HALOTHANE-ETHER IN CARDIAC SURGERY*

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THE PURPOSE of this paper is to describe our experience, both experimental and clinical, with halothane-ether in cardiac surgery; and then to show the effectiveness of this azeotropic agent for this type of surgery on humans. At the Quebec Institute of Cardiology, Laval Hospital, Ste-Foy, we have been studying during the past two years the development of a more effective method of anaesthesia for cardiac surgery. Authors reporting on use of the azeotropic mixture of halothane-ether, state that anaesthesia is improved with it in both general and pulmonary surgery.¹ Furthermore, this mixture is favourably compared with the best available anaesthetic agents. With a view to testing the effectiveness of this new mixture, in the field of cardiac surgery, we have first studied the effects of the mixture on cardiovascular function, particularly on arterial blood pressure, electrocardiogram tracings, and cardiac output, in the Research Department.

I. EXPERIMENTAL

1. Procedure

Our investigations were carried out on dogs, of 20 to 30 pounds average weight, for which standard premedication was given (morphine-atropine) one hour before anaesthesia. Light anaesthesia was induced with a hypnotic dose of thiopentone, 150 to 200 mg., and the animal's trachea was intubated with a "Portex" cuffed tube and connected to a Boyle's machine with Azeotec vaporiser. However, the anaesthetic agent under test, halothane-ether, was not administered until the monitoring equipment was set up and initial readings were recorded. This permitted sufficient time to elapse so that thiopentone had virtually no effect on the physiological parameters being measured. For maintenance of anaesthesia the azeotrope halothane-ether (31.7 vol. % ether, 68.3 vol. % halothane) was used with high flows and equal volumes of nitrous oxide-oxygen in a semi-closed circuit. The respiration, as desired, was either spontaneous, assisted manually, or controlled with or without positive and negative pressure by the Jefferson ventilator model GH3. These studies were repeated three times on 30 different dogs. They were conducted at various degrees of anaesthesia, determined both by clinical signs and by electroencephalogram data: analgesia (Artusio's stage), light surgical anaesthesia, and deep surgical anaesthesia.

2. Results

A. ARTERIAL PRESSURE AND ECG TRACINGS

During the stage of analgesia, a slight tachycardia of about 150 per minute was observed, as compared with a normal of 130. A variable hypertension to 160, 170,

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180 mm. Hg occurred compared with 140 as normal, which we believe is due to the lightness of the anaesthesia. Dogs are not adequately sedated in this stage of analgesia, and they cannot be co-operative like humans. In light surgical anaesthesia, no significant changes in arterial pressure or electrocardiogram tracings were observed. By contrast, in deep surgical anaesthesia, a significant degree of hypotension down to 80–70 mm. Hg, as well as a severe bradycardia of 40–50 per minute, was noted.

B. CARDIAC OUTPUT STUDIES

Experiment 1

Procedure.—For our first cardiac output studies, a gasometric method based on the Fick principle was used:

$$\text{cardiac output} = \frac{\text{consumption of oxygen per minute}}{\text{arterio-venous oxygen difference}}$$

These studies were made on 20 different dogs with the tests repeated three times on each of these dogs. Fick's method is a laboratory procedure and is not practical for clinical anaesthesia, as it requires cardiac catheterization to obtain a venous mixed blood specimen from the pulmonary artery, an arterial blood specimen by femoral or radial puncture, and at the same time, an expired air sample to determine minute oxygen consumption. In order to reduce the chances of error by an oxygen supersaturation, which is always a possibility in halothane-ether anaesthesia, for a certain period of time we replaced oxygen in our mixture by compressed air before collecting the expired air sample.

Results.—In light anaesthesia, in all these dogs, figures comparable with normal cardiac output, measured on anaesthetised dogs, were obtained (that is 1.5, 2, 2.5 litres per minute). For the determination of the theoretical cardiac output on dogs, a formula published in the *Handbook of Biological Data* (1956, Saunders, Philadelphia) was used: $\text{Norm} = K:A (\text{sq. cm.}/W^{2/3})$ (K is a constant = 11.4 and W represents the weight of the dog expressed in grammes).

Experiment 2

Procedure.—In a second group of 10 dogs, with tests repeated three times, the Coomassie Blue dye dilution curve method was used for determination of cardiac output during halothane-ether anaesthesia. We may say now that this method is far more reliable and practical during clinical and experimental anaesthesia.

Results.—Here again in light surgical anaesthesia, with this method of measuring cardiac output, little change was observed compared with normal figures; and in this series the figures were found to be 1.5 and 2 litres per minute.

The experiment on dogs having shown encouraging results, we then started to use the azeotropic mixture during cardiac experimental surgery, and after a few months of satisfaction with it, we finally used the azeotrope halothane-ether for cardiac surgery in clinical practice on humans.

II. CLINICAL EXPERIENCE

1. Statistics

Since the beginning of January, 1959, the halothane-ether azeotropic mixture has been used with satisfaction in the Department of Anaesthesia of the Quebec Institute of Cardiology, Laval Hospital, Ste-Foy. At that time, we started to use it only on good-risk patients, but within a year this method of anaesthesia has become a daily practice for our cardiac surgical cases. By the end of April, 1961, we had used it in a total of 100 different cardiac surgical cases, including some 17 cases of open heart surgery with the help of extracorporeal circulation.

Table I presents a brief analysis of all the cases reported in this paper with type of surgery used.

TABLE I
TYPES OF SURGERY

<i>Open heart surgery</i>			
	A.S.D. closure		12
	Pulmonary valvulotomy		3
	V.S. defect closure		1
	Mitral commissurotomy		1
<i>Closed heart surgery</i>			
Mitral commissurotomy	46	Blalock operation	2
Mitral and tricuspid commissurotomy	1	Beck operation	2
Aortic commissurotomy	2	Left heart ventriculography	1
Patent ductus	14	Carotid arteriography for vascular tumour	1
Aorta coarctation	10	Atriotomy for removal of a	
Aneurysm of thoracic aorta	2	foreign body	1
Traumatic femoral aneurysm	1		

2. Technique of Anaesthesia and Anaesthetic Equipment

A. TECHNIQUE OF ANAESTHESIA

(a) Premedication

It is a habit in our group to use a mixed premedication for adults. This means a non-barbiturate hypnotic Noludar® combined with the antihistamine Phenergan® on the previous evening and morphine-atropine, morphine-scopolamine, or Pamergan® one hour before surgery. Papaverine and glyceryl trinitrate are successful in coronary surgical patients. We also believe that morphine has decided advantages, in patients who have been decompensated or who may develop pulmonary oedema. For children, depending on their degree of nervousness, we use, if indicated, a rectal barbiturate the night before and morphine-scopolamine on the morning of the operation. For infants we use, on the operative morning only, a hypnotic rectal dose of thiopentone or methohexital sodium followed by a small dose of atropine intramuscularly. In our opinion, in cardiac surgery as for other types of surgery, the dosages of preoperative medication must be adjusted according to age, weight, surface area, and general condition of the patient. In fact cardiac surgical patients more than any one else, because of their anxiety and nervousness, must be prepared by adequate premedication

and psychological preparation. The rule for premedication is, then, that it should be generous but not depressant.

(b) Induction of Anaesthesia

In adults, induction is generally carried out with a little intravenous thiopentone (125 to 250 mg.) or more recently with a little methohexital (60 to 80 mg.), followed by the azeotrope. We made an exception for 10 poor-risk patients in our series, to whom only the azeotrope was given by inhalation. In children, to avoid too much respiratory depression, inhalation anaesthesia is used alone, and no barbiturate is given.

(c) Relaxation

When required for relaxation during cardiac operations, a muscle relaxant drip (succinylcholine) is administered intravenously in 0.1 or 0.2 per cent solution. It is also used in intermittent doses for intubation. Flaxedil® is also used for the same purpose, mostly in children, by intermittent and repeated doses of 1 or 2 per cent solution. We have also used intramuscular succinylcholine (1.1 to 2.1 mg. per pound of body weight) for a few children, but we did not like the prolonged effect of the intramuscular route for curare.

(d) Ventilation

As in any other type of thoracic surgery, respiration is either spontaneous or assisted for closed chest surgery, and controlled manually or mechanically with the Jefferson ventilator with or without negative pressure as desired for opened chest surgery.

(e) Maintenance of Anaesthesia

The technique of administering the azeotrope during maintenance of anaesthesia will be described later in detail. Let us remember now that a high concentration of oxygen administered through an unobstructed airway to a lightly anaesthetized patient (0.5, 1, or 1.5 per cent vapour of halothane-ether) is essential during maintenance of anaesthesia.

B. ANAESTHETIC EQUIPMENT FOR CARDIAC SURGERY

The great majority of the cardiac cases reported in this paper were adults and were anaesthetized with a Boyle's apparatus using a Fluotec or more recently an Azeotec vaporizer, with a high flow of 4-6 liters of nitrous oxide - oxygen (50:50 v./v.) for vaporization of the azeotropic volatile mixture in a semi-closed circuit. The minority of the cases reported, children and infants, were anaesthetized with the same anaesthesia apparatus and vaporizer but in the open circuit with the paediatric anaesthesia accessories. We like the Fluotec or Azeotec because of their great precision, safety, and efficiency. Moreover, for safe administration and a more precise halothane-ether 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 halothane-ether and nitrous oxide - oxygen vapour always remain the same and do not vary with the patient's ventilation.

C. ANAESTHESIA MONITORING

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. However, we recommend some monitoring in the operating room, depending on the severity of the cardiac case. For our cases, we used the following monitoring equipment: ECG, EEG, multichannel recording apparatus for arterial, venous, and intracardiac pressures; temperature recorder such as telethermometers; quick and accurate method of determining arterial oxygen and carbon dioxide tension (Polarograph), blood pH, and blood volume.

D. ANAESTHESIA AUXILIARY EQUIPMENT

We also had available for all the cases reported in this paper complete auxiliary anaesthesia equipment for cardiac surgery, such as cardiac defibrillator and pacemaker, control temperature unit ("Thermorite"), accurate scales for pre- and post-operative weighing of the patient, and complete equipment for bronchoscopic aspiration and intravenous therapy.

III. DISCUSSION AND RESULTS

We have indicated our great satisfaction with the halothane-ether azeotropic mixture in cardiac surgery especially for the following two reasons: first, safety of the azeotropic mixture from the aspect of cardiovascular function; second, a successful clinical experience with it in cardiac surgery.

1. *The Cardiovascular Function*

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 Dobkin⁴ 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, predominant vagal effect on the heart. Arrhythmias may occur during rapid induction and during deep anaesthesia. In experiment on dogs, ventricular fibrillation is easily produced during light halothane anaesthesia if epinephrine is injected.

The effect of halothane-ether on the heart is reduced significantly when the 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. *Successful Clinical Experience with Halothane-Ether Anaesthesia*

Among all the cases done and reported in this paper, as complications, from the anaesthesia point of view, we had only a few cases of a slight degree of hypotension during our mitral surgery. In fact during the monitoring of these cases we have not seen any burst suppression on the EEG tracings, which is significant of profound hypotension. We observed no significant ECG changes with halothane-ether anaesthesia. With halothane, we quite often had ECG tracings showing inversion of P waves, nodal rhythm, and ventricular extra-systoles.

IV. CONCLUSION

After using the azeotropic halothane-ether mixture in anaesthesia for heart surgery, on a relatively small series of cardiac cases, of various ages and for various operations, we are extremely pleased with these first anaesthetic results, and we believe we are justified in increasing the number of cardiac cases done with this technique. Progress has been made during the past ten years in the anaesthetic management of patients undergoing cardiac surgery, but there is still room for improvement in the many phases of management, and for avoidance of anaesthesia complications.

From the beginning we have been aware of the problem of cardiac recovery during halothane-ether anaesthesia for cardiac surgery. At the present time a series of experiments dealing with this problem is under way and the results will be the subject of another paper in the very near future.

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