HEART SOUNDS DURING FLUOTHANE ANAESTHESIA*

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THE RECENT INTRODUCTION of Fluothane (CF_3CHClBr) as an anaesthetic agent has prompted great clinical interest. Considerable enthusiasm has been evoked because this drug is a potent inhalational agent which is non-explosive, non inflammable, and provides a rapid induction of, and recovery from, anaesthesia (1, 2, 3, 4). Fluothane, however, is not without certain undesirable characteristics, as might be anticipated on the basis of previous experiences with other halogenated hydrocarbon compounds employed for anaesthesia. Some of these properties have been observed during clinical trials conducted in the present series of 125 patients anaesthetized with Fluothane. Depression of the tidal volume of respirations, to as low as 50 cc., 75 cc., or 100 cc., with the concurrent onset of tachypnoea, has occurred with considerable regularity when respirations have not been either assisted or controlled; hypotension, occasionally profound, has resulted without warning in several instances; and cardiac irregularities, consisting of either premature ventricular contractions or nodal rhythms, have been recorded on the electrocardiogram in 8 of the 125 patients who were anaesthetized with Fluothane. These unpleasant effects usually have occurred as the result of increasing depths of anaesthesia, and often have been reversible when the level of anaesthesia has been lightened again.

The depth of anaesthesia produced by a given concentration of inhaled Fluothane vapour, however, varies with the individual patient, and cannot always be judged adequately by clinical signs. The safety of widespread usage of Fluothane anaesthesia will have to be predicated upon reliable methods of ascertaining the depth of anaesthesia if these deleterious toxic effects are to be avoided. Calibration of the vaporizer by which the anaesthesia is to be administered provides considerable aid in determining the approximate anaesthetic level, but is not an infallible method in view of the sudden changes in the concentration of the vapour of this extremely potent agent that may result from alteration in the volume of even several inhalations. Determinations of the level of the agent in the arterial blood would provide definitive information, but these tests are technically difficult to perform and in any event cannot give immediate results for use in the conduct of clinical anaesthesia. Electroencephalography will provide minute-to-minute data for the control of the level of anaesthesia, but monitoring apparatus of this type is still not available to the majority of anaesthesiologists. The present study was therefore undertaken as an attempt to develop a practical and simple clinical method for monitoring Fluothane anaesthesia.

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TECHNIQUE

The changes that occur in the heart sounds during anaesthesia produced by either cyclopropane or ether have been reported by Rence, Cullen and Hamilton, (5) who observed that during deep levels of anaesthesia the usual predominance of the intensity of the first heart sound over the second heart sound became reversed, the second heart sound becoming greater relative to the first. These workers employed an Electron-cardioscope to demonstrate and record the heart sounds simultaneously with cathode-ray tracing, and sound-tape analysis was then done with camera and sound spectrograph. Their observations have been confirmed in the present study, which has employed phonocardiography and an optical recording system. Excellent tracings of the heart sounds during anaesthesia can be recorded by this means and have shown that the "reversal" of the two

FIGURE 1 Heart sound "reversal" during anaesthesia. The upper tracings show the amplitudes, frequencies, and durations of the heart sounds of a patient before operation (control) and during cyclopropane anaesthesia. The middle tracings show similar records of a patient anaesthetized with ether, and the lower tracings are those from a patient anaesthetized with nitrous oxide-oxygen-Fluothane.

major heart sounds occurs not only with cyclopropane or ether, but also during anaesthesia produced by Fluothane (Fig. 1) Rence, Cullen and Hamilton made the suggestion that the changes in the heart sounds might serve as a qualitative guide to the determination of the anaesthetic level during cyclopropane or ether anaesthesia, and the fact that similar changes have been observed during Fluothane anaesthesia indicated that monitoring the heart sounds might also provide a guide to the safe dosage of Fluothane.

METHODS AND MATERIAL

An attempt therefore has been made to utilize the "reversal" of heart sounds during Fluothane anaesthesia as a practical determination of anaesthetic level and as an indication of the approach to toxic doses. The subjects were fifteen patients undergoing gynaecological surgery, all of whom were in good health except for the pelvic disorder for which operation was being undertaken. Anaesthesia was produced with the semi-closed technique by nitrous oxide-oxygen (6 litres·3 litres) and Fluothane, occasionally with a small (100–200 mgm) dose of thiopentone for induction. Heart sounds were monitored aurally by an acoustic stethoscope and an amplifying stethoscope, both applied to the precordium, and

FIGURE 2 The electroencephalographic tracings recorded from fronto-occipital leads on a subject anaesthetized with nitrous oxide-oxygen-Fluothane. Below the tracings are scales indicating the time interval of one second and the amplitude of 100 μ V.

visually by a cathode ray oscilloscope. Simultaneous phonocardiograms and electrocardiograms were recorded intermittently as indicated on a Sanborn Twin-Beam optical recorder (Model 62). Electroencephalograms were recorded on an Edin Anesthograph (Model 555). Blood pressures were taken with a cuff sphygmomanometer. The inhaled concentration of Fluothane vapour was recorded in terms of the setting on the Heidbrink ether vaporizer (that is, setting of 2.0 = 1.8 per cent inhaled concentration at the flow rates of gases employed in this study)

The depth of anaesthesia was estimated by reference to the electroencephalographic pattern pertaining at any given moment. Four electroencephalographic levels were discerned during anaesthesia produced by Fluothane, all similar to the patterns produced by different levels of other anaesthetic agents. The tracings of a subject anaesthetized with nitrous oxide-oxygen-Fluothane (without Pentothal induction or surgical intervention) is illustrative of the levels of anaesthesia as determined by electroencephalography in the present study (Fig 2). The first pattern is characterized by low voltage, fast activity at 8-12 cycles per second, clinically, this corresponds to definite, but very light, Fluothane anaesthesia. The second pattern consists of waves of a higher voltage and a somewhat slower frequency of 6-8 cycles per second, in which the wave form is remarkably pure. The third pattern is a mixture of fast activity, of similar voltage to the preceding pattern, superimposed upon slow frequency, high voltage waves. The fourth pattern is characterized by almost pure delta waves of slow frequency, 2-4 cycles per second, and high voltage, 100-300 μ v.

RESULTS

The results are contained in Table I which lists the concentration of inhaled Fluothane vapour (as indicated by the vaporizer setting with a fixed flow of gases), the electroencephalographic pattern (according to the classification described above), the electrocardiographic changes, the blood pressure, and the type of respiration, for each of the fifteen subjects at the time of "reversal" of the heart sounds. The heart sounds did not, in fact, reverse in four patients (M. B., A. G., R. C., and E. A.), despite high concentrations of inhaled Fluothane vapour (for example, patient E. A., vaporizer setting=5.0) and electroencephalographic evidence of a deep level of anaesthesia (patterns 3 and 4). There was no correlation between the concentration of the inhaled Fluothane vapour and changes in the heart sounds: "reversal" occurred at a vaporizer setting of 1.0 in three patients, 1.5 in one patient, 2.0 in three patients, 2.5 in one patient, and 3.0 in three patients. There was also no correlation between the electroencephalographic pattern and changes in the heart sounds: "reversal" occurred during pattern 1 in four patients, pattern 2 in six patients, and pattern 3 in one patient. An approximate correlation could be established between the concentration of the inhaled Fluothane vapour and the electroencephalographic pattern in most instances, the lower vaporizer settings (1.0 to 2.0) producing electroencephalographic patterns 1 or 2, and the higher vaporizer settings (3.0 to 5.0) producing electroencephalographic patterns 3 or 4. There was no correlation between

"reversal" of the heart sounds and the level of systolic arterial pressure, which was normal in nine of the eleven patients showing such a change in heart sounds, and in three of the four patients in whom the heart sounds did not reverse throughout the anaesthetic period. There also was no relation between the effects of Fluothane upon either the type of respiration or the pulse rate and the occurrence of "reversal" of the heart sounds.

TABLE I

PHONOCARDIOGRAPHIC "REVERSAL"* OF HEART SOUNDS CORRELATED WITH CONCENTRATION OF INHALED FLUOTHANE VAPOUR, ELECTROENCEPHALOGRAPHIC PATTERN, ELECTROCARDIOGRAM, BLOOD PRESSURE AND RESPIRATIONS

Observations at time of "reversal" of heart sounds					
Patient	Vaporizer setting	EEG pattern	ECG	Blood pressure	Respirations
R C	3 0	2	Normal	Normal	Assisted
M V	2 5	2	Normal	Normal	Normal
M B	No "reversal" @ 3 0	No "reversal" @ 3	Normal	Normal	Normal
K G	1 0	1	Normal	Normal	Normal
B C	1 5	2	Normal	Normal	Normal
B L	1 0	1	Normal	Normal	Normal
C V	2 0	2	Bradycardia	Depressed	Assisted
A G	No "reversal" @ 3 0	No "reversal" @ 3	Normal	Normal	Normal
E N	1 0	1	Normal	Normal	Normal
L K	2 0	2	Normal	Normal	Normal
R C	No "reversal" @ 5 0	No "reversal" @ 4	Normal	Normal	Normal
C M	3 0	3	Bradycardia	Normal	Assisted
S O	3 0	1-2	Normal	Normal	Normal
E A	No "reversal" @ 2 5	No "reversal" @ 3	Bradycardia	Depressed	Controlled
M C	2 0	2	Normal	Depressed	Controlled

*"Reversal" refers to a change from the usual predominance of the 1st heart sound over the 2nd, to a predominance of the 2nd heart sound over the 1st, as described in the text

DISCUSSION

Four heart sounds can be recorded by phonocardiography, but the first and second sounds (6), which signify the beginning and end of systole respectively, are louder and more commonly heard than the diastolic sounds, the third and fourth heart sounds (7). The first heart sound is of relatively long duration, low in pitch, and soft in quality, and is caused by complex musculo-valvular mechanisms which have been hypothesized to include the closure of the auriculoventricular valves, the tension set up in the valve leaflets and chordae tendinae as the intraventricular pressure rises, the rush of blood from the ventricles and the shock transmitted to the walls of the aorta and pulmonary artery, the contraction of the ventricular muscle, and vibrations set up by the auricular muscle at the end of its systole (8). The intensity of the first sound is related to the tension developed during the isometric phase of ventricular contraction (9). The second sound is shorter, sharper, and of higher pitch, and results from the vibrations set up in the column of blood and arterial

walls coinciding in time to the closure of the semilunar valves and the subsequent opening of the atrioventricular valves (7). The intensity of the second heart sound is related to the height of blood pressure in the great vessels at the onset of diastole (9).

The changes in the heart sounds during deep anaesthesia produced by either cyclopropane or ether were attributed by Rence, Cullen and Hamilton (5) to a depression of cardiac action, indicating low energy output and tending to suggest a direct cardiotoxic action. This concept that the changes in heart sounds are due to a decrease in the contractile force of the heart may well pertain to the data in the present study, but the effects of hypoxia, hypercarbia, and particularly surgical stimuli could not be sufficiently controlled to warrant such a conclusion. It is of interest, in this regard, that "reversal" of the two major heart sounds were not seen during anaesthesia produced by nitrous oxide-succinylcholine or during induced hypothermia to a temperature of 86°F. in human patients (10).

Changes in the heart sounds during Fluothane anaesthesia were discernible on the oscilloscope when they did occur, but were not always distinguishable by acoustic stethoscope until the "reversal" was pronounced. Furthermore, an equalization of the first and second heart sounds generally occurred prior to true "reversal," which was noted slightly later when the second sound became predominant. There is therefore a disparity between the results in this study of Fluothane and the findings of Rence, Cullen and Hamilton that "reversal" occurred with ether or cyclopropane before the sounds assumed an equality of pitch and intensity (5).

CONCLUSIONS

1. The usual predominance of the intensity of the first heart sound over that of the second heart sound frequently may be reversed during anaesthesia produced by Fluothane, the intensity of the second heart sound becoming greater relative to the first heart sound.

2. Four electroencephalographic patterns were discerned during anaesthesia produced by Fluothane, and a good correlation could be shown to exist between these patterns and the concentration of the inhaled vapour of Fluothane in most instances.

3. No constant correlation could be defined between the changes in the heart sounds and either the concentration of the inhaled vapour of Fluothane or the electroencephalographic patterns produced by this drug.

4. Preliminary attempts to employ the changes in heart sounds during Fluothane anaesthesia as a guide to anaesthetic depth have been unsuccessful.

RÉSUMÉ

Nous avons donné l'anesthésie à 125 malades avec un dérivé ethane nouveau-venu: le Fluothane (CF_3CHClBr); chez huit de ces malades, nous avons dépisté des contractions ventriculaires prématurées ou un rythme nodal. Ces effets

nuisibles sur le cœur de l'anesthésie au Fluothane, nous les avons attribués soit à un surdosage de l'agent anesthésique, soit à de l'hypoventilation malgré toutes les précautions prises pour éviter celle-ci en recourant à la respiration assistée et même à la respiration contrôlée

Nous avons noté le fait que les bruits cardiaques étaient fréquemment inverses au cours de l'anesthésie au Fluothane et nous avons pensé qu'en amplifiant ces bruits nous pourrions les employer comme indices de la profondeur de l'anesthésie et moniteurs de l'imminence de la toxicité cardiaque. Alors nous avons enregistré simultanément des phonocardiogrammes et des électrocardiogrammes sur un Sanborn Twin-Beam Optical Recorder et des électroencéphalogrammes sur un anesthésiographe Edin (model 555) avant et pendant l'anesthésie au Fluothane chez 15 malades soumises à de la chirurgie gynécologique. Nous avons essayé d'établir une relation entre les changements dans les bruits du cœur et la profondeur de l'anesthésie telle qu'indiquée par les tracés électroencéphalographiques et/ou la concentration des capteurs de Fluothane inhalées

Comme résultats, nous avons réalisé que les bruits cardiaques ne sont pas toujours inverses au cours de l'anesthésie au Fluothane, et, par contre, cette inversion peut survenir précocement au cours de l'administration de l'anesthésie. Nous n'avons pas pu établir de relation constante de cette inversion ni avec la concentration des vapeurs de Fluothane inhalées ni avec le tracé électroencéphalographique enregistré au cours de cette anesthésie, bien qu'il soit possible d'en établir une, dans la plupart des cas, entre la concentration des vapeurs inhalées et les tracés électroencéphalographiques. Nous en arrivons à la conclusion que, bien que l'inversion des bruits cardiaques apparaisse fréquemment au cours de l'anesthésie au Fluothane, il n'est pas possible d'utiliser cette inversion comme signe clinique de la profondeur de l'anesthésie

REFERENCES

- 1 JOHNSTONE, M The Human Cardiovascular Response to Fluothane Anaesthesia Brit J Anaesth, 28 392 (1956)
- 2 BRYCE-SMITH, R & O'BRIEN, H D Fluothane A Non-Explosive Volatile Anaesthetic Agent Brit Med J, 2 969 (1956)
- 3 STEPHEN, C R, BOURGEOIS-GAVARDIN, M, FABIAN, L W, GROSSKREUTZ, D C, DENT, S & COUGHLIN, J Fluothane A Preliminary Report Anesthesiology, 18 174 (1957)
- 4 BRYCE-SMITH, R & O'BRIEN, H D Some Observations on Fluothane Proc Roy Soc Med, 50 193 (1957)
- 5 RENCE, W B, CULLEN, S. C & HAMILTON, W K Observations on the Heart Sounds during Anesthesia with Cyclopropane or Ether Anesthesiology, 17 26 (1956)
- 6 RAPPAPORT, M B & SPRAGUE, H B Physiologic and Physical Laws that Govern Auscultation, and their Clinical Application The Acoustic Stethoscope and the Electrical Amplifying Stethoscope and Stethograph Am Heart J, 21 257 (1941)
- 7 LUISADA, A. A & ARAVANIS, C Phonocardiography as a Clinical Method of Examination. Med Clin N A, 235 (Jan, 1957)
- 8 BEST, C H & TAYLOR, N B The Physiological Basis of Medical Practice Sixth edition. Baltimore Williams & Wilkins Co (1955)
- 9 WRIGHT, S. Applied Physiology. Ninth edition New York Oxford University Press (1952)
- 10 LITTLE, D M, Jr, & GIVEN, J B Unpublished data