THE CLINICAL USE OF HALOTHANE ANAESTHESIA DURING CARDIOPULMONARY BYPASS FOR OPEN-HEART SURGERY

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DURING open heart surgery with cardiopulmonary bypass, whilst extracorporeal circulation is in progress, the anaesthetist is faced with the problem of maintaining anaesthesia without access to the lungs. In addition, markedly altered blood circulation raises problems with regard to the intravenous route of anaesthetic administration. At the commencement of perfusion, he is faced with the mixing of two blood volumes—that of the anaesthetized patient and that of the donor blood used to prime the pump oxygenator. This mixing inevitably causes marked alteration in the level of anaesthetic agents in the patient's circulation, unless some means of equilibrating anaesthetic levels in both blood volumes can be achieved. In the lightly anaesthetized patient, the dilution of anaesthetic concentration occurring may have the undesirable effect of allowing excessive movement on the part of the patient: even return of consciousness is not unknown. The addition of intravenous anaesthetic agents and relaxants to maintain an even level of anaesthesia is extremely difficult to judge and, as these agents are eliminated relatively slowly from the body, control may be far from flexible. This makes the desired rapid postoperative recovery from the influence of anaesthetic agents and relaxants difficult to achieve, unless extremely fine judgment is exercised in their use.

Certain properties of halothane led us to believe that this agent might prove useful in overcoming these difficulties. Firstly, the clinical use of halothane for cardiac and thoracic surgery, not requiring cardiopulmonary bypass, has shown us that it is capable of providing adequate and safe anaesthesia for these procedures when it is used as the principal anaesthetic agent with nitrous oxide and oxygen without the use of relaxants or of intravenous anaesthetic agents. Secondly, the easy control of the depth of anaesthesia obtained using small changes in the inhaled concentration seems to indicate that its concentration in the blood is readily alterable in either direction. Following the successful experimental use of halothane anaesthesia for cardiopulmonary bypass procedures in dogs (Bull et al., 1959) it was decided to extend its use to clinical practice for patients undergoing open heart surgery using the DeWall-Lillehei pump oxygenator, with halothane as the principal anaesthetic agent both before and during extracorporeal circulation.

Twenty-eight consecutive cases have been anaesthetized in this way.

METHOD OF ANAESTHESIA

Premedication.

Eighteen cases in the series received pentobarbitone 3 mg/kg by mouth 2 hours before induction and pethidine 1 mg/kg together with atropine 0.6 mg (1/100 grain) by intramuscular injection 1 hour before anaesthesia. In the remaining ten cases pethidine was omitted and pentobarbitone alone was used.

Induction.

In all patients in this series anaesthesia was induced using nitrous oxide, oxygen and halothane. Nitrous oxide and oxygen in the proportion of 70 per cent nitrous oxide to 30 per cent oxygen were delivered through a "Fluotec" vaporizer. At the commencement of induction the halothane concentration was increased fairly rapidly during the first 1 or 2 minutes to 1 per cent and thereafter more slowly to 1.5 per cent. After about 5 minutes, the larynx and trachea were sprayed with 2 or 4 per cent lignocaine,
the total dose of lignocaine never exceeding 2 mg/kg body weight. Intubation was performed after a further 2 or 3 minutes of inhalation of 1.5 per cent halothane, nitrous oxide and oxygen mixture.

**Maintenance.**

Anaesthesia was maintained with nitrous oxide 70 per cent, oxygen 30 per cent, and halothane 1 per cent using a high flow rate via a semiclosed system with carbon dioxide absorption.

Spontaneous or assisted respiration was allowed up to the time of thoracotomy. Just prior to opening of the chest a very brief period of over-ventilation invariably allowed full control of respiration to be achieved and in no case was any relaxant used. Controlled respiration was continued—the halothane concentration still at 1 per cent—up to the time of commencing extracorporeal circulation. During extracorporeal circulation anaesthesia was maintained in the following manner. A Fluotec vaporizer was placed on the oxygen supply line to the DeWall bubble oxygenator, which was set up as described by McKenzie and Barnard (1958), but included a stainless steel canister debubbler. During priming of the oxygenator and the helix reservoir with blood, this vaporizer was set at 1 per cent. However, oxygen flow during priming was of the order of 1 l/min and as the Fluotec vaporizer used in this series was the Mark I model, it is likely that the halothane concentration delivered with the oxygen was less than 1 per cent. During perfusion, oxygen flow through the Fluotec was always in excess of 4 l/min and so the concentration of halothane delivered to the oxygenator was assumed to correspond closely to the vaporizer setting (Mackay, 1957; Hill, 1958). In eighteen cases the Fluotec setting was maintained at 1 per cent throughout perfusion and in the remaining ten cases the setting was deliberately altered from 1 per cent to 0 per cent. The oxygen to blood flow ratio through the oxygenator was in all cases approximately 2.5 or 3 to 1. Some variation of perfusion rate without corresponding adjustment of oxygen flow during individual perfusions makes it impossible to give this figure more accurately.

At the conclusion of extracorporeal circulation, pulmonary ventilation was recommenced using nitrous oxide and oxygen only. In all but three cases this sufficed for maintenance during closure. In the three cases mentioned halothane 1 per cent was added for short periods as required.

**RESULTS**

The natures of the operations, the ages and the weights of the patients, the durations of extracorporeal circulation, the rates of perfusion and the mean perfusion pressures in each patient are given in table I.

**General.**

The premedication indicated proved satisfactory in all cases and the patients were either asleep or extremely drowsy. The omission of pethidine from premedication in some patients was not governed by any contraindication to its use and both types of premedication provided equally satisfactory sedation.

During induction and intubation no difficulty was experienced. Anaesthesia was rapidly and smoothly achieved. Short-lived coughing during spraying of the larynx and trachea was not uncommon but laryngeal spasm was never encountered. During the period of surgery preliminary to extracorporeal circulation it was necessary to increase halothane concentrations to 1.5 per cent for short periods in two cases during the first 30 minutes of anaesthesia. In all the other cases, 1 per cent halothane provided adequate anaesthesia and allowed easy control of respiration during both extrathoracic and intrathoracic preliminary surgery, prior to cardiopulmonary bypass.

During bypass, no clinically detectable variation in the depth of anaesthesia occurred unless the halothane concentration supplied to the oxygenator was altered. In the ten cases where such alteration was made, it appeared that 0.7 per cent was the critical level below which respiratory movements in the patient commenced. When a change in the depth of anaesthesia was brought about by an alteration of the halothane concentration to the oxygenator, a period of five to ten minutes elapsed before this became clinically obvious. By maintaining 1 per cent halothane with the oxygen to the bubble oxygenator no respiratory or other movement on the part of the patients occurred except in two cases. In these
two cases three or four gentle diaphragmatic contractions occurred after five minutes of perfusion and then ceased. This was thought to be due to low halothane concentration achieved during priming of the pump oxygenator in these cases. In one other case diaphragmatic contractions occurred after twenty minutes of perfusion. This coincided with a temporary obstruction of the superior vena caval catheter and was corrected as soon as the obstruction was relieved.

**Halothane levels in the blood.**

In four cases samples of arterial blood were taken for estimation of the halothane content. All samples were taken from a cannula placed in the right internal mammary artery. Halothane estimations were performed by the method of W. A. M. Duncan (1959), modified by J. E. Kench and E. J. Duncan (in press). The results of analysis are given in figure 1.

**Blood gas values and pH.**

Arterial and venous samples taken before perfusion, during perfusion, at 20 minutes and 10 minutes after perfusion, were subjected to analysis for oxygen saturation and carbon dioxide content. The arterial samples were all taken from the right internal mammary artery. Venous samples were obtained either from a catheter placed in the inferior vena cava via the saphenous vein, or from an arm vein. The result of these estimations is given in figure 2. The pH values of arterial blood samples taken at the same times as above in 12 of these cases are given in table II. The pH estimations were carried out on fresh arterial blood using the Beckman model “G” pH meter.
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Mean oxygen saturations and carbon dioxide contents of venous and arterial blood in 28 patients presented as a histogram.

By a simplified method (Turner, 1959). In three cases, simultaneous arterial samples and mixed venous samples from the venous well were obtained at known perfusion rates just after closure of the cardiac defect. Using the Fick principle, oxygen uptake was calculated from these values and gave the results indicated in table III.

Perfusion pressures.
Perfusion rates and mean perfusion pressures were as indicated in table I and in all except one case the perfusion pressures were monitored by a strain gauge attached to a catheter in the right internal mammary artery.

Electroencephalograph.
Electroencephalographic monitoring was available in all adult patients. No undue suppression of cortical activity attributable to the anaesthetic agent or technique was evident. This will be the subject of a further communication.
The heart.

In the twenty-eight patients operated upon using halothane anaesthesia, the heart tolerated handling during various surgical procedures extremely well. Apart from occasional extrasystoles and short bouts of atrial fibrillation, no serious arrhythmias were noticed.

The arterial pressures were continuously recorded by means of a polyethylene tube in the internal mammary artery and the inferior vena caval pressures by means of a polyethylene tube in this vessel. In none of the cases in this series were any unusual changes noticed which could suggest inadequate cardiac function.

During total cardiopulmonary bypass the heart behaved normally. It tolerated potassium citrate asystole extremely well and took over adequately after the discontinuation of asystole and total bypass.

**Postperfusion.**

At the end of perfusion, ventilation of the lungs was recommenced using only nitrous oxide and oxygen. The blood pressure in all cases returned to near the level recorded before perfusion, provided that the patient's blood volume had been satisfactorily maintained. In this connection it must be emphasized that accurate assessment of blood loss throughout the operation must be energetically striven for and any deficiency rapidly made good. Nitrous oxide and oxygen provided adequate anaesthesia at this stage and permitted controlled respiration until the closure of the chest, except in the three cases already referred to. All the patients were awake and able to answer questions intelligibly within ten minutes of the end of anaesthesia.

**DISCUSSION**

The state of anaesthesia obtained with halothane, when used as described, has been entirely satisfactory, both from the point of view of surgeon and of the anaesthetist. A degree of stability and control was achieved more easily than has been possible in our hands using thiopentone and relaxants in a series of thirty cases reported by...
one of us (Ozinsky, 1959). There was no death in the series and no morbidity which could be attributed to the anaesthesia. As halothane is eliminated by the lungs there is the advantage that there need be no fears regarding circulatory, renal or hepatic elimination of this agent.

Hypotension before or after perfusion has not been of such a degree as to cause anxiety. A fall in systolic pressure of some 10 to 20 mm Hg from pre-anaesthetic levels is usual. Pressures during perfusion may remain somewhat lower than those which have been encountered with comparable perfusion rates using thiopentone and relaxants. This is probably due to the action of halothane on peripheral vessels described by Burn and Epstein (1959). If so, it is felt that this may be an advantage as it would indicate a lesser degree of peripheral vasoconstriction from sympathomimetic stimuli induced by reflexes brought about by the altered haemodynamics of total body perfusion under light anaesthesia. Such sympathetic stimuli may be a potent cause of metabolic acidosis (Griffiths et al., 1939; DeWall et al., 1956). It is felt that some degree of vasodilatation is also beneficial in the immediate postperfusion stage because it allows the traumatized heart to take over initially against a diminished vascular resistance.

The postoperative recovery and the electroencephalographic recordings have given no indication that cerebral hypoxia occurred in any case. Clinical observation also confirmed the existence of a good peripheral circulation as evidenced by good colour of conjunctivae and extremities throughout perfusion.

Encephalocardiographic recordings and the observation of an experienced cardiac surgeon have given no indication of cardiac arrhythmias or increased myocardial instability which could be attributed to the anaesthesia. In cases in which elective cardiac arrest was produced with potassium citrate (see table I) the resumption of normal rhythm was not delayed. In four cases in which ventricular fibrillation accompanied the termination of potassium citrate arrest, defibrillation was not difficult to achieve.

There is no indication of any interference with gas exchange in the oxygenator. The three figures obtained for oxygen uptake, although too few to provide conclusive evidence, appear to be satisfactory. There is no notable depression in oxygen consumption, but it is interesting to speculate on the possible results of using higher blood anaesthetic concentrations. In one experiment on a dog, one of us (A.B.B.) has deliberately produced cardiac arrest during perfusion with blood containing a high halothane content. This arrest was reversible on eliminating the halothane via the pump oxygenator system, and the possibility remains that a general depression of all tissue metabolism may be attainable, thus permitting the use of lower perfusion rates when this state has been achieved.

The blood halothane levels obtained show a satisfactory state of consistency throughout bypass. Clinical observation and e.g. monitoring have led us to the conclusion that 1 per cent halothane provides adequate and safe anaesthetic conditions.

SUMMARY

A technique of anaesthesia for open heart surgery using the Lillehei-DeWall pump oxygenator is described. Halothane, without intravenous agents, is used as the principal anaesthetic agent and is administered via the lungs prior to, and during, extracorporeal circulation and via the bubble oxygenator during cardiopulmonary bypass. The results obtained in twenty-eight unselected patients, in whom most types of open heart surgery were undertaken, when anaesthetized in this way are discussed. There was no mortality or morbidity in this series.

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REFERENCES
Kench, J. E., and Duncan, E. J. A note on the determination of bromchlor trifluoroethane in blood. (To be published.)
Turner, T. J. A simplified method of pH determination. (To be published.)

BOOK REVIEW


The book sets out the results of the experience gained at the Centre de Réanimation de l'Hôpital Claude Bernard by joint staffs of the departments of Medicine and Otolaryngology. Professor Aboulker, Director of the Department of Otolaryngology has collaborated for the best part of five years with a Neurorespiratory Resuscitation Centre originally conceived and run by Professor P. Mollaret "et une remarquable équipe de médecins et de physiologistes". More than 520 tracheotomized patients were treated and followed up. The practical sections of the book make excellent reading and one is impressed by the management and after-care of the tracheotomies. Much attention is paid to minute clinical detail; for instance, the diagnosis and treatment of crusting after opening of the trachea is better dealt with than in any other book the reviewer has read on the subject. There is much in the book which appears irrelevant from this side of the Channel, but when one remembers that up to 1950 there was no French textbook on physiology, one will appreciate that the author felt compelled to deal with the physiology of respiration and how it is disturbed by respiratory obstruction.

From the point of view of the anaesthetist there is only one short chapter of eleven pages which is exclusively devoted to the matter. It is competently handled by Dr. Vourc'h who gives a commonsense view of the indications for and the contra-indications against intubation, the accidents that may occur, finishing up with the statistics obtained at the hospital. It is possible, indeed probable, that conditions in France differ considerably from those in England. Many of the services for which it is proposed to call in the help of the laryngologist can equally well be supplied by the anaesthetist. The modern anaesthetist is an expert with the laryngoscope and he must be very clumsy or faint hearted if he cannot do a tracheotomy when it is urgently required.

The standard of the illustrations is very high, particularly the tomograms of the abnormal trachea and endoscopic views obtained from tracheotomized patients. One readily recalls that the French are past masters, indeed pioneers, of endoscopic filming of the respiratory tract. Records thus obtained have inestimable value in teaching and follow-up. The style varies a good deal as one would expect in a book produced by multiple authorship; some beautiful Gallic prose is often spoilt by tiresome tirades; the clarity of factual explanations is, however, unsurpassed. On the whole this is a most informative volume.

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