THE MANAGEMENT OF RESECTION OPERATIONS FOR PULMONARY TUBERCULOSIS*

AZMY R. BOUTROS, M.B., D.A., F.F.A.R.C.S.†

SINCE THE INTRODUCTION of effective antimicrobial agents in the management of pulmonary tuberculosis, our approach to this subject has undergone drastic changes. Before the use of these agents, surgery was embarked upon as a last effort to save a tuberculous patient's life, by closing or removing a cavity, and inevitably resulted in high mortality and morbidity rates. Resection operations, in particular, were extremely hazardous and very rarely, if ever, done.[1] This was partly due to the surgical techniques used in these cases at that time, and partly because the majority of these patients were too ill to be suitable for thoracoplasty. A series of resections by Thornton and Adams in 1942 showed a mortality rate of 45 per cent for pneumonectomies and 25 per cent for lobectomies.[2] However, with the advent of antimicrobial drugs, and the great improvement in surgical and anaesthetic techniques, there was a tremendous improvement in the outcome of resection operations, which were actually done on a correct basis for the first time. A series of 238 patients undergoing resection operations at the Midhurst Sanatorium in Britain, and described by Todd in 1956, showed no operative or immediate postoperative mortality.

Generally speaking, the indications for pulmonary resection operations at the present time include most patients for whom thoracoplasty would have been the operation of choice in the past, and patients with some residual disease who were previously often considered well treated on a medical regimen alone.[3] Pulmonary resection operations are fairly major procedures, and a high degree of competence and alertness of surgeon, anaesthetist, and nursing staff, as well as a thorough understanding of the basic problems involved, are essential if consistently excellent results are to be expected.

Pulmonary resection operations comprise the following procedures: pneumonectomies, lobectomies, segmental resections, and subsegmental resections, or a combination of the last three. Anaesthetic management is essentially the same in all of these procedures, with minor variations in cases of pneumonectomies.

A. PREOPERATIVE MANAGEMENT

I. *Selection and Medical Preparation of Patients*

The medical and surgical teams are responsible for the preliminary investigations of the patients, including plain chest X-ray, tomography, bronchography, and bronchoscopy. They are also responsible for the selection of cases suitable for surgery as far as the disease is concerned, and for preparing the patient with

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†Assistant Professor, Department of Anaesthesia, University of Saskatchewan, and University Hospital, Saskatoon, Saskatchewan.

antimicrobial agents. However, the anaesthetist would be wise to inquire about the details of the medical regimen followed in each case, with an eye on the fact that most of the antimicrobial drugs used are not without some hepatotoxic or nephrotoxic effects, though they are usually mild and unimportant.

Postural drainage, in wet lung cases, should be carried out in an effort to make the lungs as dry as possible. Physiotherapy and breathing exercises are extremely important. Briefly, these consist of training the patient to do unilateral and bilateral thoracic expansion, diaphragmatic breathing and coughing exercises, as well as shoulder exercises and body alignment.[4] It must be emphasized that the optimum time to start these exercises is about one week before the operation and not postoperatively. Patients are not ready to co-operate if faced with physiotherapy for the first time when they are suffering from postoperative pain.

II. *Preoperative Assessment of the Patient by the Anaesthetist*

A favourable outcome of pulmonary resection operations is very much dependent on attention to details. Generally speaking, the medical staff in sanatoria are mainly concerned with treating the pulmonary lesion itself. Thus it is up to the anaesthetist and the surgical team to satisfy themselves as regards the fitness and preoperative condition of the patient. The following routine is suggested:

1. A thorough history and general physical examination.
2. Routine urine analysis, haemoglobin content, and blood count.
3. Routine E.C.G. on all patients over the age of 40 and whenever there is any reason to suspect the presence of cardiovascular abnormalities in the younger age group.
4. Renal and hepatic function tests whenever there is any question of the kidneys or liver being damaged.
5. Pulmonary function tests. Assessment of pulmonary function should be carried out on every case. The type of work the patient can do and his response to moderate exercise can be significant. Our patients are put through a standard exercise tolerance test which is very helpful in assessing their cardiorespiratory function. Routine estimations of maximal breathing capacity, vital capacity, and timed vital capacity, as well as bronchospirometry, for every case, are insisted upon in many centres. There should be no hesitation in performing these tests whenever there is the slightest doubt about the patient's pulmonary function, and in patients who are having repeat pulmonary resections on the same or the other lung.

Measurement of the pCO_2, pO_2, pH, and serum bicarbonate levels can be extremely valuable in assessing the patient's pulmonary function preoperatively and in the follow-up period postoperatively, particularly if some degree of pulmonary emphysema exists. A high pCO_2 preoperatively should be corrected before attempting any resection procedure; otherwise it is more than likely that the patient will develop carbon dioxide narcosis postoperatively, thus making the prognosis very unfavourable.

6. The anaesthetist should visit the patient prior to the day of the operation and again re-emphasize the importance of breathing exercises. If the patient

is suspected of having a labile cardiovascular system due to age or other causes, he should be put in the position he is going to assume on the operating table (prone, lateral, etc.) and the effects on blood pressure and pulse noted.

7. The patient's blood should be typed and a minimum of six units of donor blood cross-matched for him. Obviously, not all patients require that much blood during surgery. On the other hand, the massive bleeding and oozing that are liable to occur at any time during the operation more than justify this extravagance.

III. *Premedication*

The suggested premedication for an adult male of average weight is as follows. Pentobarbital, 100 mg. is given the night before the operation. This dose is repeated 90 minutes before induction and is followed by meperidine, 100 mg., and atropine, 0.6 mg., 30 minutes later. The use of quinidine preoperatively, as a prophylactic measure against cardiac arrhythmias, was advocated some time ago,[5] but there is hardly any justification for its use nowadays.

B. Operative Management

Apart from the problem of an open chest, which is common to all types of thoracotomies, pulmonary resection operations for pulmonary tuberculosis present certain other problems and risks. Though most of these problems may also be encountered in other types of thoracotomies, they are especially significant in these patients.

I. *Excessive Secretions*

Theoretically speaking, patients scheduled for pulmonary resections should be dry. Sometimes, however, this is very difficult to achieve, no matter how energetic the preoperative medical and physical treatment, and, even when the patient is dry preoperatively, he is still liable to get excessive secretions in his tracheobronchial tree when the diseased lung is manipulated.

The dangers of excessive secretions are as follows:

1. Contamination of, and spread of infection to, healthy lung tissue. This can occur even if the patient's sputum was negative for tubercle bacilli preoperatively. Manipulation of the diseased area of the lung can set free active bacilli which were hitherto encapsulated.

2. Mechanical obstruction of small bronchioles. This can be caused by a surprisingly small amount of tenacious secretions or clotted blood and leads to areas of collapse or foci of infection in the lungs. This can mean the difference between a stormy, complicated postoperative period and a smooth, uneventful recovery. Large volumes of secretions and blood usually lead to more acute obstructive manifestations and interference with the adequate ventilation of the patient. Death from asphyxiation may occur if the condition is not corrected without delay.

3. Harmful reflexes may be precipitated by the presence of excessive secretions in the tracheobronchial tree.

Excessive secretions can be dealt with as follows:

1. Proper selection and preoperative preparation of patients.

2. Correct positioning of patients on the operating table. It is the author's opinion that the prone or Parry Brown position[6] is the best from the point of view of proper drainage of excessive secretions, provided that the surgeon does not object to a posterior approach. The only disadvantage ascribed to this position was the sudden cardiovascular collapse that occurred in some patients with limited cardiorespiratory reserve when they were turned face down.[3] However, we found that if the patient is allowed to remain in the supine position, after induction of anaesthesia, until his blood pressure starts to rise again, following the usual transitory hypotension caused by the induction, turning him onto his face very seldom produces any untoward effects. A patient whose cardiorespiratory reserve is so poor that the adoption of the prone position is contraindicated is probably not fit for a pulmonary resection operation, which is, after all, an elective procedure.

3. Suction. Effective tracheobronchial suctioning is one of the most reliable measures for getting rid of excessive secretions. It should be done on a routine basis every so many minutes, and not only if the anaesthetist suspects the presence of excessive secretions. Certain details are worth mentioning here:

(*a*) To avoid pushing any existing secretions distally into the smaller bronchioles and alveoli and thus making them difficult to reach, suctioning should be performed prior to inflating the lungs. It must also be emphasized that suctioning should be repeated after inflating the lungs. Vigorous inflation of the diseased lung after it has been collapsed by the surgeon for 15 to 20 minutes is liable to dislodge a fair amount of secretion. This should be dealt with immediately.

(*b*) The inflated cuff of an endotracheal tube may compress the lumen of the tube enough to make it impossible for the suction catheter to be introduced properly. This occurs rather often with portex endotracheal tubes, as they tend to be softened by the body heat. The anaesthetist may think that the patient is dry when, in fact, his suction catheter is halted at the level of the cuff, leaving a pool of secretion just distal to its tip. It is always advisable to measure the length of the suction tube necessary to allow its tip to emerge from the lower end of the endotracheal tube prior to the induction of anaesthesia, and there should be no hesitation in deflating the cuff just before suctioning is contemplated if there is any possibility that it is compressing the endotracheal tube.

(*c*) More vigilant suctioning is required whenever a fair-sized bronchus has been opened, as this may allow blood to seep into the bronchial tree from the operative field.

(*d*) At the end of the operation the tracheobronchial tree should be thoroughly sucked out and cleaned. The patient should be reconnected to the anaesthetic machine and allowed to breath pure oxygen for a few minutes after every suctioning. The practice of leaving the suction catheter inside the endotracheal tube while the patient is being extubated cannot be too strongly condemned. This can leave the lungs dangerously empty of oxygen or air, particularly if the patient holds his breath immediately after extubation.

(*e*) It must be realized that suction is not the complete answer to the problem of excessive secretions. No amount of suctioning can remove secretions from the segmental bronchi or, indeed, the smaller lobar bronchi, and it is unwise to rely completely on suctioning while neglecting other measures.

3. Early recovery of consciousness and an active cough reflex is, in our experience, the most important safeguard against the possibility of secretions producing postoperative pulmonary collapse or infection. It is our practice to have the patient coughing a few minutes after the wound is covered. The anaesthetic technique should be tailored to ensure such an outcome in every case. It is not enough to have the patient responding to painful stimuli or just barely blinking his eyes. He should be able to hear, understand, and obey the anaesthetist's commands to cough and breathe deeply.

4. Occasionally, the use of a one-lung anaesthesia technique may be advisable in the case of a pneumonectomy. As a rule, only the left bronchus is used for instrumentation—i.e., a blocker in the left bronchus for a left pneumonectomy and an endobronchial tube in the left bronchus for a right pneumonectomy. It is the author's opinion, however, that the use of blockers, Carlen's tubes, and ordinary endobronchial tubes for one-lung anaesthesia is rather unsatisfactory and mostly unnecessary. If one is forced to use the one-lung technique, the Macintosh-Letherdale series of tubes is probably the most satisfactory.[7]

5. Immediate postoperative bronchoscopy. This is practised as a routine in many centres to ensure a thorough tracheobronchial toilet. However, in our experience, we find that the need for bronchoscopy very seldom arises, as most of the patients are coughing vigorously at the end of the operation. Apart from this, a bronchoscopy performed at the end of a major operation would be an extra burden on the cardiorespiratory functions entailing an unnecessary prolongation of anaesthesia, and consequently delaying the onset of an efficient cough reflex.

II. *Blood Loss and Blood Replacement*

By and large, excessive bleeding during pulmonary resections may occur during the separation of massive pleural adhesions, during the hilar dissection of distorted, fibrosed segments or lobes, or if a large vessel is inadvertently opened during the course of the operation. Certain measures should be taken to avoid, or at least minimize, the harmful and often disastrous effects of blood loss:

1. Patients who have a haemoglobin content of less than 11-12 gm. per cent should not be operated upon until this anaemia has been corrected.

2. Two intravenous drips should be a routine in every case. They should be secure, and at least one of them should have a 15 or 16 gauge needle, while the other should have not less than an 18 gauge needle. Blood transfusion should be started when the skin incision is made.

3. It is always wise to be about 250–300 cc. ahead of the blood loss at all times. The only exceptions to this rule are cases undergoing pneumonectomies, where it is advisable to be 500 cc. of blood behind the loss the patient has incurred. This is to avoid straining the right heart, which is already overworked from the loss of half of the pulmonary vascular bed. Occasionally, when the

patient is losing blood rapidly, the anaesthetist should order extra blood when the second or third unit of blood has been given, to allow for the time required for cross-matching, so that by the time the sixth unit has been used, the new supply of blood is available.

4. The value of giving one gram of calcium for every three or four units of blood is dubious, particularly in view of the fact that a large number of anaesthetists use calcium gluconate, which is a very weak source of calcium ions. They seem to feel that if this does not do any good, at least it will not harm the patient. However, a number of workers in this field believe that calcium injections can be actually harmful to the patient, particularly if, owing to the rapid transfusion of large amounts of cold stored blood, the heart is colder than normal.[8]

5. The use of cautery and diathermy by the surgeon is extremely helpful in reducing the blood loss and the operative time. There is no doubt that the majority of modern thoracic surgeons now realize the advantages of cautery and diathermy, and prefer to use them. The anaesthetist should not try to dissuade the surgeon from doing so for the sole purpose of using an explosive anaesthetic agent; rather, he should be proficient in the use of non-explosive techniques.

III. *Pattern of Ventilation*

The success of any major surgery depends to a great extent on the co-operation and understanding between the members of the surgical and anaesthetic teams. This is particularly true in pulmonary surgery. By virtue of his control over the patient's breathing and the movements of his lungs, the anaesthetist can create havoc in the operative field. Conversely, he can be of great help to the surgeon, particularly during delicate dissections of which pulmonary resection operations have more than their fair share. The anaesthetist must, therefore, vary the pattern of ventilation from time to time to produce optimal working conditions for the surgeon. On the other hand, he should insist on a period of vigorous ventilation at least once every 15 minutes, or whenever the patient shows signs of hypoventilation. Air leaks due to an opened bronchus are usually easily controlled by increasing the rate of flow of the anaesthetic gases. Furthermore, the leak is usually controlled quickly by the surgeon. Occasionally, the leak is massive and very difficult to block. This can be worrying to the anaesthetist because, apart from poor ventilation of the lungs, these leaks may allow blood and secretions to gain access to the tracheobronchial tree. It is the duty of the anaesthetist to inform the surgeon of such a situation without delay. Although packing the area with swabs usually controls the leak partially, occasionally the surgeon is forced to apply a clamp on the hilum of the whole lung. This, obviously, will control the leak very effectively, but the anaesthetist should be well aware of the effects on the right side of the heart of sudden interruption of blood flow to a whole lung, particularly as the patient is usually slightly overtransfused, as already mentioned. Needless to say, acute right-sided heart failure could result.

Reinflation of a collapsed lung is best achieved by maintaining a moderate positive pressure on the anaesthetic bag for a fairly long period (about 5–10

seconds). This is much more effective in opening up the alveoli and small bronchiolar passages than the use of excessively high pressures for a short period.

IV. *Dangers of Contamination and Infection*

The anaesthetist is continuously having his hands contaminated by the patient's saliva and secretions. There is also the possibility of the patient coughing during intubation or emergence from anaesthesia. Though the majority of these patients have negative sputum preoperatively, it is unwise to assume that the secretions sucked out during and after the operation are free from active tubercle bacilli. As already mentioned, manipulation of the lesion in the lung may free some active organisms. It is thus much safer to consider every case a potentially infective one and take all the necessary precautions.

V. *Sample Anaesthetic Technique*

The technique used by the author at the Saskatoon Sanatorium is as follows. After induction with a relatively small dose of thiopental (200–250 mg. for an adult male) and 30 mg. of *d*-tubocurare, the patient's larynx and trachea are sprayed with a topical anaesthetic solution and intubation is performed. Anaesthesia is then maintained with nitrous oxide/oxygen and smaller increments of the relaxant. Small doses of meperidine intravenously are used occasionally. The lungs are ventilated manually using a semi-closed circle with carbon dioxide absorption. When the surgeon starts to close the skin incision, the nitrous oxide is turned off and the patient ventilated with 100 per cent oxygen. Atropine 0.8–1.0 mg. is given intravenously in two divided doses. By the end of the operation the patient is fully conscious and breathing spontaneously, yet Neostigmine 0.5–1.5 mg. is given without hesitation if there is any doubt that there is even a slight degree of residual curarization or interference with an effective cough reflex. This technique has proved very satisfactory and has resulted in excellent and smooth postoperative periods. A statistical survey of our results will be published at a later date.

C. Postoperative Management

The postoperative care of a patient after pulmonary resection is the responsibility of the surgeon, anaesthetist, and recovery room nurse. The role of the anaesthetist in the early postoperative period is mainly to ensure adequate ventilation.

Smith *et al.*,[9] measuring the vital capacity, timed vital capacity, and oxygen saturation in post-thoracotomy patients, reached the following conclusions. The vital capacity was decreased to an average of 50 per cent of the preoperative levels in all thoracotomy cases, despite the fact that, clinically, they seemed to be doing well. The timed vital capacity showed little change from preoperative levels, indicating that the lowering of the vital capacity was due to restrictive, rather than obstructive, interference with breathing. The average oxygen saturation reached a low of 2–3 per cent below preoperative levels on the second and third postoperative days.

From the above findings, it is obvious that the ventilation of patients during the first few days after thoracotomies is, to say the least, precarious, and that these patients are probably ventilating at their maximum breathing capacity level all the time. Thus, every effort should be made to avoid or correct any added embarrassment to breathing. Proper expansion of the lungs is of prime importance. This can be achieved, in most cases, by breathing exercises and coughing. Patency of the chest drainage tubes is also important, and there should be no hesitation in inserting another tube if the pre-existing tubes are either blocked or not sufficient for adequate drainage. Negative pressure (up to 30 mm. Hg) applied to the underwater seal helps to expand the lung, and is used routinely on our patients. Relief of pain with liberal doses of narcotics enables the patient to expand his chest to a greater extent, leading to marked improvement of ventilation, particularly when a small dose of levallorphan is given with the narcotic drug. The use of steroids postoperatively has been advocated by Sealy *et al.*[10] They claim that steroids prevent the development of bronchiolar spasm, which can be dangerous in post-thoracotomy patients.

Postoperative Tracheostomy

Patients who are unable or unwilling to cough, and patients with pre-existing pulmonary disease, such as emphysema, who have border-line pulmonary function, are very liable to develop postoperative pulmonary complications, leading to severe respiratory insufficiency. Such patients should have a tracheostomy performed as soon as the operation on the chest is finished. Mechanically assisted ventilation should be instituted without delay if the patient shows any signs of respiratory inadequacy. Occasionally, the use of continuous epidural analgesia and automatic ventilation may be necessary to ensure adequate relief of pain and the co-operation of the patient, as well as to prevent the development of bronchospasm, and to counteract depression when narcotics are used to alleviate pain.[11]

D. Decontamination and Cleaning of Anaesthetic Equipment

The routine followed in our Sanatorium is as follows:

1. All tubes and equipment are soaked in Wescodyne® solution for 3–5 minutes. Cuffs of endotracheal tubes are soaked for 15 minutes. Wescodyne's formula consists of an iodine complexed with certain types of surface-active agents that have detergent properties. It is claimed to be capable of killing tubercle bacilli within 10 minutes.
2. All articles, except rubber cuffs of endotracheal tubes, are then boiled for 10–15 minutes.

Summary

The management of resection operations for pulmonary tuberculosis is discussed under the following headings:

1. Preoperative management including the selection and medical preparation of the patient, preoperative assessment, and premedication.

2. Operative management with particular emphasis on the various problems encountered in these cases, such as excessive secretions, blood loss and blood replacement, pattern of ventilation, and the dangers of contamination. A sample anaesthetic technique is also described.
3. Postoperative management and postoperative tracheostomy.
4. Decontamination and cleaning of anaesthetic equipment.

Résumé

De façon générale, la résection pulmonaire est indiquée, chez les tuberculeux, dans les deux cas suivants: ou bien pour enlever un reliquat de tuberculose chez un malade que, souvent, autrefois, on aurait traité médicalement, ou bien, lorsque l'opération de choix, dans le passé, aurait été la thoracoplastie. Les opérations se pratiquent pour enlever une cavité ou un foyer persistant d'infection; elles comprennent les techniques suivantes: pneumonectomies, lobectomies, résections segmentaire ou sous-segmentaire, ou une combinaison des trois dernières techniques.

Bien que les équipes médicale et chirurgicale soient responsables des études préparatoires et du choix des malades, il serait sage que l'anesthésiologiste s'enquiert des détails du traitement médical suivi dans chaque cas, tout en se rappelant que la plupart des médicaments antimicrobiens ne sont pas sans effets toxiques sur le foie ou le rein. On doit assécher les poumons le mieux possible par un drainage postural. La physiothérapie et les exercices respiratoires sont très importants, et l'on doit souligner que le temps le plus avantageux pour commencer ces exercices est d'environ une semaine avant l'opération, et non après.

En plus d'une histoire et d'un examen physique complet du cas, l'évaluation de la fonction pulmonaire doit se faire dans chaque cas. Les pCO_2, pO_2, pH et le taux des bicarbonates dans le sérum sont extrêmement précieux avant et après l'opération.

L'auteur recommande que ces malades soient assurés d'au moins six bouteilles de sang, et que l'on commence les transfusions dès le début de l'opération, de façon à maintenir une avance de 250 à 300 cc. sur le sang perdu.

Chez ces malades, des sécrétions trop abondantes posent un problème, et peuvent provoquer la contamination du tissu pulmonaire sain et la dissémination de l'infection à ce même tissu; ces sécrétions peuvent aussi provoquer de l'obstruction mécanique des bronches et des bronchioles, et elles risquent de provoquer des reflexes dangereux.

L'accumulation de sécrétions doit être aspirée immédiatement et de façon efficace par le tube endotrachéal, et on doit redoubler de vigilance. Les sécrétions doivent être aspirées avant de ré-insuffler le poumon; à la fin de l'intervention, on doit prendre soin de bien nettoyer l'arbre trachéo-bronchique. Un réveil rapide et un reflexe de toux sont la plus sûre protection contre un collapsus ou une infection pulmonaire post-opératoire secondaires à des sécrétions. Les malades incapables de tousser, on qui ne le veulent pas, et les porteurs d'une maladie pulmonaire persistante, par exemple: l'emphysème avec une fonction

pulmonaire à la limite inférieure de la normale, devraient être trachéotomisés dès la fin de l'opération.

L'anesthésiologiste doit se souvenir que, malgré des analyses négatives d'expectorations, il n'est pas sage de présumer que les sécrétions manipulées durant l'opération soient exemptes de bacilles tuberculeux actifs. On doit prendre des précautions pour éviter la contamination et l'infection des membres du personnel de l'anesthésie; les appareils d'anesthésie doivent être décontaminés à la fin de l'opération. L'auteur suggère une méthode courante pour nettoyer les instruments d'anesthésie.

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