ANAESTHETIC TECHNIQUES IN THORACIC SURGERY*

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THORACIC SURGICAL ANAESTHESIA excels in its many opportunities for the clear and dramatic demonstration of applied physiology and pharmacology and the versatility of the anaesthetist. In this field, the anaesthetist can best fulfil his obligations to the patient and the surgeon only if he knows the physiopathology of his patient and the applied pharmacology of the anaesthetic agents used. There is no one technique of anaesthesia, or one anaesthetic agent suitable for all thoracic procedures. In this paper, the choice of the anaesthetic agents and techniques for thoracic surgery will be discussed, and problems of thoracic anaesthesia and technical solutions will be reviewed. Finally, practical personal considerations on anaesthesia for thoracic surgery will be presented at the conclusion of the paper.

I. CHOICE OF THE ANAESTHETIC AGENTS AND TECHNIQUES FOR THORACIC SURGERY

Let me point out immediately that for thoracic surgery, except for minor cases such as drainage of the pleural cavity, our preference is for general anaesthesia with endotracheal or endobronchial intubation (this intubation might be done under transtracheal block on poor-risk patients, e.g., those with bronchopleural fistula). The tracheal or bronchial catheter allows a free airway and rapid inflation of the lungs, which might be very important in the occurrence of cardiac arrest; and general anaesthesia, in contrast to the high spinal or epidural, maintains the patient's compensative mechanisms.[1] After an extensive clinical experience with a variety of anaesthetic agents and techniques (ether anaesthesia, balanced anaesthesia, poteniated anaesthesia, pharmacologic hibernation, a controlled hypotension, and steroid anaesthesia), light halothane-ether anaesthesia has proved to be our agent and technique of choice for thoracic surgery. In adults, induction of anaesthesia is generally carried out with a little barbiturate; but in children and in poor-risk patients halothane-ether only is given by inhalation. If required, succinylcholine is administered for relaxation. We have already indicated in previous papers our great satisfaction with the halothane-ether azeotrope for anaesthesia both for pulmonary[2] and cardiac[3] surgery, for the following reasons:

1. Safety of the mixture from the cardiorespiratory aspect.
2. Practicability of this technique of anaesthesia.
3. Successful clinical experience with it in thoracic surgery.

1. *Safety of the Mixture*

(*a*) *From the respiratory viewpoint* a 1.5 per cent inhaled vapour concentration suffices to maintain anaesthesia. Consequently, in thoracic surgery, where one nearly always encounters some difficulty with oxygenation, the azeotropic

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mixture permits a more than satisfactory oxygen saturation. Moreover the bronchodilatator effect improves our patients' ventilation, which is so often reduced with respiratory disease. In our series of cases, no patient showed any serious anoxia or even hypoxia during surgery. In summarizing, let us say that with halothane-ether no respiratory difficulty occurs, whereas halothane alone reduces the respiratory minute rate. Postoperatively, atelectasis is reduced to a minimum.

(*b*) *From the cardiovascular viewpoint.* After sufficient experience on dogs and clinical experience on humans with the azeotrope, we believe, as many other authors do, that circulatory dynamics and cardiac arrhythmias do not present the same problems as with halothane anaesthesia alone. As Dobkin pointed out: "Halothane has a characteristic action on the heart and circulation which in man lies closer to chloroform than to cyclopropane when used in the concentration required for surgical anaesthesia (0.5 to 1.0 per cent)." Blood pressure depression is proportional to the rate and concentration administered. In less than 1 per cent concentration, severe hypotension can usually be avoided. During maintenance of anaesthesia, blood pressure rises somewhat above the induction level, but remains below the normal control level. Hypotension is more likely to occur with muscle relaxants such as *d*-tubocurarine. Pulse rate is usually lowered. Ventricular force is reduced as the depth of anaesthesia is increased. The slight reduction in peripheral resistance and marked reduction in myocardial power result in a fall in cardiac output, myocardial irritability, and predominant vagal effect on the heart. Arrhythmias may occur during rapid induction and during deep anaesthesia. In experiments on dogs, ventricular fibrillation is easily produced during light halothane anaesthesia if epinephrine is injected.

The effect of halothane on the heart is reduced significantly when the halothane-ether azeotrope is used. Blood pressure is less affected, there is less tendency to slowing of the pulse rate, and the hypotensive response to *d*-tubocurarine is not seen as frequently. Cardiac output does not fall as rapidly with increases of the depth of anaesthesia. Myocardial irritability is also less with the mixture than with halothane alone. Little myocardial depression is seen when less than 1.5 per cent of the mixture is used. Fatal ventricular fibrillation was induced by epinephrine very readily with 0.5 per cent halothane but not with the 1 per cent halothane-ether azeotrope.

2. *Practicability of This Technique of Anaesthesia*

A good reason for our satisfaction with the halothane-ether azeotrope in anaesthesia for thoracic surgery is its cardiorespiratory safety. Moreover, since halothane renders the mixture non-flammable, the use of the electric cautery or bistoury is facilitated, a tremendous advantage in thoracic surgery. Consequently, this method is essentially practical.

3. *Successful Clinical Experience in Thoracic Surgery*

This method of anaesthesia for thoracic surgery has been used successfully in more than 800 cases in our hospital; however, as we said before, there is no one anaesthetic agent or one technique of anaesthesia suitable for all thoracic procedures, and we still believe that different techniques and agents might success-

fully be used in thoracic anaesthesia. All we can say now is that in our hands this halothane-ether technique has given us our best results so far. More details on the application of this technique will be given at the conclusion of this paper where our personal practical considerations will be presented as a "daily practice in thoracic anaesthesia."

II. General Problems of Thoracic Anaesthesia[4,5,6]

Generally speaking, the thoracic surgical patient brings with him many cardiopulmonary disturbances. During the preoperative period, complete evaluation of pulmonary function, cardiac reserve, and blood volume is imperative. Recent advances in the surgical treatment of disease of the pulmonary and cardiovascular systems demand a deeper understanding of the function of these systems. Surgical treatment is being currently advocated for patients in whom respiratory and cardiac function are borderline. These patients' reserves should be accurately evaluated. In our opinion, the anaesthetist must know the normal data of the major cardiopulmonary function tests before surgery. Clinical assessment of cardiopulmonary function might also be done from the history and physical examination of the patient. According to the classification of "Baldwin," total pulmonary function studies may be evaluated by mechanical tests which consider the lungs as bellows, and by alveolar respiratory tests which are concerned with the quantity and quality of gas exchange at the inspiratory alveolar, capillary, and tissue levels. *The mechanical* tests are either *static in type* (for vital capacity, inspiratory capacity, tidal volume, expiratory reserve volume, residual volume, functional residual capacity, total lung capacity = RV/TLC $\times$ 100 = normal) or *dynamic* (for walking ventilation, progressive work in treadmill, maximum breathing capacity, timed vital capacity). *The alveolar respiratory tests* include tests for *intrapulmonary gas mixing* (e.g., helium closed-circuit diffusion tests, diffusing capacity O_2), and *arterial blood studies* (eg., O_2 tension). *Bronchospirometry* gives us information on the function of the individual lungs. We consider these tests essential when a total resection of the lung is proposed. For the evaluation of cardiac reserves. The *venous pressure* and *circulation time* are two very helpful tests. Venous pressure is a criterion of the function of the right ventricle (N = 2 to 10 cm H_2O). The circulation time is the estimation of the degree of decompensation in any heart disease, especially in left ventricular failure (N = 8 to 12 seconds). The higher the figure the greater is the degree of decompensation. *Electrocardiogram tracings* are taken before and after exercise. When doubt exists as to the evaluation of the impairment of cardiac function, this can be determined by the use of a treadmill or "stair steps" exercise. It is important to know the duration of time that exercise can be sustained, and the changes in arterial blood pressure and electrocardiogram tracings. If the patient shows depression of the sensorium, this sign should be interpreted as evidence of cerebral hypoxia. If the patient develops hypotension or paroxysmal ventricular tachycardia, these are signs of impaired cardiac function. Where it may be done, *cardiac output determination* at rest and after exercise certainly provides good information (N = 3–3.5 L./min./m.^{2} of surface area). On the other hand, we must never forget the importance of clinical infor-

mation contained in the history of the patient: degree of dyspnoea, excessive fatigue, palpitations, anginal pain, etc. This clinical information is available to every anaesthetist and there is no need for specialized laboratories and personnel. It has been reported that many thoracic surgical patients (e.g., tuberculous patients) show reduction of blood volume. Some clinical signs may help in this field, but we like to rely on laboratory tests (e.g., isotopes or the dye dilution method). The weighing of the patient on an accurate scale immediately before and after surgery may also be of some interest for determination of alteration in blood volume.

III. Solutions of These Problems

1. *Preoperative Treatment of Cardiopulmonary Disturbances*[7,8]

In the light of all the studies mentioned above, we are able preoperatively to correct deficiencies and prevent complications as far as this is feasible. Pulmonary insufficiency is treated by respiratory exercise under the supervision of a trained physiotherapist. Patients are taught how to breathe and cough. Emphysematous patients are given intermittent positive pressure with the Bird apparatus and aminophyllin, which is mainly helpful when there is an elevation of the venous pressure. Bronchodilators such as Vaponefrin, antibiotics, or detergents given in aerosol may be indicated both in obstructive endobronchial lesions and in bronchiectasis. If necessary, blood volume is restored to its normal value. Rest, low-salt diet, duretics, and digitalis are the most specific treatment for cardiac failure.

In addition to these cardiopulmonary disturbances, the thoracic surgical patient carries with him on the operating table, in various degrees, numerous alterations and hazards of his cardiorespiratory physiopathology[9] associated with any thoracic injury[10]: anoxia, hypercarbia, paradoxical breathing, mediastinal shift, tachycardia obstruction of vena cavae, hypotension, reduction of cardiac output, vago-vagal reflexes, heat loss, blood loss, secretion problems, spread of the disease in tuberculous patients, for example.

2. *Preoperative Treatment of Alterations and Hazards of Open Pneumothorax*

The following are recommended:

(*a*) Light plane of anaesthesia with high oxygen tension.

(*b*) Adequate ventilation with controlled respiration with a mechanical device (e.g., Bird mark 4 respirator is recommended). The Radford nomogram[11] for predicting the optimal tidal volume from the breathing frequency, body weight, and sex of the patient is useful.

(*c*) The use of face-down posture in the few wet cases where bronchial intubation is not feasible because of modified anatomy of the tracheobronchial tree.

(*d*) Adequate control of temperature by the use of a special mattress on the table in connection with the Thermorite apparatus.

(*e*) Complete replacement of blood loss by accurate weighing of sponges and measurement of drainage bottles.

(*f*) Ready removal of secretions when dealing with the tuberculosis patient where bronchogenic spread may occur.

IV. Specific Problems of Thoracic Anaesthesia

General problems of thoracic anaesthesia are now reviewed and solutions proposed. Specific problems are related to crushing injuries of the chest, cardiac surgery, mediastinal surgery, bronchopleural fistula, and paedriatric cases.

1. *Crushing Injuries of the Chest*[12,13,14]

The aims of the treatment are as follows:

(*a*) To ensure a free airway, evaluate breath sounds (atelectasis, retained secretions, pneumothorax), aspirate the trachea, if indicated by bronchoscopic aspiration; if prolonged unconsciousness, do tracheotomy immediately and ventilate the patient.

(*b*) To treat shock. It has been estimated that when more than 30 per cent of the volume of blood is lost rapidly and is not replaced immediately by transfusions, death usually occurs. If necessary, blood pressure is maintained with Levophed® or Aramine® solutions. Adequate fluid and electrolyte replacement is done by careful charting of fluid intake and output and frequent serum electrolyte assessment. The use of a gastric suction may decompress the gastrointestinal tract and avoid gastric dilatation.

(*c*) To drain the chest and reduce pneumothorax, large rubber or plastic tubes and electrical suction to water trap bottle must be employed.

(*d*) To immobilize fractured ribs, the chest is strapped with adhesive plaster.

(*e*) To control respiratory embarrassment, bronchospasm, and pain. (1) By *continuous* epidural analgesia in repeated doses (20 to 30 c.c. Pontocain 0.15 per cent solution) up to the third dorsal segment. (2) By *mechanical* assistance of the respiration (the "Bird" apparatus will deliver a mixture of 45 per cent ogygen and 55 per cent air with adequate humidification). N.B.: repeated estimations of pO_2 — pCO_2, pH, and serum bicarbonate are indicated for assessment of adequate ventilation. (3) By *frequent bronchial toilet*, doing tracheal and bronchial suction frequently and changing the tracheostomy tube.

2. *Cardiac Surgery*[15]

We consider that two steps are necessary before anaesthesia in a cardiac surgical patient, when the surgery involves treatment of the cardiac lesion itself. These are evaluation and preoperative care of the patient.

A. *Evaluation of the Patient for Cardiac Surgery*

This evaluation must include diagnosis of the pathologic changes in the heart, and an evaluation of the impairment of cardiac function.

After this estimation, preoperative care of the cardiac surgery patient can be started. The optimal state of cardiac balance must be obtained before anaesthesia and operation.

B. *Premedication for Cardiac Surgery*

The rule for premedication is that it should be generous but not depressive. Psychological preparation is very useful. The cardiac surgical patient more than anyone else needs sedation and relaxation because of his nervousness and anxiety.

C. *Anaesthesia for Cardiac Surgery under Normothermia*

The establishment of surgical anaesthesia for cardiac surgery can be considered from many points of reference: as Dillon and Kavan[16] of Los Angeles mentioned in their paper, two factors are important:

(*a*) Is hypothermia to be used?

(*b*) Is cauterization considered surgically necessary?

The first and most important principle of anaesthesia for cardiac surgery is adequate ventilation and oxygenation of the patient. Particularly smooth induction is recommended.

The second principle of anaesthesia for cardiac surgery is that it should be as light as possible and yet give the patient amnesia.

The third principle of cardiac anaesthesia is the placement of large-bore needles or cannulae in veins for the rapid replacement of blood.

D. *Value of Monitors in Cardiac Surgery*[17]

Instruments used as monitors during cardiac surgery are believed by many workers in this field to be of considerable value. We are among those who believe in monitoring, but we do not rely entirely on monitors. First of all we pay attention to clinical signs. Among these instruments are the electrocardiogram, electroencephalogram, pH meter, pressure transducer for arterial and venous pressures, and continuously registering thermometer.

E. *Anaesthesia for Cardiac Surgery under Hypothermia*[18]

Moderate surface hypothermia is used less and less for cardiac surgery and is now replaced by deep hypothermia by means of a pump oxygenator and heat exchanger which is more widely used for two good reasons:

1. The tendency for cardiac surgery to be done with open-heart technique.

2. The safety of this method of hypothermia by complete protection of vital centres during the time surgery is done. In some cardiac operations, pure valvular pulmonary stenosis on children, for example, moderate surface hypothermia is still used and the thermorite blanket is employed and supported initially with crushed ice in plastic bags. This moderate hypothermia by surface cooling is reserved for short procedures. The anaesthetic problems incident to hypothermia are those of induction, during which period the prevention of shivering is most important and controlled by the use of curare.

F. *Anaesthetic Problems of the Extracorporeal Circulation*

The general management prior to the onset of extracorporeal circulation is the same as for any other type of cardiac surgery. During perfusion, the patient is kept from moving by an appropriate dose of curare. Here, electronic monitoring is imperative and particularly the electroencephalogram. Only amnesia is necessary for the patient on the heart-lung machine.

3. *Mediastinal Surgery*

The mediastinum may be the site of infection, tumours, or cysts. This surgery, of itself, does not involve any specific problem, except the application of those

general principles of thoracic anaesthesia previously discussed in this paper. Oesophageal surgery, if we except congenital atresia, is dealing usually with geriatric patients who present profound disturbances in fluid and nutritional balance, and nutritionally depleted patients are relatively poor anaesthetic risks. Partial restoration of body stores and satisfactory restoration of the fluid balance is imperative before operation. Nutritional disturbances are the major problem of this type of thoracic surgery.

4. *Bronchopleural Fistula*[19]

The incidence of large bronchopleural fistula after resection of the lung for tuberculosis or carcinoma is still present despite improvement of thoracic surgical methods. In such patients, anaesthetic difficulties can arise as a result of spill-over of secretions and leakage of air from the bronchial tree. To solve this problem, we recommend a preoperative aspiration bronchoscopy, done under topical anaesthesia, in the sitting position, followed by bronchial intubation with either a Carlens or a Gordon-Green tube. The latter is used for right-sided fistula, the former for left-sided. In this situation careful subsequent testing of tubes must be done to ensure that the catheter is correctly placed. Only when the anaesthetist is satisfied that the unaffected lung is protected may the position of he patient be altered, or general anaesthesia induced.

5. *Paediatric Cases*

A. *Anaesthetic Equipment*

The management of the paediatric surgical patient has received considerable emphasis in recent years. Anaesthetic equipment designed for adults is not suitable for children. For infants, we recommend Ayre's T-tube; for children the open circuit and the Forregger paedriatric set, if the respiration is controlled manually, and the Bird apparatus with non-rebreathing technique by use of Rubens' valve if the respiration is controlled mechanically. For wet lungs, as in bronchiectasis, the face-down posture is imperative as bronchial intubation is not feasible.

B. *Temperature Control*[20]

Temperature varies with age in paedriatric patients. There is a drop in temperature in the majority of infants under 6 months of age. Between 6 months and one year, 50 per cent experience a drop, and the other half experience a rise; between one year and puberty, fever is common. It is a good routine practice to place all paediatric patients on a water mattress on the operating table and to check their rectal temperature throughout the operation. In thoracic anaesthesia, a moderate drop in temperature not exceeding 5° C. seems beneficial in the young infant and tends to simplify the problem of adequate oxygenation. If the temperature of the infant drops precipitously, warm water is run into the mattress. Conversely any child who tends to develop fever is cooled by running cold water or ice into the mattress. Heat loss by infants or children during thoracic surgery is more important than in adults, so we must pay more attention here to temperature control.

C. *Fluid and Blood Replacement Therapy*

Fluid therapy and blood replacement are far more important in paediatric than in adult practice, since infants and children tolerate fluid, electrolyte, and blood imbalance poorly. We must pay more attention to supportive therapy for paediatric patients undergoing thoracic surgery. The use of paediatric sets for fluid and blood administration is recommended.

D. *Postoperative Care*

For the prevention of respiratory embarrassment due to the prolonged period of intubation the maintenance of an atmosphere of high humidity with intermittent aerosol therapy is mandatory during the postoperative period in the oxygen tent.

Conclusions

Anaesthetic problems for thoracic surgery have been reviewed in general and in detail, and our personal solutions to these problems is now restated.

1. *Best Choice of Anaesthetic Agents and Techniques*

Halothane-ether azeotrope is recommended with or without barbiturate induction and with succinylcholine relaxation if required. Vaporizers, such as the Vernitrol, Fluotec, or Azeotec, are highly recommended. For safe administration of azeotrope and more precise vaporization, it is important to attach the vaporizer to the anaesthetic machine between the control valve and the circle inlet and not inside the circle itself. In doing this, the fluothane-ether and the nitrous oxide–oxygen vapour always remain the same and do not vary with the patient's ventilation.

2. *Numerous Advantages of Specialized Equipment*

A. *Carlens for left side and Green-Gordon for right side* give the following advantages in pulmonary surgery[21]: (*a*) Once the chest is opened, the diseased lung may be deflated to provide greater operating space when the lung is separated from the chest wall. (*b*) The lung can be inflated when lobar or intersegmental planes are developed. (*c*) The bronchus can be divided whenever this is suitable during the resection, and left opened until it is convenient to close it. During the time the bronchus is opened, a small plastic catheter is left in place for continuous suction, with suction close to the opening of the bronchus to collect blood and secretions. (*d*) It is unnecessary to apply a clamp on the proximal part of the bronchus; thus injury to the bronchial wall is avoided. (*e*) The bronchial tree may be inspected and aspirated by a small rubber catheter through the open bronchus. (*f*) Bronchotomies and resection of the carina and of the tracheal wall are facilitated by the endobronchial anaesthesia. (*g*) In wet cases, during repeated aspirations, one lung is always ventilated, and the same plane of anaesthesia can be maintained more easily.

B. *Overholt table and pulmonary surgery.*[22] In wet cases, when for one reason or another the bronchial intubation is not feasible, the face-down posture is recommended for operation and the use of the "Overholt" table is emphasized

(e.g., in paediatric patients). But in order to provide adequate ventilation, patients in the prone position should be maintained on controlled respiration.

C. *New vaporizers such as Fluotec, Azeotec, Vernitrol.*

D. *Bird respirator and thoracic anaesthesia.* The Bird respirator is well recommended in thoracic anaesthesia because it meets all the criteria for the fundamental physiological requirements for safe intermittent positive pressure and positive-negative pressure respiration. These requirements[23] are: (*a*) to provide normal alveolar ventilation (accurate independent control of tidal volume and rate); (*b*) to achieve a precision minute volume (use of a rigid non-distensable delivery system); (*c*) to supply the optimum volume/pressure relationship needed for adequate ventilation without disturbing cardiovascular function (adoption of methods to reduce the mean airway pressure); (*d*) to provide safely the normal ventilatory volume with pressure variations (incorporation of pressure-limiting valves and warning device).

E. *Monitoring and thoracic anaesthesia.* The use of monitoring devices in thoracic anaesthesia, specifically in cardiac surgery, is believed to be of considerable value, and the use of temperature control is imperative for paediatric work.

Finally, in thoracic anaesthesia, more important than the best choice of *anaesthetic agents and techniques*, and more important than *the numerous advantages of specialized equipment*, is the *presence of an experienced and competent anaesthetist.*

RÉSUMÉ

Ce travail comprend d'abord une discussion sur le choix des agents anaesthésiques et des techniques d'anesthésie pour chirurgie thoracique, avec mise en évidence de l'halothane-éther comme choix personnel. Par la suite, les problèmes généraux et particuliers de l'anesthésie thoracique sont exposés et quelques solutions de ces problèmes sont proposées, entre autres celles qui regardent les traumatismes du thorax, la chirurgie cardiaque avec ou sans hypothermie, avec ou sans C.E.C., la chirurgie médiastinale, la chirurgie pulmonaire en présence de fistule bronchopleurale, et la chirurgie thoracique chez l'enfant. Enfin, en conclusion, quelques considérations personnelles sur l'anesthésie thoracique sont présentées et l'importance d'un anesthésiste compétent et expérimenté est soulignée.

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