactory. The youngest was a boy of 8 with a large empyema which developed in a primary effusion. The result was clinically and radiologically excellent; function tests were not done. The majority of patients were in the late teens to early thirties.

Sex of Patients

Ten cases were in women. The high proportion of males in this series is probably not of any special significance.

Side of Operation

On these 43 patients, 44 operations were done: 20 on the right side, 22 on the left, and one on both sides (Case 6).

Duration of the Condition Before Operation

In one case due to a complicated artificial pneumothorax, the condition had been present for 20 years before operation. In this case (Case 22, see Fig. 10) the result was very satisfactory. The shortest duration was three months before operation.

Table III
DURATION OF CONDITION BEFORE DECORTICATION

20 years	1 case	Complicated A.P.
15 to 20 years	No cases ..	—
10 „ 15 years	4 „ ..	Complicated A.P.
5 „ 10 „	2 „ ..	Complicated A.P.
1 „ 5 „	26 „ ..	13 complicated A.P. 13 complicated primary
Less than 1 year	10 „	6 complicated primary 3 complicated A.P. 1 ruptured cavity
	Total ..	43 cases

Investigation of Cases

Quite apart from the indication of the presence of an empyema, many of these cases were operated upon in an effort to improve function already noticeably reduced, or in an effort to reduce loss of function and deformity of the chest wall due to constrictive pleuritis when the patient grew older. Consequently pre-operative function tests were carried out in as many patients as possible, and again post-operatively wherever possible. The tests used were maximum breathing capacity (M.B.C.) and bronchospirometry, the oxygen uptake and ventilation of the individual lungs being measured as described by Fleming and West (1954). Pre-operative bronchospirometry was carried out in 28 patients but post-operatively in only 16 so far. Five patients have not had it done for various domestic reasons but have promised to attend later. The remaining seven have refused for a variety of reasons, the main one being that as they are now fit and working they do not want to lose time for such an investigation. The M.B.C. was determined in 30 cases pre-operatively and in 28 post-operatively. Effort tolerance has been noted in all cases both pre- and post-operatively, and a note has been made of the movement of the chest, air entry, and diaphragmatic movement on fluoroscopy. Unfortunately a definite record of the diaphragmatic movement was not made pre-operatively in all cases, but the postero-anterior and lateral radiographs give a good indication of the state of the diaphragm. Previous therapeutic phrenic crushes were noted. A clinical and radiographic assessment of the result of operation has been made in all cases, but M.B.C. and bronchospirometry figures are available in only a proportion. These will be discussed later.

Postero-anterior and lateral radiographs were taken pre-operatively in all cases, and tomography was invariably done before cases were assessed for operation. Bronchoscopy to rule out tuberculous endobronchitis or stenosis of a major bronchus was carried out in some cases. All cases operated upon in 1953 and 1954 (22 cases) had pre-operative bronchography using an aqueous suspension of "dionosil," this being considered an essential part of the complete investigation of all cases of tuberculosis before surgery. The bronchograms showed no findings specific to the thickened pleura except crowding of the segmental bronchi in a lung occupying a reduced space and sometimes a "windswept" appearance. However, valuable evidence was gained of the bronchi related to any parenchymal disease, and anatomical details were provided which were of use when resection was carried out at the time of decortication.

Pre-operative Preparation

Apart from general measures undertaken in the preparation of any patient who is to undergo major surgery, the following special procedures were undertaken:

Physiotherapy.—The patient is taught breathing exercises, both costal and diaphragmatic. Particular attention is given to the flat and poorly moving or actually immobile affected side. Little improvement in movement was noted before operation, but the exercises are most important post-operatively. The patient is also taught how to cough properly. Once again this is most important in the post-operative phase in preventing or treating atelectasis.

Plaster Cast.—A plaster cast which will hyperextend the affected side is made pre-operatively (see Fig. 2). This is for use post-operatively. In some earlier cases of this series such a plaster cast was used to see how much improvement in movement could be gained without operation. The result was very disappointing and the cast is no longer employed pre-operatively.

Chemotherapy.—All patients coming to the operation had had some chemotherapy and at the time of operation were on an appropriate combination of two of the drugs streptomycin, P.A.S., and isoniazid. The earlier ones had short courses, but latterly more prolonged continuous therapy had been used. No patient was sputum

positive at the time of operation, and only a small proportion had ever been sputum positive. A three months' operative cover of drugs was used in all cases, but latterly the drugs have been continued for at least six months post-operatively. In some cases where parenchymal disease has been left, it may be advisable to continue much longer. While the patient is awaiting operation cavitated disease, whether ipsilateral, contralateral, or bilateral, should be controlled by postural reduction. Reference to Dillwyn Thomas's method of postural reduction has been made previously (Thompson, Savage, and Rosser, 1954).

Operation

Patients were operated on in the lateral position under general anaesthesia. The incision was as for a standard postero-lateral thoracotomy, being kept well clear of the inferior angle of the scapula. In some cases a rib was resected, usually the sixth, seventh, or eighth, but in many of the more recent cases an intercostal approach at either the upper or lower border of a rib was used. However, in cases where the chest is " frozen " and the ribs are very close together or even overlapping, it is impossible to enter the thorax without removing a rib. The rib was selected according to where the main thickening of the pleura was judged to be radiographically. On several occasions two approaches were necessary, e.g., at the sixth and eighth ribs. This helped considerably in cases where the parietal pleura was very tough, and it did not seem to be detrimental to the end-result.

The parietal pleura and lung are mobilized in the extrapleural plane using the fingers as dissectors as much as possible. This is hard manual work. Occasionally in very tough cases sharp dissection with knife or scissors is needed. It is necessary to remove this thick parietal pleura (and it is always the parietal pleura which is thickest) entirely in order to get good movement of the chest wall eventually (Fig. 1). The strip over the apex is sometimes difficult, but on the mediastinal aspect it is, as a rule, fairly easy ; in fact there is seldom much thickened pleura here due to the movement of the mediastinum across to the side of a chronic effusion. The dissection is continued on all sides round to the hilum of the lung. Special care is taken to prevent damage to any mediastinal structures. The thoracic duct and vagus nerve are preserved, and the phrenic nerve is treated with great respect, as the end-result of the operation may be markedly affected by a paralysed diaphragm. An oesophageal tube passed by the anaesthetist gives valuable evidence as to the site of the oesophagus, which may be dangerously displaced and obscured.

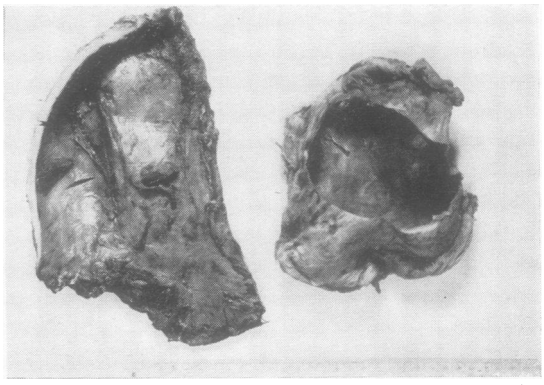


FIG. 1.—Specimen of pleura removed at decortication showing thickness (0.5–1.2 cm.) and dense structure of parietal pleura (on left) and less thick visceral pleura which enveloped a very small lung.

Removal of the thickened pleura from the diaphragm is often very difficult, as it is densely adherent and a plane for dissection can seldom be found. Great care is taken here. It is better to leave plaques of thickened pleura on the diaphragm than to damage its musculature. Small accidental incisions through the diaphragm are immediately sutured and no morbidity has resulted. At this stage the diaphragm is well freed from the lung and from the chest wall by stripping down in the costophrenic sinus all round. This is also an important step.

The visceral pleura is never as thick as the parietal, but the ease with which it strips varies. In some cases, notably A.P. cases, it may be relatively easy, but in primary cases or where there is much parenchymal disease the pleura is usually very adherent and many alveolar leaks are inevitably produced in the dissection. It is advisable to leave the thickened pleura at the site of parenchymal disease if it is not intended to resect it.

When the lung is freed it is not infrequently collapsed to the volume of a clenched fist, and the intact visceral " peel " has the same size and shape (Fig. 1). However, when the lung is inflated it usually expands well and assumes a size approximately that of the hemithorax. If an empyema is present in the mass of pleural fibrous tissue, it is almost invariably opened in dissecting the pleura off the diaphragm. In any case there is no great virtue in removing the empyema intact. In fact when a large empyema is present it should be opened and evacuated early in case a bronchopleural fistula should be present, which, by aspiration, would cause the bronchial tree to be flooded with pus. The dangers resulting from spilling pus

into the pleural space are not great, as chemotherapy and efficient expansion of the lung post-operatively prevent the re-formation of an empyema.

Another important step towards ensuring full expansion of the lung is to free the fissures and any infolding of the lung caused by thickened bands of pleura and adherence of one part of the lung to another.

After removal of the pleura and empyema any palpable parenchymal disease is dealt with on its own merits, that is, as assessed by pre-operative radiographs and palpation at operation. In this series palpable parenchymal disease was present in 30 cases. In 14 cases surgery was deemed necessary to treat it, as follows:

Thoracoplasty	4 cases
Segmental resection	8 cases
Wedge resection	1 case

The resections were carried out at the time of the decortication. The thoracoplasties, when indicated, were performed some weeks after the decortications. In one case (Case 22) a contralateral lesion was segmentally resected five months after the decortication.

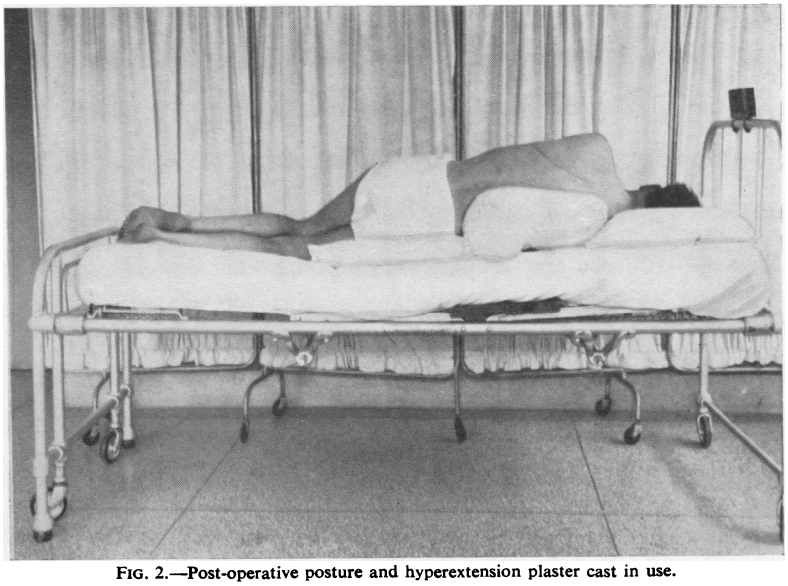


FIG. 2.—Post-operative posture and hyperextension plaster cast in use.

BLOOD TRANSFUSIONS DURING OPERATION.—The dissection of the pleura is always a bloody business and rapid intravenous replacement is essential, when 1,500 to 2,000 ml. of blood is usually needed during the course of the operation. It is not always possible to stop all bleeding before closing the chest, as there is often an extensive capillary ooze.

DRAINAGE OF THE CHEST.—In the earlier cases a posterior basal tube and either an anterior or posterior apical intercostal tube were used. The present practice is to use the usual basal tube and a long tube inserted in the mid-axillary line in either the ninth or tenth intercostal space and held against the inside of the chest wall by a catgut sling with the orifice of the tube near the apex of the pleural space (see Thompson and others, 1954). The tubes are of firm rubber, internal diameter $\frac{1}{4}$ in. with wall 1/10 in. thick, in order to prevent collapse of the tube when strong suction is used post-operatively. Each tube is atached to the skin by passing it through a rubber cuff which is then stitched to the skin. This system of fixing the tubes is useful because no stitch hole is made in the tube itself, and post-operatively the tube is easily shortened through the cuff.

If there is much air leaking from the damaged lung a third intercostal tube is sometimes placed through the seventh or eighth intercostal space in the anterior axillary line, and also held against the chest wall by a catgut sling.

POST-OPERATIVE CARE

It is felt that the success of the operation, particularly from a functional point of view, depends largely upon the efficiency of the post-operative care. It is most important that the lung should be fully expanded at the earliest possible time and kept so until all air leaks have ceased. At the same time flattening and reduced movement of the chest wall must be corrected and the diaphragm encouraged to resume a normal function.

MANAGEMENT OF THE INTERCOSTAL DRAINAGE.—As soon as the patient returns to the ward, strong continuous suction is applied through water-seal bottles to all drainage tubes. The degree of suction is approximately one atmosphere (about 30 in. of mercury) of negative pressure. This prevents fluid collecting in the pleural space, and keeps the lung expanded against the chest wall in the face of even the most severe leak of air from the decorticated lung. At present in this hospital a large

central suction pump capable of supplying multiple leads with a negative pressure of one atmosphere, and of dealing with large volumes of air, is used.

The tubes are not removed till they have ceased functioning, that is, when the air leak has stopped and the lung is fully expanded, or when a tube becomes blocked by clot. In the latter instance, if there is still a persisting pleural space it may be necessary to insert another intercostal tube under local anaesthesia. Not infrequently shortening one or other of the tubes through the cuff will evacuate a persisting space. In some cases tubes were necessary for up to 14 days post-operatively. Three patients had tubes in for periods longer than this, and these will be discussed under "Complications."

Very occasionally aspiration to evacuate a small loculated space was needed. Most of these small loculated spaces resolved without any active treatment other than the usual post-operative routine of physiotherapy and posture in a plaster cast.

POSITION OF THE PATIENT.—The patient is nursed lying on the unoperated side, and as soon as possible, usually on the second or third day, he is put into the special hyperextension plaster (Fig. 2). In this position the mediastinum tends to fall to the opposite side, the diaphragm is carried caudally, and the ribs are stretched apart—the very reverse of the situation before operation. The position is surprisingly comfortable.

The patient continues to lie in the plaster cast except for meals for three to six weeks until the chest expansion is equal on both sides or has reached its maximum. The cast is then used for sleeping until three to six months have elapsed, the time in each case depending on the duration of the condition, the extent of the decortication, and the rate of improvement.

PHYSIOTHERAPY.—Breathing exercises, as mentioned in the pre-operative preparation, are started from the first post-operative day and continued for three to six months, depending on the same factors as control the use of the plaster casts.

POST-OPERATIVE RADIOGRAPHS.—All post-operative care is guided and controlled by frequent portable A.P. radiographs in the early stages, these being taken at least 12-hourly.

PENICILLIN COVER.—Penicillin or any other suitable antibiotic is always used as an operative cover, and is continued so long as there are tubes in the chest.

COMPLICATIONS.—There were no deaths in this series.

TABLE IV

COMPLICATIONS

Drainage-tube-track infection (non-tuberculous)	3	cases
Bronchopleural fistula and empyema (non-tuberculous)	1	,,
Persistent pleural space	6	,,
Phrenic nerve accidentally injured at operation	3	,,
Reactivation of disease	2	,,
Haemothorax	1	,,

Tension pneumothorax and extensive surgical emphysema as post-operative complications have not been met with. The use of multiple drainage tubes and suction probably prevents their development.

The use of adequate antituberculous drug therapy and early obliteration of the pleural space by good suction drainage is considered to be the main factor in the prevention of tuberculous empyema after operation.

In three cases (Nos. 3, 8, 18) a tube-track became infected with pyogenic organisms. In these cases the tubes could not be removed early, but were removed by gradual shortening, controlled by serial sinograms. The sinuses took some weeks to heal, but remain healed after three years. This complication does not seem to have affected adversely the end-result.

In Case 16 a small basal non-tuberculous empyema developed with a small fistula to a subsegmental bronchus (demonstrated by sinogram). This healed after simple intercostal drainage and gradual shortening of the tube controlled by serial sinograms. However, the diaphragm has remained hitched up and relatively immobile, possibly accounting in part for the poor result (Fig. 10). The scar remains healed after two years.

Persistent pleural spaces for more than three or four weeks post-operatively were seen in six cases. In two of these thoracoplasties were carried out and the spaces successfully closed, but it should be pointed out that in both these cases parenchymal disease was present and the thoracoplasty was done primarily for this. In three cases the small spaces disappeared spontaneously in less than six months with only a little thickening of the pleura radiologically. We consider that large persisting pleural spaces, particularly if they accumulate fluid, will only cause thickening of the pleura again and so prejudice the end-result; consequently they are treated vigorously by insertion of a fresh intercostal tube and the application of suction. If such spaces are multiple with much accumulation of fluid, and particularly if the patient becomes pyrexial, we advocate immediate re-thoracotomy, removal of debris, and re-institution of suction drainage. Early full expansion and

obliteration of the pleural space without accumulation of blood and fibrin is essential for a good functional result.

Despite care, the phrenic nerve was damaged at operation in three cases. We feel that this has reduced the effectiveness of the operation from a functional point of view only in these cases.

So far there have been no cases in which new parenchymal disease has appeared after operation, but in two cases disease has become reactivated.

In Case 6 contralateral disease with cavitation and a positive sputum occurred two years after a left decortication and thoracoplasty. The patient had previously had a right artificial pneumothorax which had caused some degree of thickening of the pleura. This right-sided disease was dealt with by decortication and segmental resection. The result both for disease and function is satisfactory nine months after the second operation (Fig. 10).

In the other case (Case 7) bilateral breakdown has occurred. The sputum is positive and the patient is at present in this hospital under treatment. Further surgery may be carried out. In both these cases bronchography, after the breakdown, has shown bronchiectasis in the segments in which the active disease appeared. They are both cases treated early in the series (1951–2), and we think that if pre-operative bronchography had been carried out there would have been a better assessment of the disease, with resection at the time of decortication.

Excessive post-operative bleeding in the first 48 hours with blockage of the drainage tubes occurred in one case (Case 30). This patient required immediate re-thoracotomy and removal of the blood clot with reinstitution of suction drainage. The end-result did not appear to be adversely affected (Fig. 10).

From this presentation of post-operative complications it can be seen that only one patient (Case 7) has suffered any serious trouble following the operation. However, it is felt that he may still be saved and his disease is such that the operation alone cannot be held responsible for his present condition.

Pathology

In 31 cases a frank empyema with tuberculous pus and caseous matter was present. In two of those complicating primary effusions, a caseous hilar lymph node actually communicating with the empyema was found at operation. In three other cases a turbid fluid but no pus was present, and in the remainder no space was found in the thickened pleura. It is interesting to note the large proportion of persisting empyemata. In quite a number of cases aspiration just before operation revealed no space, but at operation an empyema was found.

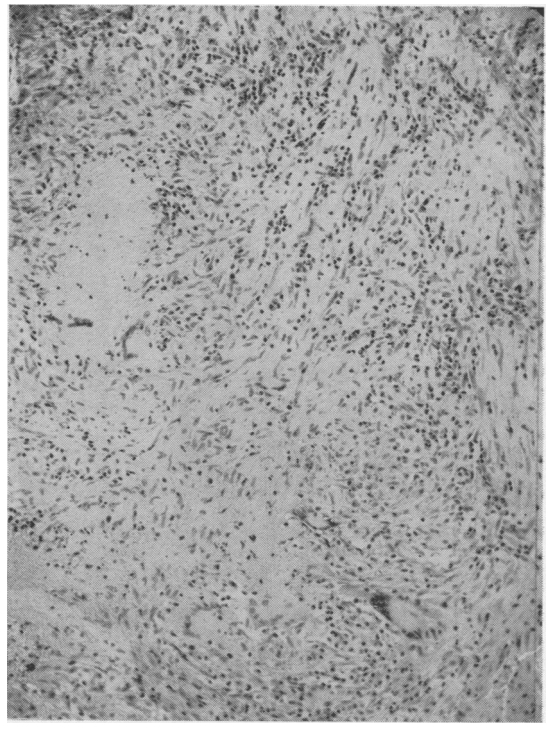


FIG. 3.—Section of pleura removed at decortication, showing dense fibrosis above, and typical tubercles with caseation and Langhan's giant cells. Haematoxylin and eosin. × 95.

The removed thickened pleura was always thickest in its parietal part (in Case 24 it was 2–2.5 cm. thick) with the visceral pleura thickened only slightly (for example, see Fig. 1).

The histology of the pleura showed dense collagenous fibrous tissue with occasional tuberculous and caseous areas. Positive evidence, histologically, of tuberculosis was always found in cases where an empyema was present, but not always in the others (Fig. 3).

In cases in which segmental resections were carried out at the time of decortication, the tissue removed showed the usual changes of pulmonary tuberculosis. There was little if any lung tissue unaffected by tuberculous disease in these specimens.

Biopsies of healthy lung were not taken in this series, and we can make no factual contribution to the histological appearance of the lung under constrictive pleuritis.

Results

A recent follow-up by personal examination or, in a few cases, by information from the Chest

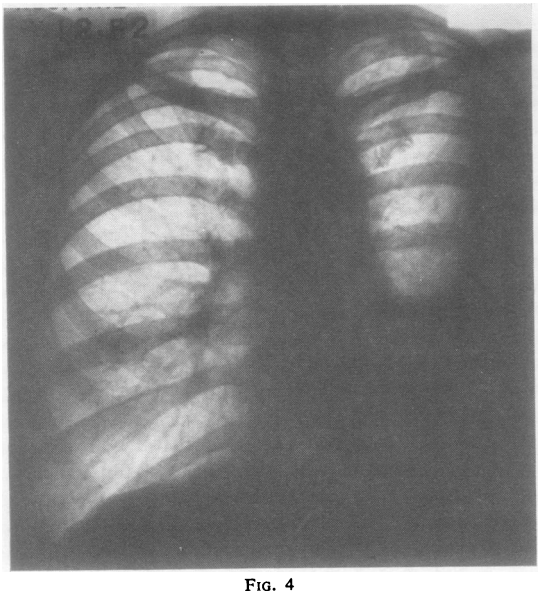


FIG. 4

Before decortication. M.B.C. 63 l./min.

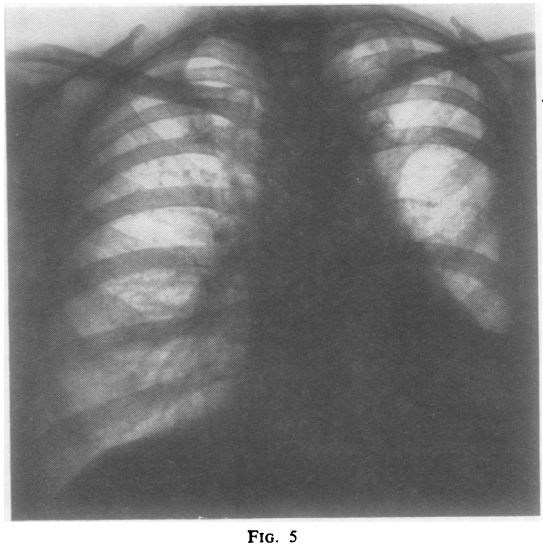
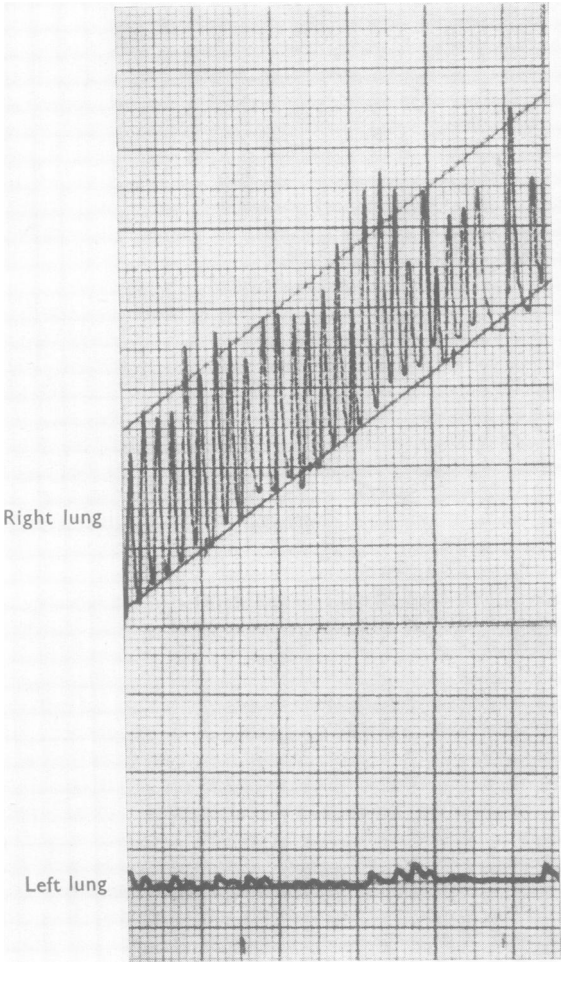
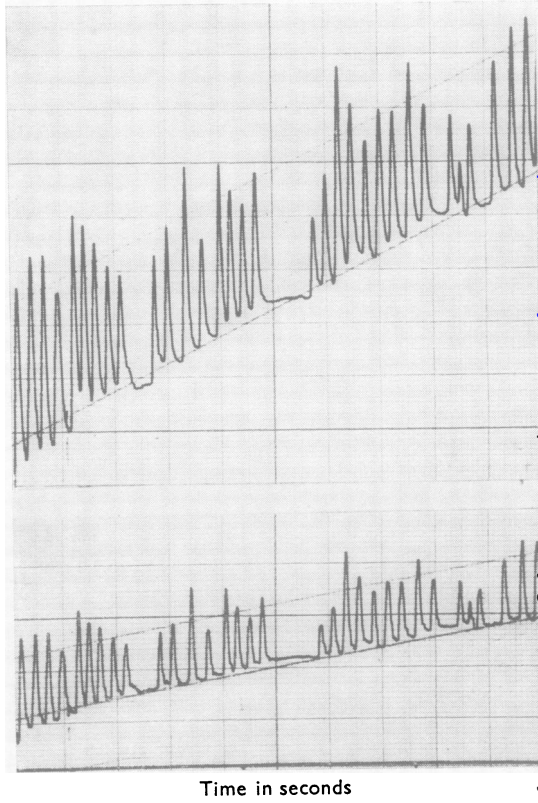


FIG. 5

21 months after decortication. M.B.C. 94 l./min.





Time in seconds

FIGS. 6a and 6b.

Clinic has been made in all cases. The follow-up varies from four and a half years to six months.

(1) In cases where an emphysema or uninfected persistent pleural space was present (34 cases), the obliteration of the pleural space has been achieved in every case. Thus the ever-present danger of complication or toxaemia from an empyema has been removed.

After removal of thickened pleura the space has been filled by expansion of lung tissue. In no case has there been greater mediastinal shift than there was pre-operatively; in fact, where this was present pre-operatively it has been reduced, if not completely, at least partially. In two cases obliteration was assisted by thoracoplasty, but, as already pointed out, the thoracoplasty was done primarily to control parenchymal disease. In three cases thoracoplasty was also carried out for remaining disease, but not until the space had been completely obliterated.

It follows from this that in many cases undesirable overdistension of the contralateral lung was relieved, thus reducing the chance of reactivation of contralateral disease from this cause. Consequently, it would seem that the contralateral reactivation in Cases 6 and 7 occurred from some other cause.

(2) Disability due to displaced mediastinum was only seen in one patient, Case 23, a woman of 47 in whom thickened pleura had been present for 20 years. In addition to shortness of breath on the slightest exertion, she had marked oedema of the ankles. In this case operation replaced the mediastinum almost centrally, and the patient is now leading a normal life for her age and position (school teacher) with much improved exercise tolerance and no oedema of the ankles (see Figs. 4 and 5). A functionless lung has been restored to reasonable function (Fig. 6).

In other cases disability from this cause may have become apparent in later years if the mediastinal position had not been corrected.

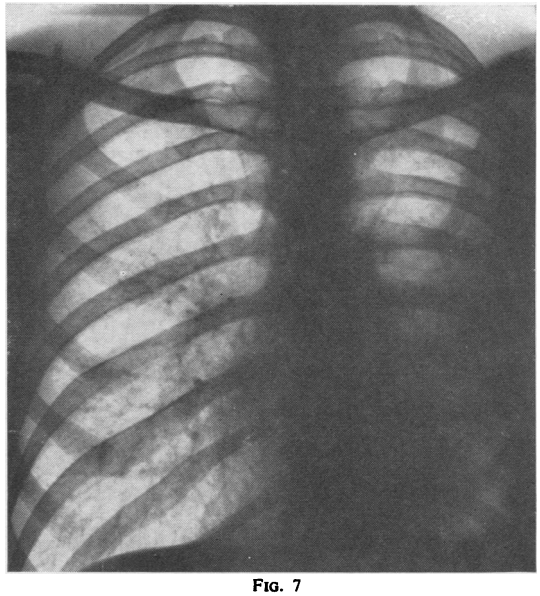


FIG. 7

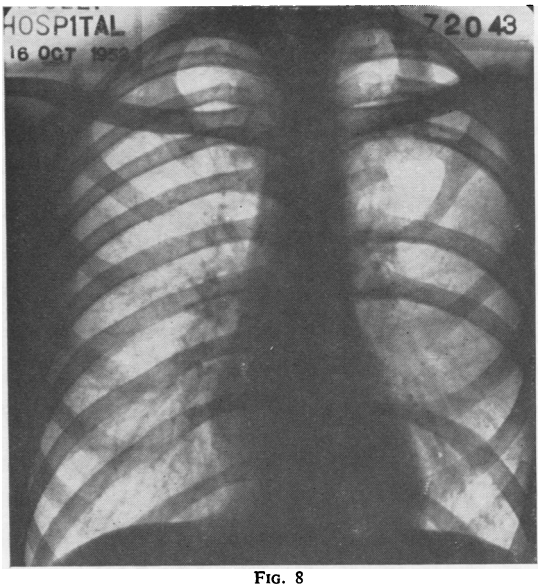


FIG. 8

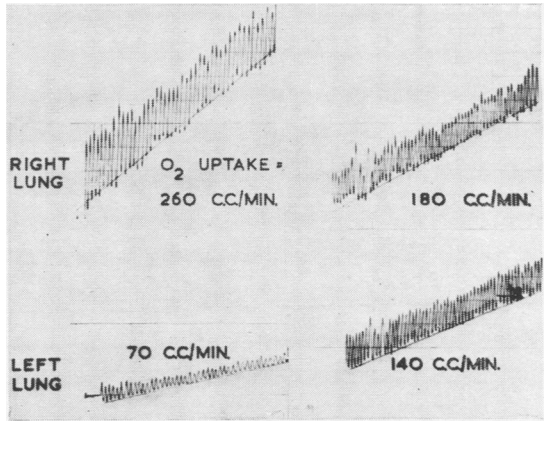


FIG. 9

FIG. 4.—Case No. 23, woman aged 47, with a left constrictive pleuritis existing for 20 years following artificial pneumothorax. There is mediastinal displacement and the function of the left lung is negligible (see Figs. 5, 6, and 10).

FIG. 5.—Case No. 23 two years after decortication. The mediastinum is now central and function improved (see Figs. 4 and 6).

FIG. 6.—Case No. 23 (see Figs. 4 and 5), example of functionless lung being restored to reasonable function after 20 years (see also Fig. 10).

FIG. 7.—Case No. 13 before operation.

FIG. 8.—Case No. 13 after decortication, showing almost normal appearance of the postero-anterior radiograph (see also Figs. 7 and 9).

FIG. 9.—Case No. 13. Bronchospirometric traces before and six months after decortication (see also Fig. 10).

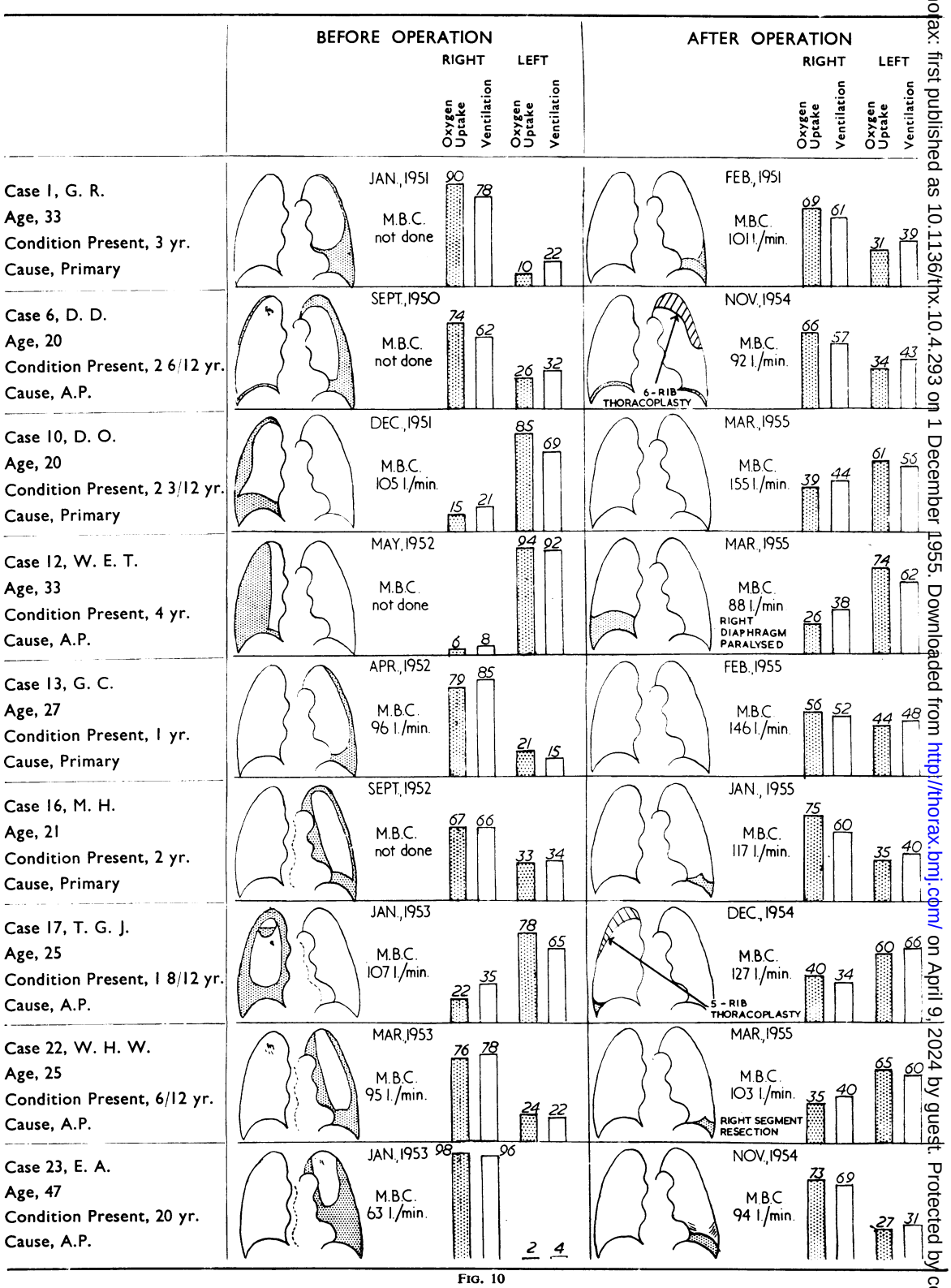


FIG. 10

FIGS. 10 and 11.—Schematic representation of radiographic appearances and functional results in those cases in which bronchospirometry in each lung expressed as a percentage of the total function. The normal

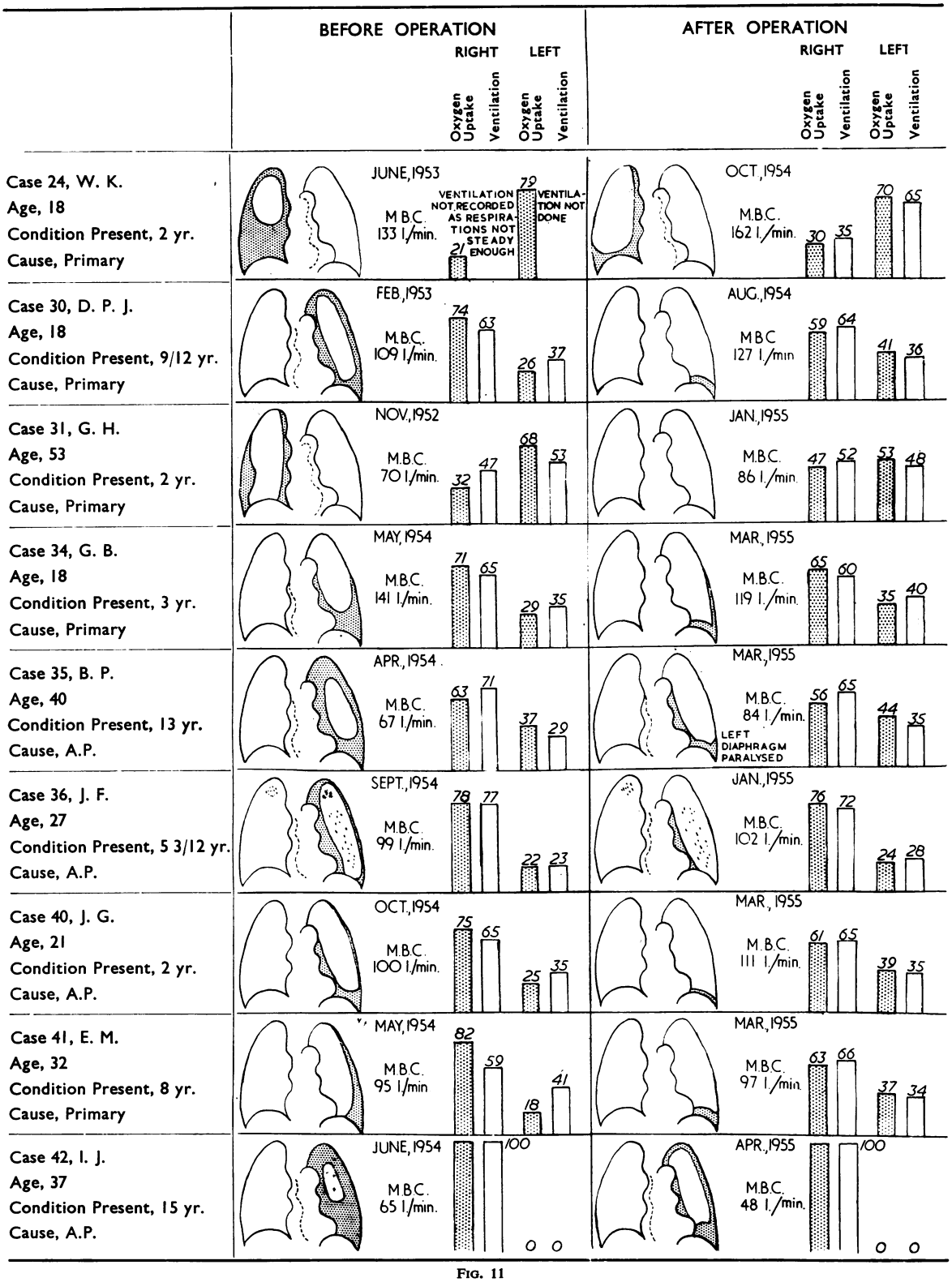


FIG. 11

was carried out before and after decortication. The shaded blocks represent oxygen uptake and the plain blocks minute ventilation value for each of these is 55% for the right lung and 45% for the left.

(3) Clinically, changes in function were judged by changes in effort tolerance, chest and diaphragm movement on the affected side, and breath sounds on that side.

Before operation 24 patients complained of shortness of breath on mild to moderate exertion, e.g., walking on the flat or climbing a flight of stairs. In all these there was some improvement in effort tolerance after operation. In a few it was marked, in one only a little, but in all cases the patient considered it well worth while. These cases also showed an improvement in chest movement and breath sounds.

Worthy of special note are Case 13, a tin worker, 22 years of age (see Figs. 7, 8, 9, and 10), and Case 28, a steel worker, 21 years of age. Pre-operatively neither of these young men had been able to do their normal work because of shortness of breath, but both are now doing full work. The other 19 were all young patients who denied any reduction of effort tolerance. Post-operatively, however, the chest movement and breath sounds improved in all cases except one (Case 34, see Fig. 11), a girl of 16. There was radiographic improvement, but the chest movement remained poor six months after operation, and the M.B.C. and bronchospirometrical results were correspondingly disappointing. A possible reason for this poor result was that the plaster cast was discarded after three months. An effort is now being made to improve chest movement by physiotherapy and a plaster cast.

Improvement in diaphragmatic movement has been seen in all cases, except those in which the phrenic nerve had been crushed or avulsed previously (six cases), or had been damaged at the operation (three cases). The functional results in these cases might have been better if the diaphragm had been functioning.

(4) Radiological improvement of varying degree was seen in all cases. In some it was remarkable, in others it was less striking, and in a few poor. Average examples are shown in the various figures.

(5) The M.B.C. was estimated both pre- and post-operatively in 25 cases, and the results are presented in Table V.

It can be seen that there is some improvement in ventilatory capacity in all except two cases. In Case 14 an eight-rib thoracoplasty was necessary after decortication to control right upper lobe disease. Case 42 had extensive parenchymal disease with bronchiectasis of both lobes, and the diaphragm was paralysed.

TABLE V

PRE- AND POST-OPERATIVE M.B.C. READINGS

Case No.	Age in Years	Duration of Condition	Pre-operative M.B.C. (l. min.)	Follow-up	Post-operative M.B.C. (l./min.)	Remarks
2	18	7 months	85	4½ yr.	143	
7	21	1¼ yr.	97	4½ ,,	121	Phrenic nerve injured at operation
10	20	2¼ ,,	105	3½ ,,	155	
11	36	1½ ,,	71	3 ,,	105	Phrenic crush before operation
13	22	1 ,,	96	3 ,,	146	
14	25	1½ ,,	80	2½ ,,	80	8-rib thoracoplasty
17	25	1½ ,,	107	2½ ,,	127	5-rib thoracoplasty
20	39	2 ,,	100	2½ ,,	114	4-rib thoracoplasty
22	25	6 months	95	2 ,,	103	L. decortication. R. 2 segments removed
23	47	20 yr.	63	2 ,,	94	Phrenic nerve injured at operation
24	18	2 ,,	133	2 ,,	162	
26	20	1 ,,	139	3 mth.	162	
27	19	8 months	132	1 yr.	146	
28	21	1 yr.	131	6 mth.	162	
29	32	4 months	66	8 ,,	84	
30	18	9 ,,	109	1½ yr.	127	
31	53	2 yr.	70	1½ ,,	86	
32	32	1 ,,	113	2 ,,	127	
34	16	3 ,,	141	6 mth.	119	Chest movement poor post-operatively
35	40	13 ,,	67	8 ,,	84	Phrenic crush before operation
36	27	5¼ ,,	99	6 ,,	102	Much parenchymal disease in lung
37	35	4 ,,	94	6 ,,	117	Two segments removed
40	21	2 ,,	100	6 ,,	111	One segment removed
41	32	8 ,,	95	6 ,,	97	One segment removed
42	37	15 ,,	65	6 ,,	48	Much parenchymal disease in lung. Bronchiectasis of both lobes, and paralysed diaphragm

All other cases showed an improvement; as much as 50 litres per minute in Case 10. This case is of further interest in that the function, particularly the oxygen uptake, improved some time after the operation.

CASE 10.—D. O., aged 20 years (Figs. 14 and 15), had had a right thickened pleura due to complicated primary effusion for two years three months at the time of operation.

Pre-operative function tests gave the following results:

M.B.C. = 105 l./min.

Bronchospirometry	Right Lung	Left Lung
Oxygen uptake	15%	85%
Ventilation	31%	69%

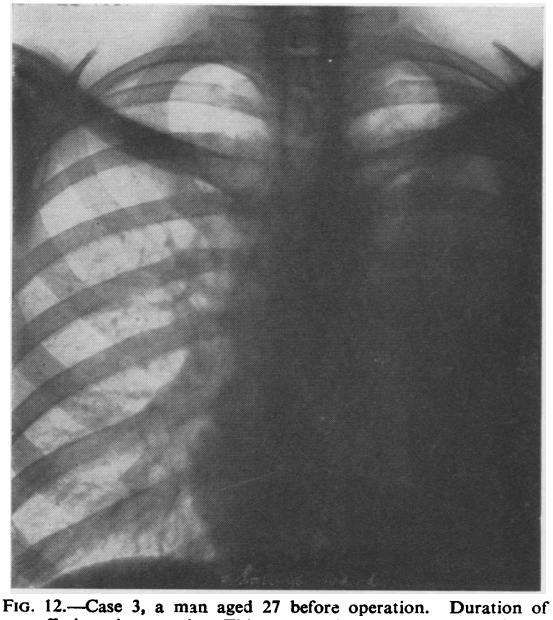


FIG. 12.—Case 3, a man aged 27 before operation. Duration of effusion nine months. This was a primary tuberculous effusion with positive bacteriology.

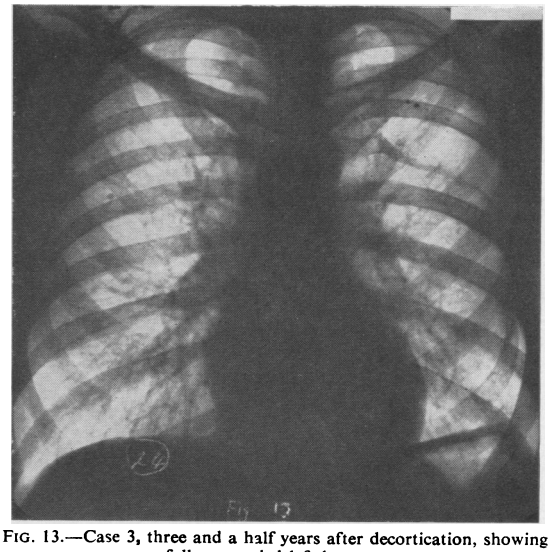


FIG. 13.—Case 3, three and a half years after decortication, showing fully expanded left lung.

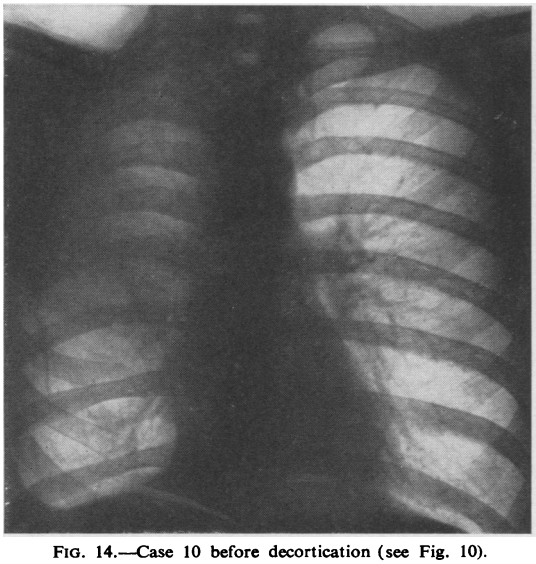


FIG. 14.—Case 10 before decortication (see Fig. 10).

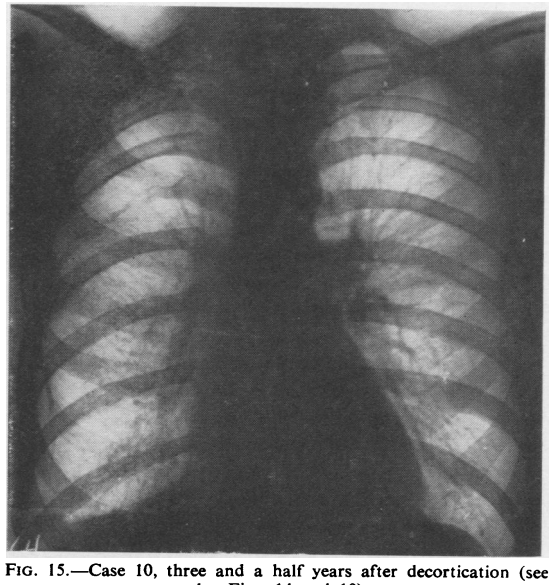


FIG. 15.—Case 10, three and a half years after decortication (see also Figs. 14 and 10).

Function tests five weeks after operation:

M.B.C. = 131 l./min.

Bronchospirometry	Right Lung	Left Lung
Oxygen uptake	23%	77%
Ventilation	45%	55%

Function tests two and a half years after operation gave the following results:

M.B.C. = 155 l./min.

Bronchospirometry	Right Lung	Left Lung
Oxygen uptake	39%	61%
Ventilation	44%	56%

Further point to this observation is given by a small number of pulmonary angiograms which demonstrate that in the early period after decortication there is a poor flow through the branches of the pulmonary artery, while some months later these have opened up considerably. This would account for the lack of improvement in oxygen uptake parallel with ventilation shortly after operation. For this reason in most cases bronchospirometry was not repeated till about a year after operation.

On the whole it would seem that those cases in which the condition had been present a long time (Cases 23, 35, and 42) the ventilatory improvement, if any, is less striking than in cases where it had been present a relatively short time.

(6) In those cases in which both pre- and post-operative differential lung function tests were carried out the findings are shown graphically in Figs. 10 and 11, and Figs. 6 and 9 depict examples of the change in function.

Significant improvement in function of the decorticated lung is seen in all except four cases, namely, Nos. 16, 34, 36, and 42. In the first a non-tuberculous empyema which developed after operation may in part account for the poor result; the second has been discussed already; in the third the pleura was not grossly thickened, but scattered calcified parenchymal disease was present in both lobes; in the last the lung had been reduced to a very small volume for 15 years, and the extensive disease has already been described.

In two cases in which the diaphragm is paralysed (Cases 12 and 13), the improvement is probably impaired by this.

In most cases the alteration in ventilation and oxygen uptake is either roughly parallel or the ventilation has improved rather more than the oxygen uptake, but in five cases (Nos. 17, 30, 31, 40, and 41) the improvement in oxygen uptake is greater than that in ventilation. This supports the suggestion that any vascular changes in the lung are not wholly irreversible. Further, Case 10 suggests, as already noted, that improvement in oxygen uptake may be slower than in ventilation. An early poor result may prove satisfactory after an interval of several years.

Discussion

Little further need be said about the indications for operation and the technique used. The absent mortality and the low morbidity rates also speak for themselves. The importance of the post-operative régime described must be emphasized, and this is judged to be imperative for the avoidance of fistulae, unexpanded lungs, and space infections. It is further discussed under function. The findings of frank tuberculous empyema in 31 of the 43 cases is a strong argument for a radical surgical approach to the condition. The gross functional loss and the chest deformities produced are further strong points in favour of surgical treatment.

Function.—Previous reports on changes in pulmonary function following decortication in tuberculous cases have largely involved a detailed analysis of a small number of cases (Gordon and Welles, 1949; Wright and others, 1949; Falk and others, 1952). These workers find little or no increase in the function of the decorticated lung following operation, and are agreed that this is in contrast to the improvement seen after decortication for haemothorax and non-tuberculous empyema. Carroll and others (1951) do report improvement in function and find that the best results are obtained in the cases with the shortest histories. Our Cases 35 (duration 13 years) and 42 (duration 15 years) with their disappointing functional results (see Fig. 11) would support this thesis, but Case 23 (Figs. 4, 5, 6, and 10), showing marked improvement in function after 20 years, demonstrates that this rule is by no means absolute, and useful function may be restored after long periods.

The functional results presented here are better than any previously reported except those of Patton, Watson, and Gaensler (1952), and it is felt that there may be two reasons for this. First, the meticulous attention to the post-operative period, with emphasis on early and full re-expansion of the lung, avoidance of accumulation of pleural fluid, and the use of the hyperextension plaster cast; and secondly, the fact that we wait nearly a year before reassessing the function. Many of the reported cases have been investigated at a much shorter period after operation, and for reasons already stated we think that this is unwise, as full restoration of function may not yet be complete. There is no doubt that functional improvement of significant degree can be achieved in most cases, and we are now prepared to recommend operation on that ground alone. This is particularly important in the younger age groups where the loss of function is often associated with a severe and progressive contraction of the hemithorax with resulting deformity. The importance of such conditions later in life is not known, but they are surely better avoided.

Patton and others (1952) have studied the function in a series of patients up to three years after decortication, and also find that function tends to

improve steadily with the passage of time, and that the final result is not closely related to the duration of the condition before operation. In some of their cases only visceral decortication was carried out. We feel that this would unfavourably influence the functional result, as the chest wall movement must be severely limited by the presence of the thick parietal layer and deformity would be liable to be progressive.

Any discussion of functional results must take into consideration the pathology of the underlying lung. In our cases where there was pre-existing extensive parenchymal disease it was only to be expected that final function would be poor. However, in many of these cases the major portion of the lung is free from tuberculous disease, and the actual pathological changes caused by the collapse are the important features. There is remarkably little accurate information on the histological appearance of this lung, and we are unable to make any addition to it. However, in a case of pleuropneumonectomy carried out two and a quarter years after collapse of the lung, it was reported that "the areas of macroscopically normal lung tissue showed on microscopy that they were partially collapsed, and there was thickening of the alveolar septa which appeared to be partly due to increased cellularity and partly due to increase of connective tissue."

Gordon and Welles (1949) quote Vorweld as finding similar appearances together with tortuosity of the blood vessels and dilatation of capillary spaces. Gardner (1925) demonstrated, in pneumothorax cases, that there was interlobular fibrosis and considerable endarteritis often even of the larger vessels near the hilum. It is inevitable, if arterial hypoxia is to be avoided when a lung is collapsed, that there must be a reduction in the blood flow to that lung. If this has been in existence for a long period, it cannot be expected to return to normal immediately, but we feel that the evidence presented shows that considerable improvement can take place even after a long period, though naturally this will occur more rapidly and completely in cases operated upon early. Opening of the larger vascular channels before perfusion of the alveoli is restored would account for the arterial hypoxia reported after decortication (Gordon and Welles, 1949; Wright and others, 1949) and for the delayed improvement in the oxygen uptake we have already noted.

All reports are agreed on the pathology of the pleura and the fact that fibrosis may extend into the interlobular septa and limit expansion and function. However, the striking features are the relative ease with which the visceral "peel" is achieved, and the great toughness of the material removed. To one who has handled these "peels," often up to 2 cm. in thickness and with the consistency of boot leather, it must be obvious that the pleura has finished demonstrating its astonishing powers of healing referred to in the annotation in the *Lancet* (1955), and that the only hope of improving function and avoiding further deformity to the chest wall is by removing such tissue.

For the future, prevention of such long-term effects may well be the answer. Attention to aspiration, chemotherapy, posture, and physiotherapy as described by Birath (1952) when fluid develops should limit the development of empyema and of constrictive pleuritis with its resulting effects. However, where the condition is established, it is felt that the present report demonstrates that decortication can be a safe and satisfactory method of treatment.

SUMMARY

A study of 43 tuberculous patients in whom decortication of the lung was carried out is presented. The condition of constrictive pleuritis occurred in about equal numbers in primary pleural effusion and as a complication of pneumothorax treatment. The cases have been followed from between six months and four and a half years from operation. The indications for operation are discussed and include functional considerations as well as the frequent finding of a tuberculous empyema (31 cases).

Pre-operative investigations and treatment and operative and post-operative methods are discussed. Of great importance are the use of adequate post-operative suction to secure early and complete expansion of the lung with space obliteration, and the use of hyperextension plaster casts to expand the hemithorax and the lung.

There has been no mortality and little morbidity.

Pre- and post-operative bronchospirometry has been carried out in 18 cases, and maximum breathing capacity measurements and clinical assessment in most of the others. In the majority of these cases lung function has been considerably improved. The functional assessment is not usually made until one year after operation.

It is concluded that in selected cases of tuberculous pleural disease decortication of the lung is a safe and satisfactory procedure, removing infection, obliterating space, re-expanding the lung, and improving function.

We are especially grateful to Mr. Dillwyn M. E. Thomas for suggesting this study and for his help and encouragement, and to Dr. L. R. West for carrying out many of the functional studies. Thanks are due to Dr. H. M. Foreman, M.B.E., Dr. L. R. West, Mr. H. R. S. Harley, and Mr. Dillwyn M. E. Thomas, under whose care the patients were treated at Sully Hospital, to the chest physicians of South Wales for their assistance in following up patients, to Dr. R. M. E. Seal for pathological studies, to Mr. W. R. Probert for helpful criticism, to Miss V. Davies and her staff for providing Figs. 10 and 11, and for making the plaster casts and the estimation of the maximum breathing capacities, to Mrs. B. Marshal for the photographs, and to Miss J. Hilary-Jones for the typing and secretarial assistance.

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