# EXTRAFASCIAL APICOLYSIS WITH THORACOPLASTY: INDICATIONS, TECHNIQUE AND COMPLICATIONS

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## Introduction

Paravertebral thoracoplasty was first practised by Sauerbruch (1920), who pointed out that posterior segments of the ribs should be resected in order to reduce the capacity of the hemithorax to the greatest possible extent. This operation served its purpose well to begin with, for in those early days selection was more restricted and closure of cavities was viewed with less importance in assessing results than is the case to-day. Sauerbruch's operation undoubtedly provided the first great stimulus to major surgery in pulmonary tuberculosis. Paravertebral thoracoplasty and its attendant additions, such as resection of transverse processes or the anterior ends of the ribs, gives lateral relaxation of the underlying lung. But it gives no vertical relaxation, and, moreover, closes cavities in 35 per cent. of cases only, judging from our own experience.

The principles underlying the persistence and closure of pulmonary cavities were discussed in a recent paper in this journal (Price Thomas, 1942). The conclusions were that most tuberculous cavities persist because air is trapped within them by a valvular mechanism in the draining bronchi; that they close when these draining bronchi are occluded; and that all methods of treatment, excepting chemotherapy and external cavity drainage, depend for their success on the same fundamental mechanisms: relaxation of the lung and elimination or reduction of inspiratory pull on the draining bronchi. Either of these may convert a check valve into a stop valve and so close the cavity.

Of the methods of treatment available, an artificial pneumothorax completely freed from adhesions is undoubtedly best. Its success derives from the concentric relaxation of the lung which is then possible, and which in turn leads to relaxation of the cavity and draining bronchi and elimina-

tion of any inspiratory drag. We believe that the reason why we have failed to achieve more than 35 per cent. of favourable results with paravertebral thoracoplasty is that vertical stress on the lung is not eliminated by this operation. This stress maintains the patency of the draining bronchi and so the cavity fails to close. The degree and effect of this vertical tension can be appreciated best when operating again upon a patient with an unsuccessful lateral thoracoplasty: after the regenerated rib has been removed the forcible inspiratory tug on the apex of the lung is readily seen; the cavity and apex of the lung expand and contract with each respiratory cycle. Once the apex is free to retract towards the hilum of the lung, respiratory variations in size cease dramatically. Further convincing evidence of the part played by vertical stress in maintaining a patent bronchus has been found when cavities have been opened accidentally during operation: free blowing from the bronchus is usually heard when the contents of the cavity have been removed, but it ceases and the cavity can be sutured with ease as soon as the apex and the diseased area are mobilised and vertical stresses are thus eliminated. Artificial variations in endo-bronchial pressure from an anæsthetic apparatus do not confuse the explanation of such facts as they have been observed during operations under local anæsthesia.

Visual evidence that bronchial closure occurs as a direct result of apical mobilisation has recently been obtained. In a cavity which had been drained by Dr. R. J. Maxwell, using the Monaldi technique, the draining bronchi were still patent after seven months' drainage, as shown by injections of iodised oil into the cavity (Plate XVI, Fig. 1). The patient had a modified Semb thoracoplasty performed by one of us, when mobilisation was carried down to and over the aortic arch. Cavernograms taken fifteen days afterwards show that the bronchi have been occluded (Plate XVI, Fig. 2). This is the first time, as far as we are aware, that the occurrence of bronchial occlusion as a result of active methods of relaxation has been demonstrated.

Indirect evidence has been obtained while treating a large cavity with mean positive pressure of 2 cms. of water. This patient also had a modified extrafascial operation of the same extent as above, with resulting cavity closure. The presence of positive pressure in the cavity indicates a check valve action in draining bronchi, and the closure of the cavity, in our opinion, could occur only as a result of a functional and complete stenosis of these bronchi. This case also conflicts with Eloesser's opinion that thoracoplasty is unlikely to close cavities which have a positive pressure (1941). We would agree with Eloesser if the aim of a thoracoplasty were to deform the cavity walls and bring them into opposition; but it cannot be upheld if our present conception is correct, that the essential factor is relaxation of the area of the draining bronchi.

The conditions obtaining in an artificial pneumothorax are reproduced, as nearly as possible, by the operation of apical mobilisation with thoracoplasty, first extensively practised by Bull, Holst and Semb. In our series of cases the use of this operation has doubled the number of favourable results achieved with lateral thoracoplasty alone.

Bull combined an extrapleural stripping with rib resection, leaving the intercostal bundles intact. The disadvantages, as pointed out by Semb, are that infection is prone to occur in the space originally occupied by the apex of the lung, and that the apex gradually returns to its original position. Holst excised the upper intercostal bundles, a manœuvre which largely prevented undesirable re-expansion of the apex and materially reduced the incidence of infection.

In his original operation, Semb (1936) combined mobilisation with resection of the upper five ribs. This proved to be a formidable affair and on this account was modified to what is now accepted as the standard operation—resection of three ribs with appropriate mobilisation. The severity of the former procedure was mainly due to the large area of chest wall which became mobile and to the large part of the lung thus subjected to paradoxical movement.

Semb later introduced mobilisation in the extra-fascial, as opposed to the extrapleural, plane. In our opinion the advantages of this are as follows:

1. The apex of the lung is less liable to re-expand after the extra-fascial operation. It seems probable that this is due (*a*) to retraction of the endo-thoracic fascia over the apex and (*b*) to the descent of the subclavian vessels and, to a lesser extent, the brachial plexus over the apex as it lies in its new position. That such descent eventually occurs can be observed at a second operation on a patient who previously has had the extrafascial operation done; then it will be seen that the vessels ride immediately over the apex from the mediastinum. If the previous operation has utilised an extrapleural stripping the vessels descend to the apex in a loop from a higher level.

2. Mobilisation in the extrafascial plane decreases the danger of opening cavities, as stripping is carried out in a plane removed farther from the pleura.

3. The extrafascial operation is applicable to all types of cases. It is imperative in those where the endo-thoracic fascia is so involved that an extrapleural operation is impossible; and with practice in the easier group of cases the operator becomes so conversant with the topography of the mediastinum in the region that mobilisation is practicable almost always.

In this paper we propose to describe the operation of thoracoplasty with extrafascial mobilisation, including certain minor modifications in technique

which we use. The most important of these is the resection of very limited segments of the posterior ends of the fourth and fifth ribs, an addition which permits extensive stripping of the apex on the mediastinal surface and in the paravertebral gutter but at the same time leaves a relatively stable chest wall below the level of the third rib. In properly selected cases it is possible by this technique to cover the cavity and the drainage area at the first stage. This is a great advantage, for although remobilisation can be carried out at later stages it is then more difficult technically and often not so efficient. Employment of this technique has increased the prospect of cavity closure to above 90 per cent., and in our opinion is worthy of consideration.

*Partial Thoracoplasty.*—Protagonists of the complete (as opposed to the partial) operation point out the frequency with which recurrences occur just below the resected area due to functional lines of stress, so it has been thought. A more reasonable explanation of recurrence is that the original partial operation failed to cover the diseased area efficiently. If a partial operation is undertaken, relaxation should be carried downwards for a distance of at least one rib and one intercostal space below the lowest limit of disease. In all cases it should extend downwards to include the seventh rib, for only by this means can the scapula be properly bedded in front of the unresected eighth rib. Failure to do this leaves the body of the scapula at its original level, and when absorption and organisation of the subscapular exudate occurs the posterior portion of lung then tends to return to its original position; as this area is the seat of disease in about 80 per cent. of cases it is in need of relaxation more than any other part. Exceptionally a more limited operation can be performed—for example, when a bilateral operation is contemplated and four or five ribs will amply cover the disease on one side. Another objection to any wholesale use of the complete operation is that many a healthy lower lobe will thereby be unnecessarily collapsed.

### Indications for Thoracoplasty.

The indications for thoracoplasty have widened greatly since Sauerbruch enumerated those of strictly unilateral, predominantly fibrotic disease in a patient who is non-toxic and apyrexial. Those with such favourable indications are regarded as good risks today, for they are stable chronics. Others, however, are frequently seen who fail to reach so high a standard either because they have bilateral disease or show some measure of toxæmia. Yet not infrequently operative intervention is canvassed for these patients when other methods have failed or are inapplicable because thoracoplasty offers then the only chance of ameliorating or arresting the disease. There

is no easy way of making a selection, however detailed the review and however wide the discussion. But, at any rate, those who often have to make this kind of decision find that it is usually possible to grade patients in a manner that resolves many of the difficulties.

Taking a long view of these patients they can be placed in one of four main categories: (1) the stationary chronic; (2) the relapsing chronic; (3) the slipping chronic, and (4) the hopeless chronic. We have adopted this classification as it gives an indication of the progress of the disease. The stationary chronic is usually apyrexial, in good general condition, and shows little or no signs of toxæmia; the main symptoms are cough and sputum. The relapsing chronic, as the name implies, resembles the stationary case at times, but has intermittent periods of pyrexia, toxic symptoms, increase in cough and sputum and loss of weight. Though recovery follows, he rarely reaches the original state. The slipping chronic is one who gradually retrogresses, although such retrogression may be slow. Naturally the rapidity of the downward path is of great significance; when rapid, it condemns the patient to the category of the hopeless. The sedimentation rate, taken in conjunction with other clinical data, is a great help in assessment, especially of the last three groups; but it can only be of value if there are serial readings. It is alterations rather than the absolute value of individual readings which are significant. Usually a stationary chronic has a B.S.R. of 10 mm. to 15 mm. (Westergren) in the first hour. The relapsing chronic may show figures from 50 mm. to 90 mm. during toxic phases, whilst the slipping chronic may have a constant rate at such levels. Any rise should be viewed with concern, even though at the time there is no clinical confirmation of reactivated disease. The relapsing chronic should be treated during a phase when the disease is least active; and a survey of the previous history will generally allow this to be anticipated. With the slipping chronic no such favourable change can be expected, and an operative decision must be judged on the state of affairs at the time.

Some authorities hold the view that those included under slipping chronics should not be accepted for operation, as their mortality is high and deaths discourage more suitable patients awaiting operation. There is something to be said for this objection in a closed community, such as a sanatorium, where every patient knows all that happens in the institution; but this objection can only be upheld during the early period of the introduction of surgery when a surgical disaster tends to be unduly magnified. Later, after a series of good results, it has not the same force, for, if patients are taken completely and frankly into the medical attendant's confidence, an occasional fatality does not have the same effect. To refuse operation to a patient in this group if there is a reasonable chance of success is scarcely

justifiable. In many other conditions with a high risk operation is not withheld on the score of a possible fatality unless the risk is prohibitive. We do not suggest that every patient in this group should be accepted for operation, but those who are should be submitted to the closest preparatory scrutiny and observation. Stable chronics cause no anxiety, but relapsing and slipping chronics demand the greatest care.

Apart from the pulmonary lesion, consideration must be given to the presence and activity of any extrapulmonary focus. Laryngeal involvement is an indication rather than a contra-indication; it only constitutes the latter when advanced enough to cause pain that interferes with feeding or with effective coughing, and in these the pulmonary condition itself generally rules out active intervention. Intestinal lesions usually contra-indicate operation; once tuberculous ulceration is well established in the gut it will end fatally, despite arrest of the pulmonary focus. Infection of the genito-urinary track, unless advanced, is no contra-indication. Post-mortem figures show that a high percentage of those with pulmonary tuberculosis have cortical lesions in the kidney which are capable of retrogression; when, however, the medulla is grossly involved, the chances of arrest are poor. Cardiac lesions, when present, must be carefully assessed. Diabetes does not contra-indicate operation, as this can usually be controlled; not infrequently it improves when the pulmonary lesion is effectively treated. Other conditions contra-indicating operations in general will also do so as regards thoracoplasty.

The question of age has to be considered. Over the age of forty-five years operation is rarely indicated, although in our series of patients two were over fifty, one of them being fifty-nine years. Those whose general condition and whose cardiovascular system give no cause for anxiety, and whose pulmonary lesion warrants operative treatment should not be refused operation because they are over forty-five years of age. More important perhaps than the age of the patient is the age of his disease. We have formed a clinical impression that disease of long standing, that is of eight to ten years when the course has been a relapsing one, calls for much more careful consideration than the patient's age. Many of these subjects carry a considerable risk. Although, by the usual tests, their cardio-vascular systems appear satisfactory, we have a conviction that the prolonged toxæmia has often impaired their capacity to withstand the post-operative course with success.

When operation has been decided it is our custom to take the patient completely into our confidence; there is nothing to lose by doing so and everything to gain. The patient has already faced the worst news when he is told that he is suffering from tuberculosis; we have the advantage that

our talk with him has to do with its arrest. We feel that it is important that the final goal of arrest should be firmly fixed in the patient's mind, and that being done he should be encouraged to cultivate a quiet mind about the means to be adopted for attaining this end. The operation is discussed with the reasons for its necessity and for the number of stages to be done, and the post-operative course of treatment is also outlined. In this way patients in nearly every instance are ready to co-operate; and they welcome rather than dread the operative sequence, as a door through which they may escape this thing with which they have been afflicted.

### Pre-operative Treatment

Thoracoplasty is an operation of election and so allows ample time for pre-operative preparations. A decision to operate does not absolve the medical attendant from the need for constant vigilance for the occurrence of any event which will necessitate postponement of the operation or for making certain that the patient is operated on during a period of improvement. The usual pre-operative measures common to all surgery are instituted; there are, however, certain special points which need mention.

1. *Respiratory rehabilitation.*—Many patients, especially women, are predominantly costal breathers and use the diaphragm little if at all. Their respiratory reserve is thus less than it might be, and a relatively small additional load can produce respiratory distress. We have been impressed by the dramatic improvement which tuition in the correct use of the diaphragm and abdominal muscles can give to a dyspnœic costal breather. Breathing exercises are generally considered harmful to patients with pulmonary tuberculosis; we agree with this so far as the vigorous inspiratory exercises often employed. But we believe that tuition before thoracoplasty in a correct use of the diaphragm and abdominal muscles has many advantages. Pulmonary tuberculosis is usually apical and the more normal base of the lung is not sufficiently utilised unless the diaphragm works well. Again, after thoracoplasty, costal respiration is severely disturbed or even non-existent for several days; and a patient who relies on it for normal respiratory function will become seriously dyspnœic unless the diaphragm can carry on efficiently. Again, it is possible to increase the vital capacity by 200-300 c.c.s by mere education in correct breathing. All patients, therefore, excepting those with lesions predominantly exudative or basally situated, are given a course of pre-operative abdominal breathing exercises similar to those used for the asthmatic. The expiratory rise of the diaphragm is increased by voluntary contraction of the abdominal muscles. The patient is instructed to whistle softly during this contraction; this helps to focus his attention upon the important active phase of the exercise.

Inspiration is not forced but allowed to occur naturally, and is followed by the prolonged active expiratory phase again. During early stages abdominal contraction is assisted by manual pressure, but later this becomes unnecessary. These exercises should preferably be supervised by a trained masseuse.

2. *Tuition in arm and shoulder movements.*—After almost any thoracic operation, especially when associated with drainage of the pleural space, movements of the arm on the affected side are restricted by pain or a fear of precipitating it. Unless this restriction is overcome early, permanent limitation of movement ensues. It is our practice to institute passive movements of the shoulder joint and arm on the second day after operation and follow later with active movements at the shoulder joint and scapular movements. These movements are all more readily performed if the patient has had pre-operative instruction.

3. *Oxygen.*—Many patients require oxygen after operation. It is most efficiently administered through the B.L.B. mask, and better tolerated if the patient is familiar with the mask and appreciates the necessity for it. So often the administration of oxygen is regarded as a signal of disaster and patients are loath to accept it unless its use has been previously explained.

4. *Preoperative bed rest.*—In general complete bed rest is not enforced at this stage; on the contrary, it is better to allow the patient out of bed as this increases vasomotor tone, and acts as a mental stimulant, especially if the patient has been in bed for a long time. The patient, in any case, faces a period of five to nine months' bed rest after operation, and unless there is a definite contraindication complete bed rest before operation is unwise.

5. *Cough.*—By the time patients are submitted for operation they have usually developed a technique for producing their sputum easily. Hard unproductive coughing should be discouraged, and a gentler method suggested. This is very important in the immediate postoperative period, for violent efforts not only increase pain but also cause paradoxical movements of the lung under the resected area.

Patients with copious sputum should expectorate as much as possible before going to the theatre; probably they are more wisely operated upon in the latter half of the day, as this gives them a chance of clearing the bronchial tree of sputum.

It is needless to stress the value of a quiet but cheerful atmosphere, preferably in association with others who have previously had an operation; this association is a great comfort and support to nervous patients, and it brings operation better into a true perspective as a matter of routine. Patients should be admitted to the centre for operative treatment at least a week or ten days before operation, even when they have been under close supervision beforehand by the surgeon concerned. This allows them to

become accustomed to the surroundings and to establish friendly relations with the medical and nursing staff.

*Preoperative Medication.*—Each patient receives an injection of omnopon $\frac{1}{3}$ grain and hyoscine $\frac{1}{150}$ grain one and a half hours before and another of omnopon $\frac{1}{3}$ grain three-quarters of an hour before the operation. This standard dose is varied at need, judging by the weight and physique of the patient. If the patient is still alert and nervous during the operation further doses of $\frac{1}{3}$ grain omnopon can be given intravenously.

### Anæsthesia

In our early cases nitrous oxide and oxygen and later cyclopropane and oxygen were used, despite the fact that many Continental clinics were using local anæsthesia. Dissatisfaction with the former because of the degree of hyperventilation with its attendant paradoxical movement of the exposed apex and with the latter because of the amount of blood loss while dividing the muscles, induced us to try local anæsthesia. This method was embarked upon with great prejudice and reserve, feeling that our race was mentally unsuited to withstanding operations of this extent while conscious. Our fears were quite groundless, and now that it is an accepted fact patients often become very concerned if general anæsthesia is used, as for an anterior or anterolateral stage, and it is only when the difficulties of producing good local anæsthesia for this stage are fully explained that their peace of mind returns. General anæsthesia alone is used only in the stages mentioned above; it sometimes supplements the local when the latter is not perfect, as in the second and third stages owing to œdema of the tissues; when required, very light chloroform anæsthesia is all that is necessary.

The advantages of local anæsthesia are: (1) Quiet respiration. This is strikingly evident to anyone used to operating under nitrous oxide and oxygen, and the decrease in the degree of paradoxical movement of the apex during mobilisation must be a considerable gain to the patient. (2) Clearing the bronchial tree during the operation. The patient is instructed to give warning when he wishes to cough, the apex of the lung is supported with a swab, and the patient then easily raises his sputum. (3) Hæmorrhage. The amount of hæmorrhage from the muscles is markedly less than with general anæsthesia, doubtless due to the adrenalin used with the local anæsthetic. (4) The immediate postoperative state of the patient is often much better with local than with general anæsthesia.

In our experience the sole disadvantage in the use of local anæsthesia is the occurrence of convulsions, and although of infrequent occurrence (appearing three times only in the total experience of one of us) it can lead

to serious consequences unless recognised and properly dealt with. Personal idiosyncrasy undoubtedly plays a part, but we believe the main factor in its production is overdosage. The dose will naturally vary with the weight and physique of the patient, but in our opinion it should be less than 250 c.c. The convulsions appear early, generally within ten to fifteen minutes of the injection, are general in distribution, and mild at first, but if nothing is done will increase in severity and may go on to a condition simulating status epilepticus. Associated with this is marked fall in blood pressure due to loss of vascular tone. Treatment, other than preventive, consists of free incision of the chest wall along the line of infiltration and packing the wound with hot saline swabs to encourage the escape of the injection fluid. With these measures the convulsions usually subside and the operation can be continued.

*Technique of Local Anæsthesia.*—The solution used is a mixture of procaine ½ per cent. and decicaine 1-1,000 for nerve blocks, and half this strength—*i.e.*, procaine ¼ per cent. and decicaine 1-2,000—for infiltration of the subcutaneous and muscle planes.

Anæsthesia for the first stage is carried out with the patient at first on his back. The brachial plexus is blocked through a skin wheal in the mid-clavicular line, above the left index finger placed on the third part of the subclavian artery, which can be readily palpated just above the clavicle. An unattached 4-inch Labat's needle is now introduced downwards and backwards until the upper surface of the first rib is felt. The syringe is attached and 10 c.c. of the solution injected in this position. The needle is now withdrawn and introduced upwards towards the transverse process of the sixth cervical vertebra, and a further 10 c.c. is injected. The upper three intercostals are each injected anteriorly with 5 c.c. of solution.

*Paravertebral block.*—This can be carried out immediately or can be left until the incision is made and the ribs exposed. The technique for immediate injection is as follows: Skin wheals are placed 4 cm. from mid-line on a level with the upper seven thoracic spinous processes. In the upper spaces this skin wheal lies over the centre of the corresponding intercostal space. A 3- or 4-inch needle is now introduced through the skin wheal, and first the lower margin of the rib above and then the upper margin of the rib below the space are identified with the needle point, and by bisecting the angle thus formed the centre of the space can be found. The needle is now inserted through the external intercostal muscle, then the direction of the needle is changed to 25 deg. to the skin and is advanced until the side of the body of the vertebra is felt; it is then withdrawn ¼ inch, the syringe attached, and 5 c.c. of the stronger solution injected. The injection in this position is in the intervertebral foramen. Injection farther out (*i.e.*, intercostal

block) is practised by some, but this does not ensure anæsthesia close up to the foramen, at which point section of the nerve will be carried out during mobilisation. The same technique is carried out for all the intercostal nerves; as the spinous processes are longer in the lower dorsal region and the tenth dorsal spine is at the level of the eleventh intercostal space, the rib margins bounding the space need to be identified. When nerve block is carried out after the incision has been made the technique is simple. The space is exposed and the needle can be passed under vision, usually with the syringe attached; injection is carried out as the needle is pushed backwards along the space at an angle of 45 deg.

### Operative Technique

*Position.*—The position of the patient on the table is important. He lies on the sound side with a rubber cushion under the axilla. A chest rest supports him anteriorly, but this should not come above the level of the third rib, as if higher it prevents easy access to the anterior ends of the first and second ribs. If the rest is bulky it prevents the arm from falling away and so restricts and makes difficult elevation of the scapula. The arm is allowed to hang over the side of the table, where it is usually supported by a nurse. The pelvis is held by rests and a restraining strap placed over the thighs.

First Stage Operation—*Incision.*—The incision (Plate XVII, Fig. 3 [1]) begins about an inch above the spine of the scapula and extends downwards between the vertebral border of the scapula and the spine, but nearer the latter, as far as a point about 2 inches below the inferior scapular angle; then in a rounded sweep it crosses the chest transversely to a point 2 inches in front of the inferior angle. In placing the incision in this way—that is, relatively close to the spine—less muscle mass is cut and bleeding is not as free as when it is placed farther out. Avoiding the inferior angle of the scapula and keeping to the level of the eighth rib prevents pressure necrosis by the angle of the scapula after the first stage. The anterior extension of the incision allows free mobilisation of the scapula with good visualisation of the operative field. All stages are done through the same incision, but the wound edges are excised usually only at the final stage. If a complete thoracoplasty is necessary, a short incision is made at the third stage from just beyond the bend of the original incision downwards and backwards towards the mid-line to permit the reflection of a flap to expose the lower ribs.

*Elevation of Scapula and Preparation of Resection Area.*—When the muscles have been divided in the line of the incision, the scapula is elevated from the chest wall by sharp dissection with a knife close to the

ribs until the attachment of serratus magnus is reached. The upper border of the muscle is defined and gently freed from the region of the axillary vessels. The serratus is now incised close to the chest wall over the second space; there is often a triangular deficiency in this area, and when present it is entered close to the chest wall over the second space; the reason for keeping close to the chest wall is that now, with a swab on a curved holder, the axillary contents can be gently and easily displaced forwards whilst still contained in their fascial covering. In this way the anterior aspect of the serratus is cleared, and its attachment to the second and first ribs and the intervening space can be cleanly divided with a knife with surprisingly little hæmorrhage. Any bleeding points on the serratus should be tied rather than sealed with the diathermy to avoid damaging the long thoracic nerve, which lies close to the costal attachments. The downward detachment of the serratus can now be carried out as far as desired, usually only from the third rib. The serratus posticus is now removed completely from the posterior ends of the second to the fourth or fifth rib. The upper surface of the first rib is then cleaned with gentle gauze swabbing so that the neuro-vascular bundle is freed from it and the scaleni stand out clearly. It is our practice also with gentle finger dissection to release the fascia anterior to the scalenus anticus as it lies on the subclavian vein; this simplifies matters when this muscle is divided later. A pair of curved scissors is now pushed through the attachment of the scalenus medius on to the finger placed between the inner border of the first rib and the first dorsal nerve (Plate XVII, Fig. 3 [2]); the scissors are kept close to the upper surface of the rib and gentle traction outwards will detach the superficial portion of the scalenus medius and the posticus from their rib attachments; the redundant portion can then be excised.

It is our custom to cover as far as possible all areas of the wound not being operated on at the moment with warm flavine packs to prevent undue heat and fluid loss and contamination.

*Resection of Ribs.*—In a straightforward case the third rib is resected first rarely beyond the mid-axillary line in cases where there is only pulmonary disease. Resection of long segments of the third rib often leads to gross paradoxical movement of the chest wall which is difficult or impossible to control. The rib is cut well backwards on to the neck, by opening the costo-transverse joint with the shears, the lower blade of which then sinks into the joint while the upper encircles the neck, provided it has been properly cleaned. This manœuvre is quite as effective and not so time-consuming as that advised by Semb. The second rib is now cleaned and resected, leaving 1½ to 2 inches of bony rib anteriorly, again to prevent or limit paradoxical movement. The first rib is removed after the method of

# PLATE XVI

FIG. 1.—Male, aged 30 years. Cough, positive sputum, loss of weight and pyrexia. Bilateral disease with tension cavity at apex. After sixty-six weeks external cavity drainage by Monaldi's method. Draining bronchi shown by cavernography.

FIG. 2.—Cavernography three weeks after modified Semb thoracoplasty showing bronchi closed and only a tube track visible. Lipidol showing below the level of the track is on the skin surface.

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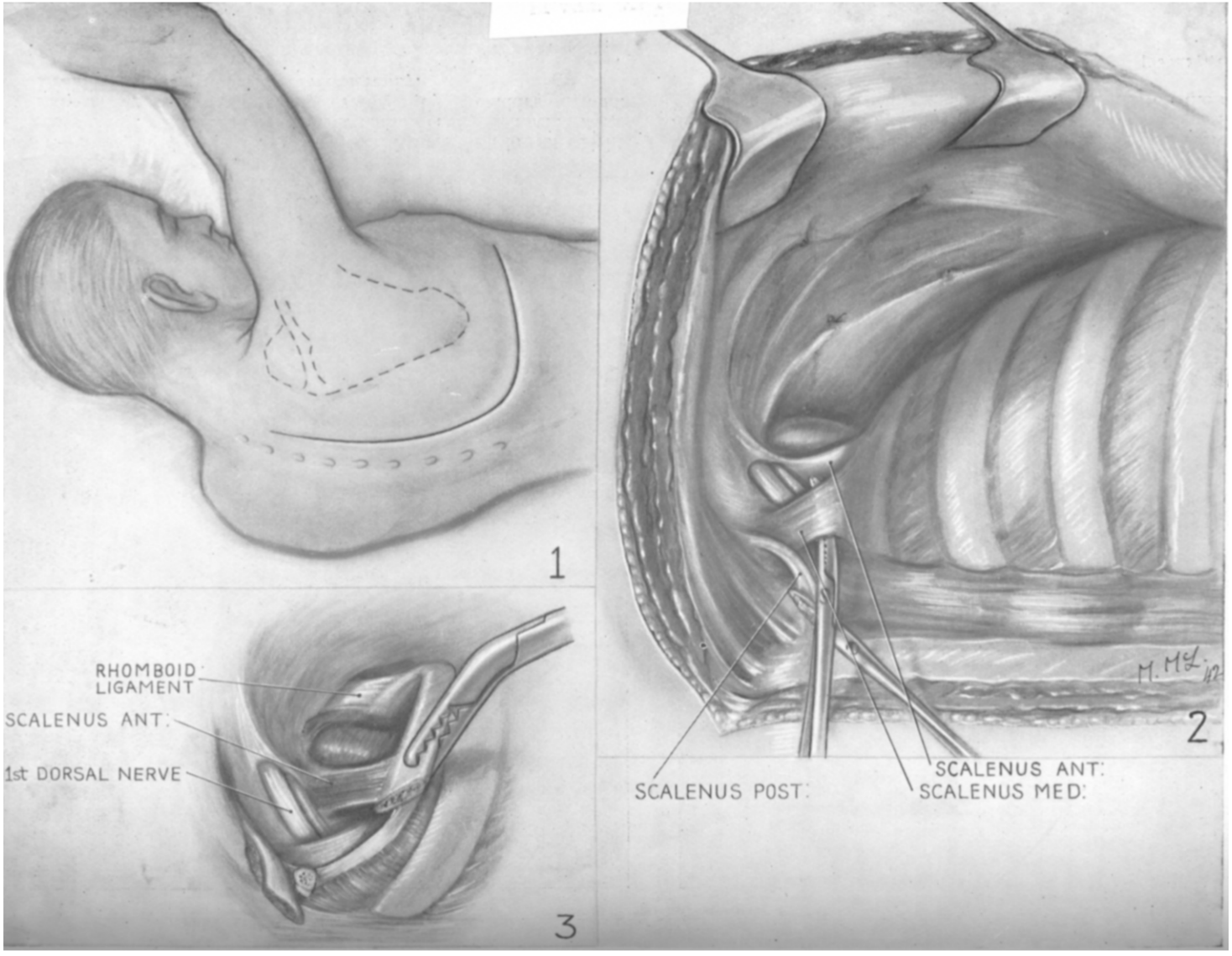


FIG. 3.

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Semb, the under surface of the posterior part is first cleaned and then the upper surface where the remainder of the scalenus medius is attached; the posterior segment of the rib is now removed. The under surface of the rib is cleaned as far forwards as possible; it usually strips easily by swab pressure. The cut end of the rib is now pulled downwards and outwards with strong sequestrum forceps, and any remaining attachment of scalenus medius is cut with scissors, thus allowing the neuro-vascular bundle to come clearly into view, and also the scalenus anticus, which is similarly cut (Plate XVII, Fig. 3 [3]). If the fascia over the subclavian vein has previously been detached from the rib there is no risk of injuring the vein at this stage as it stays behind when the rib is pulled outwards. The costo-clavicular, or rhomboid ligament, now appears; this is cleaned under vision by swab pressure, gently freeing the subclavian vein from its posterior aspect, where it is attached. Only then and with good visual control should this ligament be divided with stout scissors. The rib can now easily be divided through the cartilage. The field is now clear for mobilisation of the apex, but before this is started it is an advantage to excise the muscle bundle of the first space, for this gives a clearer view.

*Sibson's Fascia.*—Before proceeding further it may be well to say a few words about the so-called endo-thoracic fascia (Fig. 4). In health this is a layer of fascia which invests the outer surface of the pleura on the costal and mediastinal surfaces, and over the dome of the lungs; it also extends over the muscular portions of the diaphragmatic surface. It has different characteristics, however, in different positions; over the costal and diaphragmatic regions it is not a continuous layer in the sense of being a sheet, but is present as loose areolar tissue often containing fat, which attaches the pleura to the chest wall; doubtless the reason for its tenuous character here is that the firm chest wall affords all the support that is necessary. Over the mediastinum there is a definite sheet of fascia, though thin, which confines the mediastinal structures, whilst over the dome of pleura it becomes a well defined resistant sheet, obviously to confine the lung to the limits of the thorax; its function is only appreciated if it is ruptured or stretched,

PLATE XVII, FIG. 3.—(1) Right-sided thoracoplasty: Shows line of incision placed nearer mid-line than vertebral border of scapula, and extending from level of upper border of scapula to a point about 2 inches below the inferior angle, and then carried forwards to a point 2 inches in front of this. (2) Right-sided thoracoplasty: Shows scapula reflected and serratus magnus muscle reflected cleanly from the ribs. Serratus posticus has been excised so that posterior ends of upper three ribs are clear as far as outer margin of erector spinæ. Scalenus posticus has been detached and will later be cut short. A pair of forceps has been thrust through scalenus medius preparatory to detaching it. (3) Right-sided thoracoplasty: Posterior part of the first rib has been excised, and anterior end of rib is being pulled down to show scalenus anticus. Costo-clavicular (rhomboid) ligament is shown with innominate vein separated from posterior aspect (normally this is done after scalenus anticus has been cut).

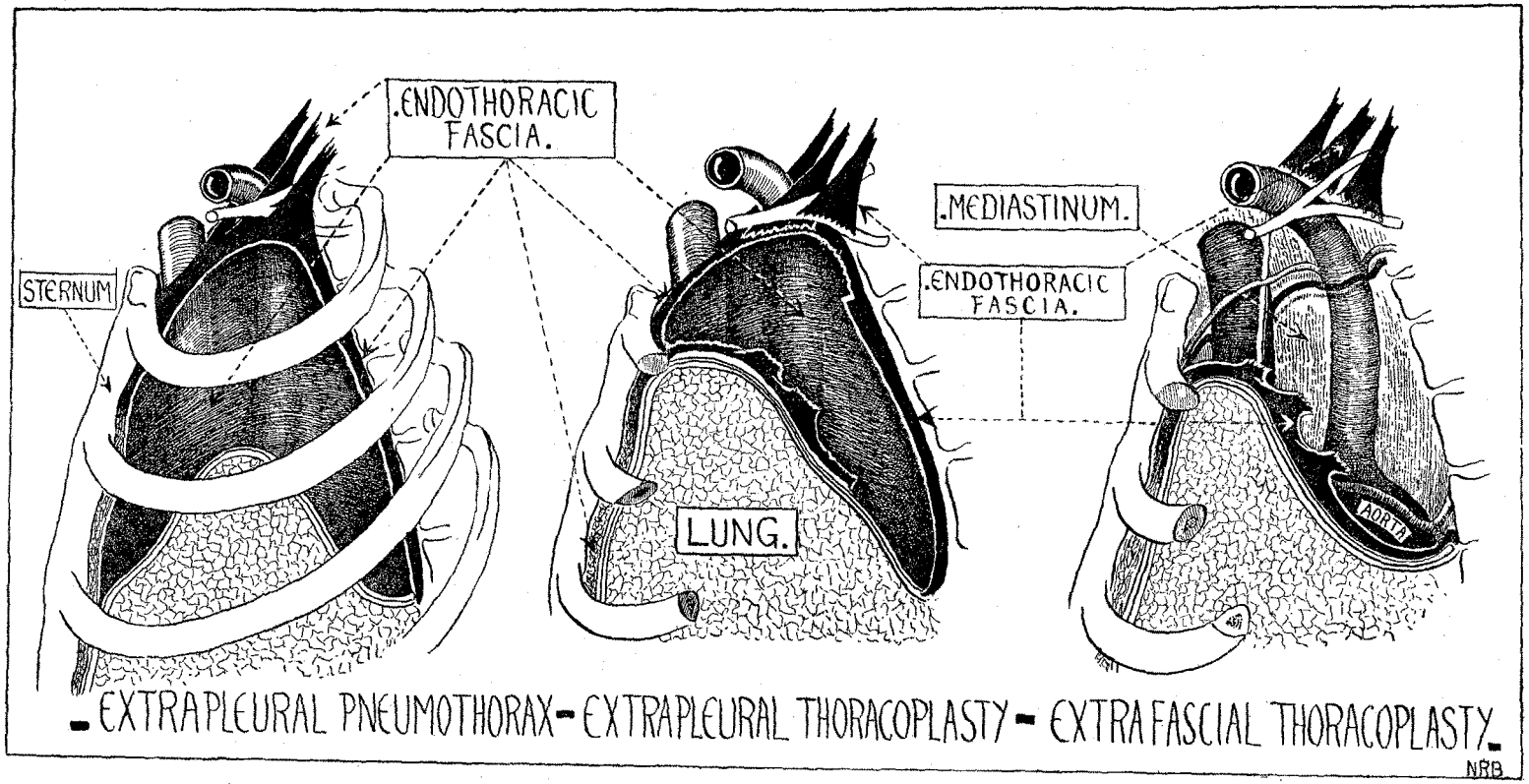


FIG. 4.—Diagrammatic representation of the essential differences in the planes in which mobilisation of the apex is carried out. (*a*) Extrapleural artificial pneumothorax. The separation is entirely in the extrapleural plane, and inside the endothoracic fascia where this fascia forms a sheet, as on the mediastinum and over the cupola of the pleura. (*b*) Thoracoplasty with apical mobilisation in the extrapleural plane on the mediastinal surface. Here the fascia is ruptured at the level of the internal mammary artery and the mediastinal investment of fascia remains in position. (*c*) Thoracoplasty with a true extrafascial mobilisation. In this case the whole endothoracic fascia is stripped down with the lung on all aspects, after section of the bands attaching it to the neck of the first rib, transverse process of the seventh cervical vertebra, and the fascial planes of the neck.

when a well marked lung hernia into the root of the neck occurs. This sheet of fascia is attached to the inner border of the first rib, the neck of the first rib and the transverse process of the seventh cervical vertebra; the subclavian vessels and first dorsal nerve arch over the top of Sibson's fascia to reach the arm, but the nerve on emerging from the intervertebral foramen separates the fascial attachment to the neck of the first rib from that to the seventh cervical transverse process. These two bands, one lying superficial to the first dorsal nerve and one between the nerve and the artery, together with the band which lies between the artery and vein resulting from the attachment of some fibres of scalenus anticus into Sibson's fascia, are sometimes referred to as Sebileau's bands.

In the presence of pulmonary disease this fascia over the diseased area becomes thickened and better defined, and as regards that covering the costal area can now certainly be called a definite sheet of fascia ; in advanced cases it inseparably binds the pleura to surrounding structures.

*Mobilisation of the Apex.*—The first step in mobilisation is to define clearly the first dorsal nerve, which is invested in a loose sheath of fascia. The fascia is deliberately incised. This makes it easy to free the nerve from the anterior surface of the band, and the latter can then be deliberately cut with a knife. Sometimes the first intercostal artery lies in the tissue cut, while at other times it lies at a deeper level (Plate XVIII, Fig. 5 [4]); in early cases it can easily be secured, but in older fibrotic cases, pressure with a small swab will control it while the next band between the nerve and artery is defined. Division of the intercostal branch of the first dorsal nerve will allow this nerve to be pushed upwards to expose the second band. It is better at this point to expose the subclavian artery a little distal to the band; this gives the correct layer and the artery can then be freed from the band. The posterior limit of the band is easily defined. The superior intercostal artery lies in relation to the posterior surface of this band, but its position is not constant and depends on the site of origin from the subclavian. In consequence it is impossible to be certain that the artery has been secured even when the band has been freed and clamped. Our present custom is to divide this band deliberately with a knife until the superior intercostal becomes visible. At times it has a high origin and does not come into the operative field; when it does it is divided between two ligatures. Gentle dissection downwards of this band soon brings the highest intercostal vein into view; this should be properly cleaned of fascia, as should the subclavian artery (Plate XVIII, Fig. 5 [5]). It is now an advantage to divide the third band between the artery and the vein; this should be done in two levels: firstly, the remains of the scalenus anticus attachment and any fascia left covering the subclavian vein, then the deeper layer which covers the internal mam-

mary artery, which here is running obliquely downwards and forwards. Very rarely this vessel may take origin from the third part and then comes vertically downwards between the subclavian vein and the periosteum of the first rib. Often the origin of the artery from subclavian trunk can be seen; this indicates the correct level, and the fascia in the average case is usually thin at this point.

If these bands are divided correctly, especially their deepest part, then the mediastinal strip will be carried out in the proper layer—that is, between the mediastinal structures and the fascia. Dissection in this layer should in the main be sharp with long-handled, curved scissors, although gentle swab pressure is also employed. It is our practice never to handle the apex; traction is maintained with forceps attached to the intercostal muscles. The points of firmest attachment in our experience are on either side of the subclavian artery where the fascia dips into the mediastinum. Better access will be obtained by dividing the periosteum of the first rib and the second intercostal bundle, after ligating the vessels. Sharp dissection with a knife is preferable in this region when the lung is adherent, as often there is no proper line of cleavage (Plate XVIII, Fig. 5 [6]).

A decision must now be made as to the extent of mobilisation which is warranted and necessary. Some idea may be obtained from the pre-operative X-rays, the size of the cavity, the extent of the disease and its age, but the final decision will be made when the apex is exposed. These have been our criteria to date: (1) A firm solid apex will tolerate an extensive mobilisation better than a soft one. (2) Likewise a non-toxic patient will tolerate a large relaxation better than a toxic one. Both factors, to a certain extent at least, depend on whether the disease is predominantly exudative or not. These two factors determine how much mobilisation is justifiable at any stage; but there is only one criterion as to what will eventually be necessary, and that is that mobilisation in the mediastinal and paravertebral regions must be carried down to soft yielding lung; only in this way can relaxation of the drainage area be obtained and the principles of treatment be applied.

Taking first the cases with a firm solid apex, it has been our custom

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PLATE XVIII, FIG. 5.—(4) Right-sided thoracoplasty: First rib has been excised and first band including the periosteum of first rib (grasped in forceps) has been divided, bringing into view the second band (the one between the nerve and artery). (5) Right-sided thoracoplasty: Second band has been cut and now in view are superior intercostal artery (here coming off at a high level) and highest intercostal vein (in this case probably joined by vertebral vein, hence its size). Third band, which is in part the deep fibres of scalenus anticus, is now ready for division. (6) Right-sided thoracoplasty: Mobilisation has been completed down to fourth rib. In this case vagus with recurrent laryngeal nerve was easily displayed and phrenic nerve received an accessory branch coming down in front of the vein.

PLATE XVIII

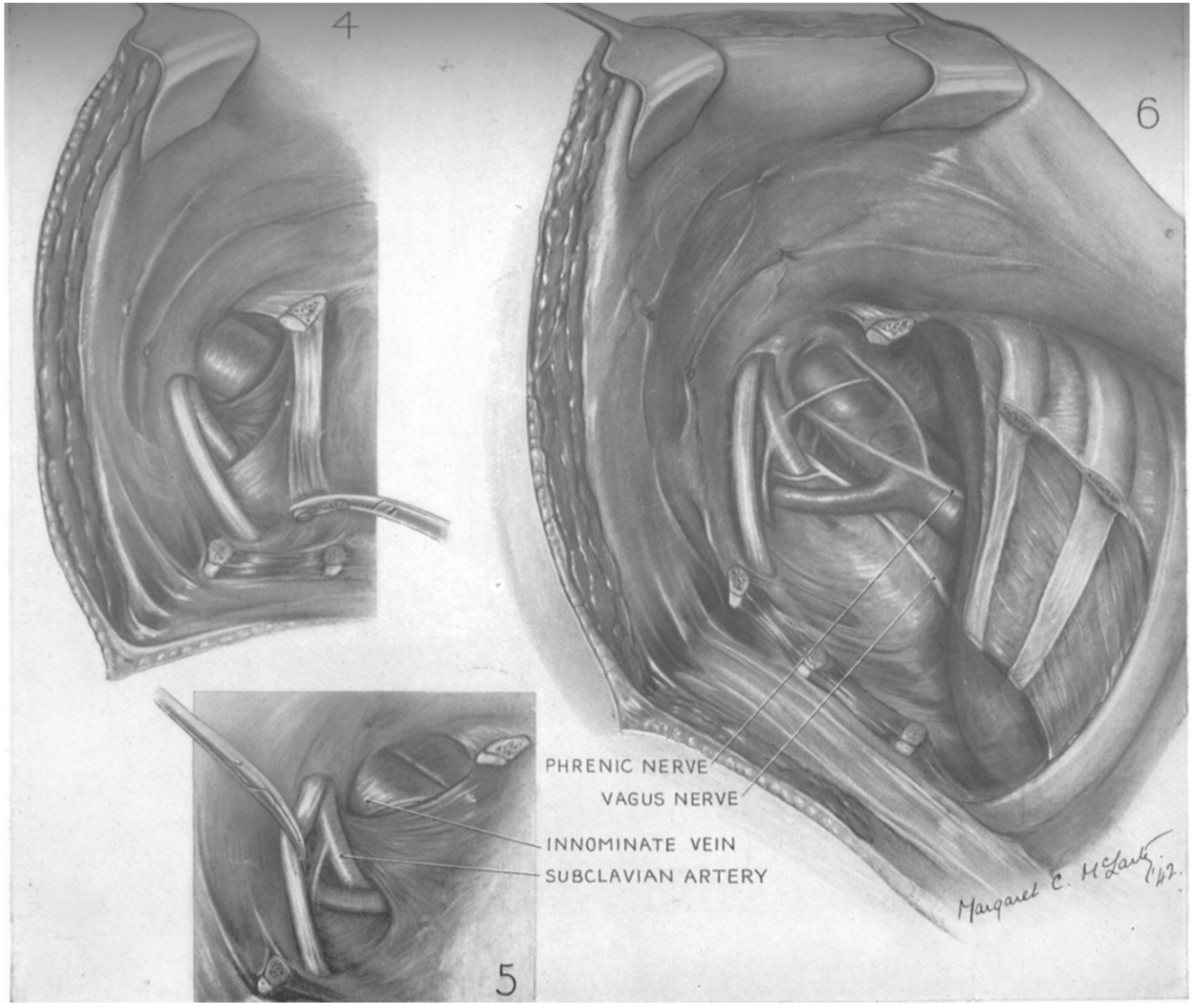

4
6
5
PHRENIC NERVE
VAGUS NERVE
INNOMINATE VEIN
SUBCLAVIAN ARTERY
Margaret C. McClark '42.

PLATE XIX

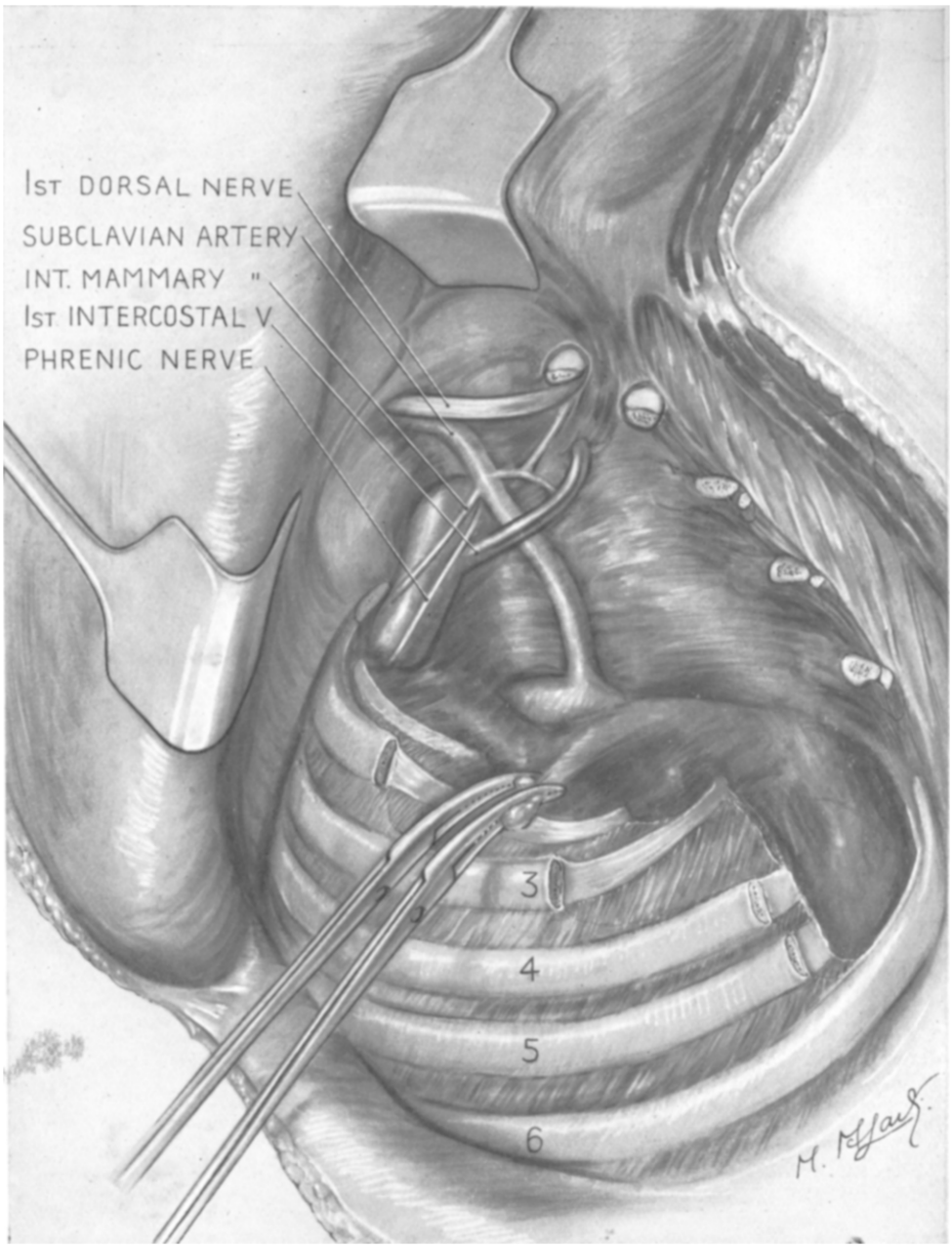
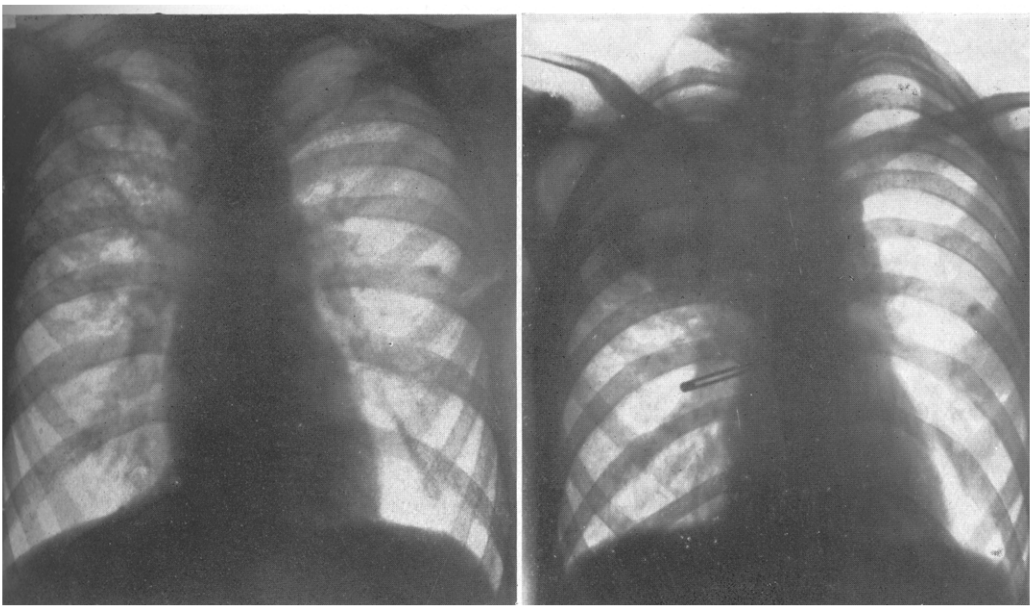



FIG. 6.—Left-sided thoracoplasty: Showing operation completed with resection of posterior ends of fourth and fifth ribs and mobilisation in costo-vertebral sulcus to level of sixth rib and on mediastinum to level of aortic arch, the upper part of which is seen. This figure and Fig. 5 (6) are composite views.



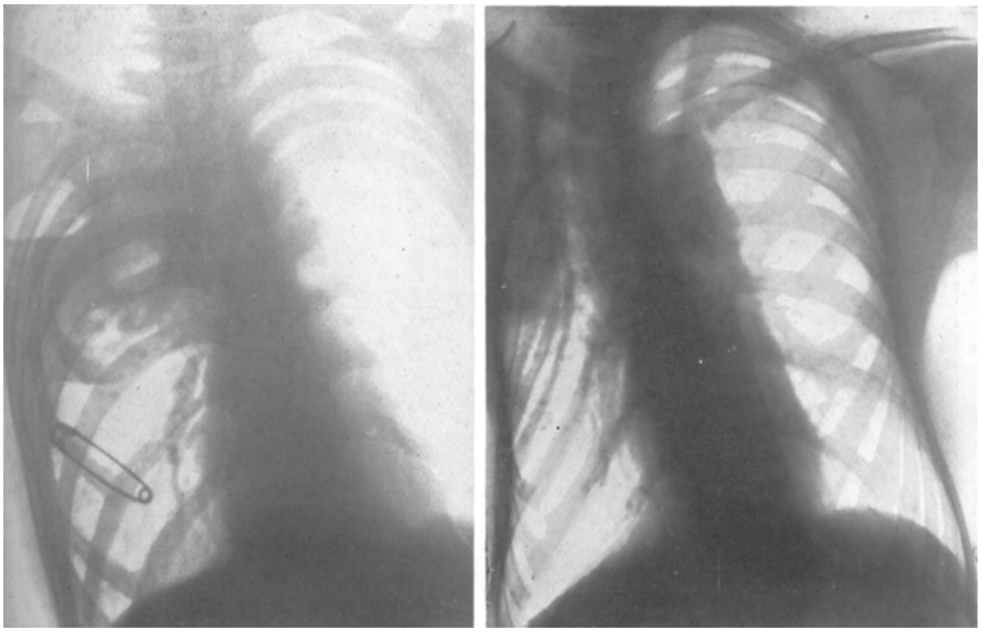


FIG. 9. FIG. 10.

FIGS. 7-10.—Male, aged 17 years. Slipping chronic case of six months' duration. Persistently pyrexial, considerably raised sedimentation rate and positive sputum. Thoracoplasty done in small stages with mobilisation at each stage. After each stage mean temperature fell by 1° F. Fig. 7: Postero-anterior radiograph, February 4, 1941. Extensive infiltration throughout right lung with cavities in upper and middle zones. Fig. 8: Postero-anterior radiograph, April 21, 1941, after resection of first rib and half second rib with mobilisation. Fig. 9: Postero-anterior radiograph, May 1, 1941, after resection of remainder of second rib and portion of third rib with further mobilisation. Fig. 10: Postero-anterior radiograph, March 4, 1942. No evidence of cavitation.

[*To face Plate XIX.*

# PLATE XXI

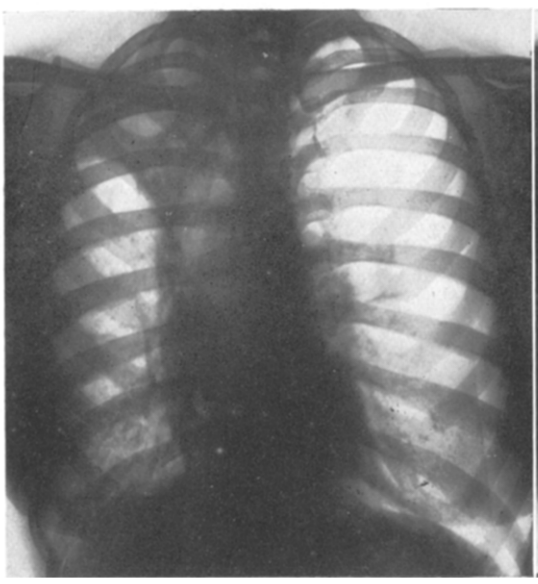


FIG. 11.

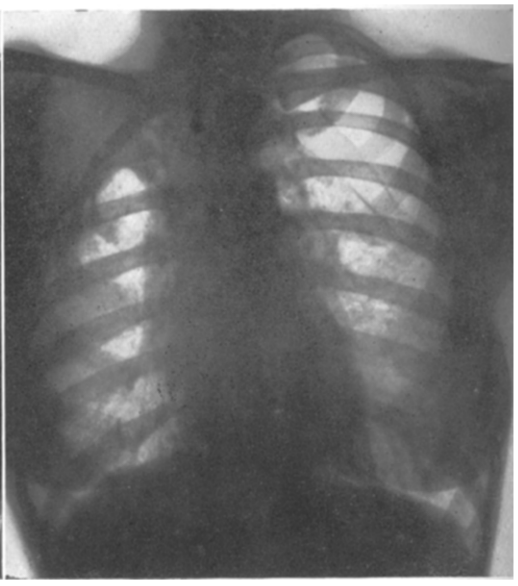


FIG. 12.

FIG. 13.

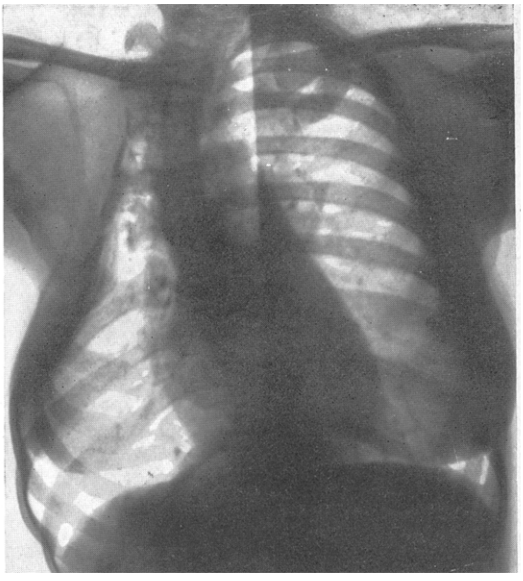


FIG. 14.

FIGS. 11-14.—Female, aged 27 years. Relapsing chronic case. Onset, 1932. In 1936 left artificial pneumothorax induced, followed by right Semb thoracoplasty. 1939 sputum positive and cavitation at right apex. Re-operation thoracoplasty with closure of cavities and sputum conversion. Fig. 11: Postero-anterior radiograph, February 18, 1936. Left artificial pneumothorax. Large right apical cavity with infiltration in mid and lower zones. Fig. 12: Postero-anterior radiograph, March 1, 1939. Honeycomb appearance at right apex. Fig. 13: Tomograph 7 cms. from back showing small cavity at right apex. Fig. 14: Postero-anterior radiograph, December 2, 1941. No evidence of residual cavitation (confirmed by tomography).

[*To face page* 125.

latterly (in the modified Semb operation) to resect segments of the fourth and fifth ribs from about 1 to 1½ inches in front of the outer border of the erector spinæ backwards; the fourth and fifth intercostal bundles are divided and ligated, and mobilisation continued until it is well below the level of induration. This may, and often does, entail stripping down over the aortic arch on the left (Plate XIX, Fig. 6), or the vena azygos major on the right—that is, practically to the lung root. This procedure does not appreciably add to the risk or shock of the operation, and it avoids the disadvantage of long fourth and fifth rib resections, leaving a large area of mobile chest wall in front. In patients with mobile apices mobilisation is stopped at the level of the upper border of the fourth rib. The third intercostal neuro-vascular bundle is divided, as the nerve is difficult to anæsthetise at the next stage. In toxic cases we have recently employed even smaller stages, taking only one and a half ribs combined with mobilisation at each operation, and it has certainly decreased the post-operative reactions (Plate XX, Figs. 7-10). Where the apex is soft and mobile the extra-fascial space is filled with 6-8 oz. of saline, which is introduced through a catheter just before the muscular layers are completely sewn up. This acts as a more efficient cushion for the apex than air during the immediate post-operative stage before an effusion has formed, thus decreasing the movements of the apex.

Second-Stage Operation.—The second stage is carried out in fourteen days if the patient's condition permits. At this time there is less œdema of the tissues, which are also relatively avascular, and the operation is consequently easier. Risks, however, should not be taken and the surgeon's comfort should never overshadow the requirements of the patient. It is far better to postpone the next stage for weeks or months than to take unnecessary risks, even though the difficulties are thereby increased.

This stage is also done under local anæsthesia. The wound is reopened and the scapula reflected; the extra-fascial space is deliberately opened and emptied of accumulated serum and clot if any is present. The requisite number of ribs are then resected, the number being determined by the considerations mentioned above. If the posterior ends of the fourth and fifth ribs have been removed at the first stage, the remaining segments are usually removed first, and the reattachment of the cut ends of the intercostal bundles to the erector spinæ muscle, which always occurs, is divided. If further mobilisation is deemed necessary, this can be carried out after the ribs have been resected, but this will only be necessary in the presence of cavitation in the dorsal part of the lower lobe, when division of the sixth bundle will suffice.

*Remobilisation.*—In cases where only the third rib was resected at the first stage, further mobilisation is usually necessary. It is difficult to start re-

mobilising afresh from above as the extra-fascial space is usually lined by a smooth membrane and a line of cleavage is difficult to identify; this also, of course, applies after smaller resections. The best method of commencing remobilisation is to divide the periosteum of the upper freshly resected rib, and the correct plane can then generally be easily identified; mobilisation can then be carried forwards, upwards, and downwards with safety, and the new extra-fascial membrane can be cut at the proper place without risk to the lung or mediastinal structure. If the operation is to be completed in two stages resection should be taken down to and including the seventh rib, the lengths of rib removed decreasing from above downwards. Care should be taken to ascertain whether the scapula fits easily in front of the eighth rib; if not, a small part of this rib should be removed as well. Proper embedding of the scapula is important for maintaining the relaxation produced by the mobilisation in the costo-vertebral sulcus.

REOPERATION.—The technique of this operation differs little from that just described in those cases where the original operation consisted merely of rib resection without mobilisation, for the relationships of the neuro-vascular structures and Sebileau's bands to the regenerated first rib have not altered materially. Consequently mobilisation is no more difficult than in cases operated on for the first time. The ribs, however, are more irregular, and there is often a bar of bone running vertically along the outer border of the erector spinæ joining the resected ribs. This must be resected back to the rib necks, otherwise difficulty will be experienced in finding the correct line of cleavage in the costo-vertebral area; also this bar, if left, may prevent comfortable embedding of the scapula.

Local anæsthesia is used for these cases also; but often it has to be supplemented with chloroform, as the intercostal block may not be efficient owing to distortion of the intercostal spaces. In cases where apical mobilisation was carried out at the original operation, the state of affairs has changed considerably (Plate XXI, Figs. 11-14). The neuro-vascular structures have dropped with the apex and are, to a certain extent, adherent to the outer aspect of the thoracic wall; it is therefore absolutely necessary, when reflecting the scapula, to dissect close to the chest wall. This can be done only with a knife, as the tissues are very tough. Dissection should be carried out until the vessels are completely and clearly exposed. If this is done properly it will be found possible, in the average case, to free the mediastinal aspect of the apex for an inch or so downwards from the top, and then the postero-superior angle can be detached in the costo-vertebral region with a knife, so increasing the view of the mediastinum. In this way, by freeing the mediastinal aspect first, and then detaching posteriorly, a considerable apical mobilisation can be effected down to the area where soft lung can be

felt. It will, of course, be necessary to resect any regenerated ribs. The first rib often shows no evidence of regeneration and the second only feebly so; below this, however, regeneration is generally good. In resecting regenerated ribs it is wiser to start on the normal rib anteriorly, and if the standard method of stripping the lower margin from before backwards, and the upper from behind forwards, is employed, resection is possible without undue trouble, though with greater labour.

Reoperation cases in general usually have a greater immediate disturbance from the operation, but toxic reactions, spread of disease, and atelectasis are less common in our experience than with the primary operation. This is what might be expected, as the disease is older, and in consequence not exudative, the apex having been more or less immobile for some time.

### Accidents during Operation.

(*a*) Probably the accident most to be feared is opening a pulmonary cavity during operation (Plate XXII, Figs. 15 and 16). This has happened three times in our experience. The first time was about five years ago during a reoperation. In this case limited mobilisation of the cavitated area was carried out, the cavity was sucked out and closed with one layer of catgut sutures. Three ribs only had been resected, and no further rib resection was performed. The result was that the cavity reopened post-operatively, and a diffuse infection of the subscapular space ensued which ended fatally. We feel, on reviewing the case, that this should not have occurred. Firstly, the primary operation was that of rib resection only. Secondly, the apex was quite soft and not firmly adherent. The prime mistake in this case was that the mobilisation was carried out in the extra-pleural plane and was done with the finger; had mobilisation been done extra-fascially, and by sharp dissection, the cavity would not have been opened. The second error was in performing a too limited mobilisation of the apex below the cavitated area and failing to control the drainage area, probably allowing increased tension inside the cavity. The third error was that suturing of the lung was inefficient; one layer of sutures was not enough to maintain an air-tight suture against the increased intracavitory tension. A fourth error will be considered in a moment. The other two cases occurred during primary operations, where sharp knife dissection was the only possible way of mobilising the apex. It may be stated that such cases will constantly occur in any reasonable series of cases, and there will always be a risk of opening a cavity. In view of the experience with the first case, and our changing conceptions of the functions of the drainage area in cavity persistence and closure, a different technique was

used. As soon as the cavity was opened, it was sucked and cleaned out and swabbed with flavine; as has been already noted, free bronchial blowing was noticed in both cases. Free mobilisation was then carried out after resecting the ribs down to and including the seventh. In one case mobilisation was taken down to the upper border of the seventh rib before soft lung was encountered, and in this case portion of the eighth rib was also resected. Free mobilisation not only relaxes the drainage area (suggested by the disappearance of the bronchial blowing which had been previously present), but it also permits closure of the cavity without tension. In these cases three layers of suture were used. Using this technique, no post-operative complication occurred, and the cavities closed in both cases with a disappearance of sputum. To revert to the first case, we feel that, even though the apex was soft, had the same technique been adopted the chances of a successful outcome would have been reasonably good, and should such a misfortune occur again we feel that, even though the apex is soft, a more extensive operation with embedding of the scapula at the first stage is justifiable and a risk that should be taken.

(*b*) On three occasions small infected pleural pockets have been inadvertently opened and have been treated on the lines indicated above without any untoward results.

(*c*) Opening an uninfected pleural space has occurred on a few occasions. In these cases the pleural opening has been closed with sutures, and the contained air aspirated from the chest immediately after the operation. This was not done in one case, and the degree of physiological disturbance was considerable. If the air is removed at the time of operation no untoward result has followed.

(*d*) Damage to vessels: On one occasion the superior intercostal artery was torn from the side of the subclavian artery. In this case the subclavian artery had to be tied. No ill effect followed ligation, and it was hardly to be expected, as at this site it is well below the very free anastomoses that occur at the root of the neck and around the scapula. The left innominate vein has been opened on one occasion during re-operation; this was controlled by digital pressure until the vein was freed and then the lateral hole was sutured; no ill effect was observed afterwards.

(*e*) Sympathetic: Damage to the sympathetic trunk occurs frequently, either from contusion or actual division; in the former the resulting Horner's syndrome is usually temporary, whilst in the latter it is permanent. Division of the trunk invariably occurs in those cases where the apex is firmly adherent in the costo-vertebral sulcus, and in most cases is undertaken deliberately to effect adequate mobilisation. The minor disability of a permanent Horner's syndrome is a small price to pay for efficient relaxation.

# PLATE XXII

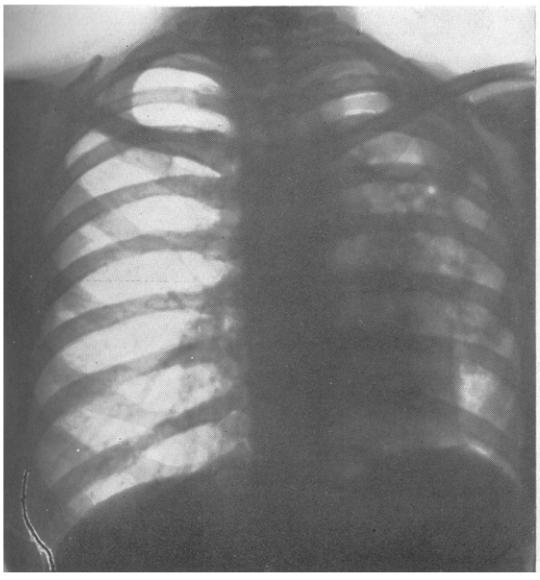


FIG. 15.

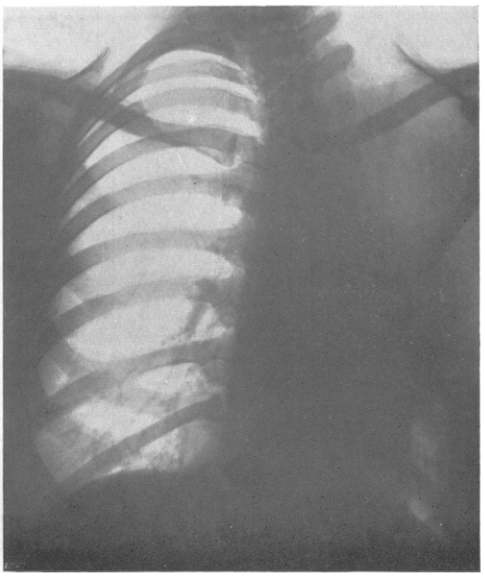


FIG. 16.

FIGS. 15 AND 16.—Female, aged 29 years. Stationary chronic case of ten years' duration. 1940 sputum positive with extensive disease in left lung. During upper stage thoracoplasty pulmonary cavity was opened. Upper seven ribs were then resected and mobilisation carried down to softer lung in region of sixth rib. Cavity then readily closed in layers. Post-operative course uneventful apart from simple atelectasis. Cavity remained closed and sputum negative. Fig. 15: Postero-anterior radiograph, July 24, 1940. Infiltration in all zones of left lung with large apical cavity and marked mediastinal displacement. Fig. 16: Postero-anterior radiograph, July 29, 1941. No evidence of cavitation.

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# PLATE XXIII

FIG. 17.

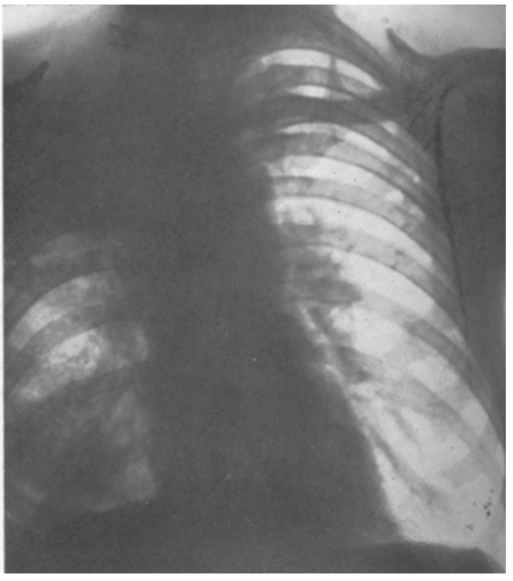

FIG. 18.

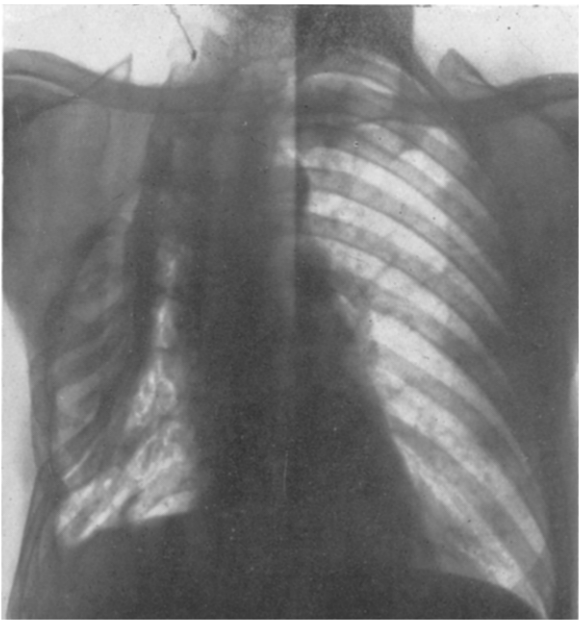

FIG. 19.

FIGS. 17-19.—Male, aged 47. Relapsing chronic case of seven years' duration. Sputum positive 1940 modified Semb thoracoplasty. Reactivation spread after upper stage necessitating extension of an originally planned seven-rib thoracoplasty. Cavities closed; sputum conversion. Fig. 17: Before upper stage operation. Postero-anterior radiograph. Fig. 18: Postero-anterior radiograph, June 27, 1940, one month after upper stage. Spread of disease at right base. Fig. 19: Postero-anterior radiograph, December 10, 1941. No evidence of cavitation. Considerable clearing of basal opacity.

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(*f*) Thoracic duct: This has been consciously divided on two occasions in cases with adherent apices. Ligation of the cut ends led to no disability in either case.

### Post-operative Course and Supervision

After the application of dressings, the chest is firmly strapped with adhesive plaster. A small pad of gauze is placed below the clavicle and held in position by strapping placed over the shoulder; this will limit paradoxical movement of the anterior portion of the chest wall where the ribs have been resected. Minor adjustments in the strapping are often necessary later in the ward, as it frequently becomes too tight.

(*a*) Position in bed: On reaching the ward the patient is placed in the semi-upright position, as this facilitates respiration and enables the patient to cough more readily. If shocked, the patient should still be placed in this position, and the foot of the bed raised on blocks.

(*b*) Oxygen: Severe oxygen lack is characterised by tachycardia, increase in the rate and depth of respiration, and cyanosis; minor degrees are associated with much less obvious changes which may be overlooked unless borne in mind. Quiet respiration is essential, particularly immediately after operation; forced respiration not only increases discomfort and pain, but has a distinct bearing on post-operative spread of disease, spontaneous pneumothorax and paradoxical movement of the chest wall.

In view of this, oxygen is used extensively and on the slightest indication, particularly so in cases with bilateral disease or a contra-lateral pneumothorax where the risk of an added spontaneous pneumothorax is considerable.

(*c*) Vomiting: Even after the use of local anæsthesia vomiting of mild degree occurs frequently; severe and persistent vomiting bears a direct relationship to the volume of ingested fluid. Fluids by mouth as a routine should be restricted to sips for the first twenty-four hours, and this should be supplemented by rectal or intravenous salines if fluid loss has been great or dehydration appears imminent. Persistent vomiting will cease readily if no further fluids are given by mouth for several hours, and then recommenced in a gradual manner.

(*d*) Pain: Is not considerable except after the stage when the scapula is embedded. Morphia in doses of $\frac{1}{6}$ grain should be given at four-hourly intervals if necessary, but it should never be allowed to diminish the cough reflex. Veganin tablets are valuable, but their use is not recommended for the pyrexial case.

(*e*) Coughing after a thoracoplasty is usually difficult and painful. Morphia, as it allays pain and anxiety, will often actually facilitate coughing. Every effort should be made to encourage expectoration of sputum, as its

accumulation in the bronchial tree will frequently precipitate atelectasis or bronchogenic spread of disease. During the expulsive effort, the hand should be firmly placed over the chest wall where the ribs have been resected in order to prevent paradoxical and painful movement. A saline expectorant in hot water is given at four-hourly intervals as a routine.

(*f*) Transfusions are rarely required immediately after operation, as blood loss is not severe when local anæsthesia is employed. They are, however, being more extensively used between stages and undoubtedly help to maintain resistance and the general condition of the patient.

(*g*) Physiotherapy: Passive followed by active arm and shoulder movements and breathing exercises are started on the second or third day after operation, as already indicated. After the second stage, when the scapula is embedded in its new position, movements should be restricted to those of the arm alone and only later, at the end of the first week, when the scapula is firmly placed, should scapular movements be instituted. If started too early the scapula may slip backwards, and its inferior angle ride on the unresected eighth rib, producing considerable pain, which may require resection of part of this rib at a later date. Once its new position is consolidated slipping of the scapula is unlikely to occur. With tuition, most patients can move their arms almost fully between stages; without it crippling restriction of arm and shoulder movements is frequent.

Some degree of scoliosis of the dorsal spine with the convexity towards the operated side is constant after thoracoplasty. It is due to the resection of the ribs and division of the intercostal bundles, so that the erector spinæ and (probably more important) the small costo-transverse muscles lose their attachment in this region. Compensatory curves of the cervical spine and deviation of the head towards the affected side also occur. The shoulder on the affected side often assumes a higher position than normal. These postural deformities should be actively and passively corrected by the nursing staff as well as by trained masseuses, especially during the early post-operative period. Some degree of scoliosis is unavoidable, but with care the head and shoulders can retain their normal positions. The use of a large mirror is of value as it helps the patient to visualise his deformity. We have not used the wedged pillows devised by Bisgard nor other thoracic appliances advocated, and have not felt the need of them for properly supervised and co-operative patients.

(*h*) Bed rest: Between stages the patient is allowed to sit in a chair for a few days prior to the next operation as the tonic effect, both mental and physical, is great. After the final stage the patient is kept in bed for twelve weeks; it is during this period that the cavity—functionally closed by the operation—becomes organically and anatomically closed and adjacent

tuberculous lesions are given a chance to heal under more advantageous circumstances.

Earlier cases in this series were allowed out of bed three to four weeks after operation if the cavity was apparently closed and sputum reduced and negative. In a proportion of these cases the cavity reappeared and sputum became more copious and positive after such activity. It might be argued that such cavities were, in fact, never closed, but we have a definite impression that the number of permanent closures has increased since the extended period of bed rest has been employed. Following the bed rest period all patients should be transferred to a sanatorium, where graded rest is instituted under careful medical supervision.

(*j*) Weights: These should be applied over the remaining unresected portions of ribs anteriorly and laterally, about a fortnight after the conclusion of the final stage. The object is to compress these unresected portions in order to diminish further the volume of the thorax. 1 lb. shot bags are used for half an hour first on the front and then on the side each morning and evening. The weights are gradually increased up to 8 or 10 lb. and the time to one hour in each situation. These weights should be continued for about three months, by which time the chest wall has consolidated and no further compression can be achieved. In cases where the pleura is soft and the chest wall is supple the use of weights can be avoided as the anterior chest wall will fall in easily and naturally.

(*k*) Thoracoplasty belt: Certain patients after a total thoracoplasty are left with an apparent weakness and mobility of the resected area which may prove disabling. Much benefit and comfort is derived from the application of a belt of any suitable padded material. Again, after three or four months this will not be required, for by then the ribs will have regenerated and the chest wall have consolidated.

### Post-operative Complications

Many of the complications about to be discussed can be prevented if the suggestions already outlined for post-operative care and management are efficiently carried out; especially is this so as regards paradoxical movement and the expectoration of sputum.

1. *Atelectasis.*—Lobar or total atelectasis is found in approximately 20 per cent. of all cases, though not all are recognised. It appears more frequently after the first than the later stages, in which case it is usually associated with more severe symptoms. Recent cases with more extensive mobilisation do not appear to be associated with an increased incidence. It is much more common on the side of operation, and lobar atelectasis is less frequent than total.

The majority are due to bronchial obstruction by mucus or muco-pus with consequent absorption of the air from the lung distal to the occlusion. Post-operative dehydration, the use of atropine or hyoscine making the sputum more tenacious, and pain which limits coughing and expectoration, are important contributory factors in its production.

Atelectasis most commonly occurs on the second or third day after operation; it rarely appears before thirty-six hours. A small proportion are quite symptomless and are found only by routine clinical and radiological examination; these are of little significance as re-aeration of the affected portion of lung occurs within a few days. The majority, however, are ushered in by a sudden rise of pulse rate, temperature, and often of the respiratory rate. The patient, previously well, feels and looks gravely ill. The cough is often suppressed and ineffective on account of pain, and what sputum is produced is tenacious and expectorated with difficulty. Too great reliance cannot be placed on physical signs at this stage; a complete examination is difficult on account of dressings; the breath sounds are often weak or absent on the side of operation in the non-complicated case as a result of immobility of the hemithorax. The most reliable signs are tracheal and mediastinal displacement towards the affected side, dullness to percussion and bronchial breath sounds. The only reliable method for diagnosis is radiological; the atelectatic lung appears as a dense homogeneous opacity with displacement of the mediastinum towards the affected side.

Treatment: Preventive measures need emphasis; every effort should be made to prevent the accumulation of sputum in the bronchial tree. The patient is moved in bed regularly; after washing he is laid flat first on one side, then on the other. This movement is often very effective in producing sputum. The nursing staff should repeatedly encourage efficient expectoration; their aid is often of great benefit to the patient. If pain prevents adequate coughing small doses of morphia should be given. Saline expectorants are given at four-hourly intervals as a routine.

In established cases the above measures are more vigorously applied. The necessity for expectoration is explained to the patient and his co-operation is sought. Saline expectorants and a mixture containing ammonium carbonate gr. x.-xv. in milk are given alternately at two-hourly intervals. Postural drainage is beneficial, though a few will not tolerate it within a few days of operation. The patient is gently and carefully laid in the lateral position with the affected side uppermost and his head on a small pillow. The foot of the bed is raised on blocks and the patient is encouraged to cough. This position is usually well tolerated for short periods, and should be repeated two or three times daily.

Apart from these every effort should be made to maintain the general

condition with adequate food and fluid. It is advisable to explain to the patient the cause of his present condition, and seek his intelligent co-operation with posture and expectoration of sputum.

As regards their subsequent course cases can advantageously be classed into three groups:

(1) *Simple atelectasis* includes by far the greatest number. In these the sputum, at first scanty and sticky, becomes more copious and less viscous; this change may occur relatively suddenly, suggesting that the bronchial obstruction has been overcome and is associated with a rapid reduction in temperature and pulse rate and re-aeration of the lung. In others the process is more gradual. Once the obstruction has disappeared the return to normal, both clinically and radiologically, is fairly rapid. The appetite during the atelectatic phase forms a useful prognostic guide; in those cases where it remains good even at the height of the illness a successful outcome is to be expected, whereas those who lose their appetite completely not infrequently fail to resolve.

(2) *Atelectasis with pulmonary suppuration* forms a fortunately rare group. Inefficiently treated cases of the above group may pass on into this one. In these signs and symptoms of atelectasis gradually merge into those of suppuration with fever, wasting and the expectoration of large quantities of purulent sputum. The immediate outlook is grave and permanent bronchiectasis is likely, should the patient survive.

(3) *Atelectasis with additional Tuberculous Disease.*—Almost all patients who do not show re-expansion of the atelectatic lobe within two to three weeks and do not develop suppuration with abscess formation will eventually show evidence of an added tuberculous process in the lobe. Signs of toxæmia are slow in disappearing, the sputum remains copious, and gradually the homogeneous radiological opacity is replaced by a diffuse, coarse, irregular mottling of the affected region. If the patient is able to overcome the added infection the thoracoplasty can eventually be completed, but it is now necessary to extend the resection of rib in order to relax the newly diseased area.

In practice a simple atelectatic lung which has not aerated within three weeks is regarded as being the seat of an additional tuberculous process, and in these, we believe, it is essential to relax this newly affected portion of lung in addition to the area already planned as only in this way can progressive disease be prevented. As soon as the general condition of the patient permits the operations should be continued. Some cases will not become quiescent until the recently diseased lung has been relaxed.

2. *Spread of Tuberculous Disease.*—A distinction should be made between reactivation of a pre-existing focus and the formation of new foci in apparently

normal lung. The former (Plate XXIII, Figs. 17-19) may be precipitated by an impairment of general resistance combined with increased mechanical strain after thoracoplasty; the latter are almost always due to the aspiration of infected material into normal bronchi and bronchioles (a bronchial embolus) where it initiates a tuberculous process. Sometimes this is preceded by an atelectatic process in the affected area, as one would expect from the pathogenesis. Likewise those with much sputum are more prone to develop a spread. Paradoxical movement of the chest wall and hyperventilation appear to be precipitating factors, and their prevention is therefore desirable as a prophylactic measure. Once the diagnosis is established small doses of gold should be administered, as we believe that it is at this early stage of the evolution of the disease that gold therapy has the most beneficial effect.

The majority resolve sufficiently to enable the operation to be completed, but it is necessary to emphasise that this should not be undertaken until the patient's general condition warrants it.

3. *Pneumonitis.*—Non-tuberculous areas of consolidation occur not infrequently, and at first are indistinguishable from tuberculous ones already described; the latter do not disappear rapidly as do the former. These areas are also probably the result of bronchial emboli, but in these tuberculous lesions do not develop. In many cases the causal organism is a pneumococcus or streptococcus, and these cases should be given drugs of the sulphonamide group after examination of the sputum to determine the predominating organism.

4. *Spontaneous Pneumothorax.*—This may appear on either side; it is far commoner in cases with bilateral disease, especially in the presence of a contralateral artificial pneumothorax. The reason for this probably is that a compensatory emphysematous process, often with the formation of bullæ, occurs in the vicinity of tuberculous lesions. After thoracoplasty increased respiratory efforts may be sufficient to rupture one of these bullæ. The importance of tuition in correct and efficient breathing and post-operative oxygen as preventive measures becomes obvious. The occurrence of a spontaneous pneumothorax may gravely imperil efficient respiration; aspiration of air from the pleural cavity is needed, and may be urgent. During this procedure the pressures should be carefully watched, and if there are signs of re-accumulation of air a needle should be left in the pleural cavity and connected to an under-water valvular seal until the bronchopleural fistula closes.

5. *Infection.*—Tuberculous or pyogenic infections may occur in the wound or the extra-fascial space. Unrecognised infection of the extra-fascial space often leads to serious wound infection as a secondary effect; but the reverse

is uncommon, as pus can more easily escape through the skin and the interposed muscles act as an effective barrier.

Any pronounced or prolonged post-operative pyrexia should require investigation, consisting of careful examination of the entire wound and clinical and radiological examination of the lungs. The usual causes of such pyrexia are (1) pulmonary, (2) wound infection, or (3) infection of the extra-fascial space.

Pulmonary causes of temperature should be revealed by radiological and clinical examination, whilst wound infection will, of course, be seen during inspection. In cases of infection of the extra-fascial space radiographs will show a ballooning of this space, and the appearance of this should always arouse suspicion of infection.

The usual causes of ballooning of the extra-fascial space may be briefly mentioned here. They are: (1) infection, (2) hæmorrhage, (3) serous exudation. When discovered, a sample of fluid should be removed without delay by aspirating either high up in the axilla or 1 to 2 inches below the clavicle in the mid-clavicular line; the fluid should be examined immediately by direct smear and cultures made as well. In the early stages of all three conditions the fluid removed will be blood-stained. In the infected group this blood will contain organisms but little pus at first. In uncomplicated hæmorrhage the fluid is almost pure blood (this condition will be considered in detail later). The third group with serous exudation will reveal only slightly blood-stained, uninfected fluid; this is an excessively rare condition, and has been seen only once in our total experience. In this case massive serous exudation into the extra-fascial space occurred after each of three stages of the operation, and on two occasions the fluid burst through the wound posteriorly. Infection fortunately did not appear and the patient made steady progress.

As already stated, infection may be either tuberculous or pyogenic; it may arise from external contamination of the wound during operation, or more commonly from the lung or endothoracic fascia and lymphatics which are divided or damaged during mobilisation (this latter factor is of great importance in the pyo-pneumothoraces where the extra-pleural lymphatics are often infected; in these cases we have ceased to mobilise the apex for this reason).

(*a*) *Pyogenic infection of the extra-fascial space* is a rare condition occurring usually after the first stage of the operation. Pyrexia, sometimes with rigors, occurring within a few days of the operation is the first manifestation. A fullness in the subclavicular region and high up in the axilla may occur, whilst radiologically ballooning of the extra-fascial space is seen. It should be emphasised that at this early stage the classical signs of infection are not

observed. If unrecognised or untreated the subclavicular fullness and axillary swelling increase in size, and become red and tender; eventually the infected material bursts through the wound posteriorly and the whole subscapular region becomes grossly infected. This is a dangerous situation, and even should survival occur permanent sinuses will probably remain, and the resultant rigidity of the walls of the space will later defy all attempts at closure.

When infection is suspected the extra-fascial space should be explored with a needle without delay, and if organisms are seen on direct smear drainage should be instituted immediately by a Malecot catheter inserted into the space through the upper axilla. In this way the posterior wound will remain uninfected and the second stage can be carried out without much delay, when, of course, care is taken not to open into the extra-fascial space. Access to the ribs will be greatly facilitated under these circumstances by carrying the anterior end of the incision up towards the axilla; the latissimus dorsi can now be cut across completely, and the scapular angle can be elevated enough to give access to the ribs. This avoids the necessity for reopening the upper part of the wound which lies over the space. In this way the scapula can be embedded at an early date and the space will undergo obliteration. Waiting too long before recognition of infection of the space leads to breaking down of the posterior wound, delay in the second stage, with rigidity of the walls of the space which will later defy all attempts at closure short of clavicular and scapular resection.

(*b*) *Tuberculous infections* are more insidious and less fulminating. Persistent unexplained pyrexia or a constant discharge from the wound is often explained by the finding of pus on exploring the extra-fascial space. Tuberculous are later in appearance than pyogenic infections, and may not become obvious for a week or more. Again radiological evidence of an unusually large or persistent collection of fluid and air in the extra-fascial space is a suggestive finding.

Treatment consists of repeated and complete aspiration of the extra-fascial space until the latter has obliterated. Further stages should not be delayed as they facilitate closure of the space.

(*c*) *Wound infection*, as already pointed out, may occur alone or in association with infection of the extra-fascial space. The latter has already been considered and emphasis laid on its prevention by early recognition and treatment of space infection. The former is more an annoying than serious complication, as it may delay further operative stages for several weeks and so reduce the chance of successful relaxation. The occurrence of infection is most probably due to the prolonged exposure at operation, and every endeavour should be made to keep the wound covered by flavine

packs during the operation. After operation the wound should be kept as dry as possible either with spirit dressings or sulphanilamide powder; a moist wound favours infection around the stitches.

6. *Hæmorrhage into the Extra-fascial Space.*—This, again, is an uncommon complication, but its recognition is important as correct treatment will prevent serious consequences. Bleeding may occur at any time during the first few post-operative days. The first sign may be an acute circulatory collapse or syncopal attack occurring when the compensatory mechanisms can no longer maintain an efficient circulation. The occurrence of such an attack should always suggest this complication.

Signs of acute blood loss may be present. Locally, evidence of bleeding is revealed by bulging of the de-costalised area of chest wall below the clavicle. Radiologically the normal air-containing extra-fascial space is seen to have been replaced by opaque material and the air now occupies the muscle planes in the neck and shoulders. Fluid levels may not be seen as the blood has usually clotted. Within a day or so, if untreated, blood seeps down through the muscle planes and discharges through the wound. Infection of the extra-fascial space via the wound is inevitable unless measures are taken to prevent it. Treatment at first should aim at maintaining the circulation with adequate fluids and transfusions. A wide-bore needle should then be introduced into the extra-fascial space and as much blood aspirated as possible. In some instances the blood will already have clotted and little will be obtained by aspiration. Within a day or so in these latter cases, the patient should be taken to the theatre and the posterior portion of the wound reopened, the scapula elevated and the extra-fascial space cleared of clot; bleeding points are not usually located. When all clot and debris are removed the space should be washed out with a solution of flavine and the wound then closed completely. Complete removal of clot and blood from the extra-fascial space prevents seepage downwards through the muscle planes to the wound and avoids inevitable infection of the space via the wound. Prevention of gross infection by early recognition and adequate treatment along the lines above is very important; once developed, infection will lead to permanent sinuses and may prevent any further operative stages.

## Conclusions

1. Apical mobilisation in association with thoracoplasty is the best method at present in use for closing apical pulmonary cavities for which other and simpler forms of relaxation therapy are not applicable or have failed. The choice of patients and their pre-operative preparation are

discussed; and the operative technique, post-operative management and complications are described.

2. An extra-fascial mobilisation is the best way of releasing the apex, because the risk of damaging the lung is less, and apical relaxation is maintained better than after an extra-pleural mobilisation.

3. Any method of relaxation should essentially include the area of the draining bronchi in addition to the cavitated region.

4. Increased mobilisation at the first stage, achieved by modifying the original Semb operation, increases the expectation of closing apical cavities.

5. Patients who carry a poor risk require small rib resections with mobilisation at each stage.

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# TREATMENT OF INTESTINAL TUBERCULOSIS BY PNEUMOPERITONEUM

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TUBERCULOUS ulceration of the intestines, due to the swallowing of infected sputum, is a common complication of pulmonary tuberculosis. It was formerly thought to be always fatal, but recognition in its earlier stages, together with more varied and more resolute treatment, now enables a more favourable prognosis to be given.

It will be referred to here as intestinal tuberculosis.

## Diagnosis of Intestinal Tuberculosis.

Although proved cases may be entirely symptomless during life (Crawford and Sawyer [1934]; Salkin [1939]), it can usually be diagnosed clinically, the most important point being careful history-taking. Accord-