LIGHT HALOTHANE ANAESTHESIA WITHOUT MUSCLE RELAXANTS FOR ATRIAL DEFIBRILLATION BY EXTERNAL DIRECT-CURRENT SHOCKS*

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ATRIAL FIBRILLATION is one of the prevalent chronic disorders of the cardiac rhythm encountered in clinical practice. Its presence, even in the absence of symptoms, is far from innocuous. In addition to increasing the risk of embolization into the systemic circulation it decreases the mechanical efficiency of the heart muscle.^{1,2}

Until recently, drug therapy in the form of quinidine was the only available method for terminating such an ectopic rhythm. The disadvantages associated with the administration of quinidine are well known. These include difficulty of administration, unreliability, and toxic reactions, ranging from gastro-intestinal upset to hypotension and sudden death.³

For these reasons, the introduction of a new electronic method for converting cardiac arrhythmias into sinus rhythm has awakened considerable interest. It consists of depolarization of the heart across the intact chest with a brief, high-energy direct-current capacitor discharge delivered electronically during a safe period of the cardiac cycle. This procedure has been designated as cardioversion and the instrument is referred to as a cardioverter. Compared to quinidine and a-c shocks, this method is safer, simpler, and more effective, which explains its already widespread use in the treatment of atrial fibrillation.⁴⁻⁶

Cardioversion of atrial fibrillation is usually carried out under general anaesthesia because of the rather unpleasant sensations produced by the passage of the electrical discharge across the chest wall. Lown *et al* use repeated doses of intravenous thiopental, while Oram *et al*, and Grogono combine it with succinylcholine and sometimes halothane (Table I).⁵⁻⁸ The technique that we have developed involves the use of halothane-nitrous oxide-oxygen. In our opinion, the light, stable, and easily controllable anaesthesia without undue cardiorespiratory depression provided by this combination seems to be more suitable for cardioversion than that obtained with intermittent injections of thiopental with or without succinylcholine.

After briefly describing the distinct advantages of direct current and discussing the electrical susceptibility of the heart, this report will summarize our experience with this method of light halothane anaesthesia without muscle relaxants, which has been used in 24 patients with chronic atrial fibrillation successfully treated by external d-c shocks.

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TABLE I
TECHNIQUES OF ANAESTHESIA OR SEDATION USED FOR CARDIOVERSION

	Lown	Oram and Grogono	Stock
Premedication	Pentobarbital, 100 mg	Meperidine 50–100 mg, hyoscine 0.4 mg	Secobarbital 100 mg, 1 m, meperidine 100 mg 1 m
Induction	Thiopental	Thiopental 250 mg succinylcholine 40 mg	—
Maintenance	Repeated doses of thiopental	Thiopental + succinylcholine or halothane 0.5–1.0% + succinylcholine	—
Recovery	3–5 minutes	—	—

DIRECT CURRENT VS ALTERNATING CURRENT

Considerable experimental investigation and clinical work have confirmed the superiority of direct-current over alternating-current countershocks in the treatment of cardiac arrhythmias^{5,6}

It was found by Lown and associates that the use of alternating-current shocks in dogs with sinus rhythm often resulted in serious disturbances of cardiac rhythm (Table II). In the animals so treated, the shock was followed by ventricular and atrial fibrillation, respectively, in 20 per cent and 70 per cent of cases, while acute ischaemic electrocardiographic changes were observed in 90 per cent of the animals. Within a week 35 per cent of the animals tested were dead.

TABLE II
EFFECTS OF D-C AND A-C SHOCKS IN DOGS WITH SINUS RHYTHM (LOWN)

	D-c shocks (%)	A-c shocks (%)
AF	0	70
VF	1.6	20
ST segment changes	33	90
Mortality	0	35

AF = atrial fibrillation, VF = ventricular fibrillation

In contrast, when direct current was used in animals with sinus rhythm, atrial fibrillation was never observed, ventricular fibrillation occurred after 1.6 per cent of the test shocks, and electrocardiographic changes compatible with myocardial ischaemia were noted in 33 per cent of the animals. None of the dogs died.

Clinically as well as experimentally administration of direct-current discharges in cases of ventricular fibrillation brought about conversion to sinus rhythm in many cases where alternating current had failed^{9–11}. However, the 1.6 per cent incidence of ventricular fibrillation which accompanied direct-current shock in animals prevented the elective clinical application of this method in the treatment of atrial arrhythmias. On the basis of a systematic study of the electrical

excitability of the heart muscle Lown *et al* developed an electronic device permitting the elimination of this hazard of ventricular fibrillation

THE ELECTRICAL SUSCEPTIBILITY OF THE HEART

Physiologists have long been aware of the susceptibility of the T wave interval of the electrocardiogram to ventricular fibrillation (the vulnerable period)¹² Lown *et al* suspected that ventricular fibrillation occurring after direct current discharge possibly resulted from striking this vulnerable phase of the cardiac

FIGURE 1 Fibrillation during zones charted on EKG. Further details in the text. Reproduced from the instruction manual of The Lown Cardioverter by courtesy of Dr. Bernard Lown (Cardiovascular Laboratories, Department of Nutrition, Harvard School of Public Health) and American Optical Company Medical Division.

cycle.⁵ A systematic exploration of this period of the cardiac cycle established that direct current countershocks given during the T wave period induced ventricular fibrillation in 35 per cent of cases while such shocks produced no arrhythmias when administered outside the T wave (Fig. 1). Careful analysis of their findings further indicated that ventricular fibrillation occurred only when the countershock was applied during the 30 milliseconds which precede the apex of the T wave.

In addition, the downslope of the R or S wave was found to be vulnerable to atrial fibrillation.

On the basis of the above findings, these authors developed an electronic synchronizer capable of releasing an electrical impulse in any preselected phase of

the cardiac cycle, thus avoiding the dangerous zones, especially that of ventricular fibrillation. This was found to be easy to carry out since the d-c discharge from a capacitor does not exceed 2.5 milliseconds (Table III).

TABLE III
ELECTRICAL CHARACTERISTICS OF A-C AND D-C DEFIBRILLATORS

	A-c unit (Zoll)	D-c unit (Lown)
Shock duration (msec)	100-300	2.5
Voltage (volts)	150-750	600-3000
Recovery time between shocks (sec)	0	15
Calibration	Volts (150-750)	Watt-seconds or Joules (10-400)
Power-line demand (amp)	20	5

Thus, the use of synchronized direct-current capacitor discharges has become a safe and effective method of treatment for atrial fibrillation.

MATERIAL AND METHOD

Twenty-four consecutive patients in chronic atrial fibrillation were lightly anaesthetized for cardioversion. There were seven men and seventeen women whose ages ranged from 21 to 63 years. All but three had previously had closed mitral commissurotomies. In most of them the postoperative administration of quinidine had failed to re-establish sinus rhythm.

The equipment used was the Lown cardioverter, it consists of four electronic components (Fig. 2).

1 A d-c defibrillator which delivers a single monophasic electrical discharge of 2.5 milliseconds' duration. It is calibrated in energy units ranging from 0 to 400 watt-seconds.

2 A synchronizer which releases the electrical pulse in any preselected phase of the cardiac cycle.

3 A cardiometer which monitors the patient's EKG and provides an R wave as a reference for the synchronizer.

4 A cardioscope for continuous display of cardiac activity.

TECHNIQUE

All patients were treated prophylactically with anticoagulant and quinidine therapy in order to decrease the possibility of peripheral embolization and the recurrence of atrial fibrillation. Most of them were also digitalized.

Premedication

One hour prior to the procedure, the patients were premedicated with 50 to 75 mg of meperidine and 25 mg of promethazine intramuscularly. The usual vagolytic drugs were omitted.

FIGURE 2 Photograph of the Lown cardioverter

Anaesthesia

In the operating room the patient is placed supine on the table with his left arm at a right angle to the trunk. The sphygmomanometer is placed on the right arm, a 20-gauge needle is inserted in a brachial vein, and a slow drip of 5 per cent dextrose in water is started. The monitoring electrodes of the cardioverter are attached to the patient (active electrodes on right arm and left leg, neutral ground on right leg). The electrocardiographic derivation so obtained (lead II) is displayed on the cardioscope and can also be recorded on an E K G machine connected to the cardioverter. Then the electronic synchronizer is preset to deliver the discharge in the terminal portion of the QRS complex.

Anaesthesia is induced by mask with nitrous oxide and oxygen delivered by semi-closed circuit with CO₂ absorption at a flow rate of 6 litres per minute. The anaesthetic mixture is composed of equal parts of nitrous oxide and oxygen to which an increasing amount of halothane vapour is added. With a 2 per cent concentration of halothane, loss of consciousness supervenes in about 4 or 5 minutes. At this point, respiration is assisted manually to compensate for any slight degree of respiratory depression and the insertion of a nasopharyngeal cannula prevents any high respiratory obstruction. Muscle-relaxant drugs are not used and tracheal intubation is not performed.

As soon as the patient is anaesthetized, halothane is discontinued, anaesthesia being maintained by nitrous oxide and oxygen in equal proportions. The electrodes of the defibrillator, whose surfaces have been smeared with an electrically conductive jelly, are placed firmly on the chest. Before the discharge is released, all personnel in the operating room are warned not to touch the table or the patient, in order to avoid any accident.

At the time of the shock, the patient's thoracic muscles contract markedly. This is usually accompanied by a slight jerk of the arms and an audible sigh. The effectiveness of the shock is established by the appearance of a tall and pointed P wave which is often preceded by atrial or ventricular disturbances of rhythm (Fig 3). Arterial and venous pressures show very little change while the pulse slows by 10 to 20 beats a minute (Fig 4).

Anaesthesia then is discontinued and only pure oxygen is given until the patient wakes up, usually 3 to 5 minutes later. Generally speaking, the whole procedure takes from 15 to 20 minutes. In cases where the anaesthesia time has to be prolonged (for example, when the electric countershock has to be repeated or haemodynamic studies have to be made) the same anaesthetic mixture can be used to maintain a light level of anaesthesia. Under these circumstances, a concentration of 0.5 to 1 per cent of halothane is usually sufficient.

RESULTS

Both anaesthesia and cardioversion were well tolerated by all the patients. No difficulties or complications were encountered with the use of halothane-nitrous oxide-oxygen. This technique of light anaesthesia without muscle relaxation seems to be quite suitable for this procedure.

FIGURE 3 Electrocardiographic tracings during cardioversion

FIGURE 4 Electrocardiogram, arterial pressure and venous pressure recorded during cardioversion

DISCUSSION

Although simple in application the technique of anaesthesia described involves details which are worthy of further comments

Premedication without Atropine

The patients scheduled for cardioversion are usually very apprehensive at the idea of being submitted to an electrical shock. They require good sedation with

out producing undue depression of their vital functions. The combined use of meperidine and promethazine appears to be ideally suited for this need. Atropine, which causes tachycardia and drying of bronchial secretions, is better avoided in patients with atrial fibrillation.

Advantages Associated with Halothane

Lown *et al* , Oram *et al*., and Grogono used thiopental as the main anaesthetic agent whereas we have substituted halothane. This has definite advantages over repeated doses of intravenous thiopental. At the concentration used, it produces a light anaesthesia, even and easy to control without any risk of serious cardio-respiratory depression or prolonged sleep.

Muscle-Relaxant Drugs

Grogono employed succinylcholine to prevent contractions of the thoracic muscles due to the passage of the electrical discharge across the chest.⁵ This muscular twitch is quite different from a convulsion crisis. It is single, brief, and harmless. We feel that the muscle relaxants, although necessary for electroconvulsive therapy, are rather superfluous in the management of atrial fibrillation by the method described above.

Furthermore, the use of succinylcholine is far from innocuous. Many authors have reported the frequent occurrence of disturbances of cardiac rhythm following the intravenous injection of repeated doses of succinylcholine.¹³⁻¹⁵ This is especially true of partially atropinized or fully digitalized patients. Therefore succinylcholine is better avoided in patients subjected to cardioversion, who are usually under digitalis medication and tolerate atropine poorly. In addition, the intravenous administration of quinidine following succinylcholine to enhance the depolarizing effect of d-c countershock may cause a return of paralysis when the patient is recovering from succinylcholine.⁵

Sedation or General Anaesthesia

In an attempt to demonstrate that the electrical discharge was not painful, Stock has recently maintained that general anaesthesia was unnecessary for cardioversion.¹⁶ According to him, although the patients were awake and alert at the time of the electrical discharge, they barely recalled it and had difficulty in describing their symptoms or reactions. This must be interpreted as the result of the heavy sedation used by Stock before the procedure (100 mg of meperidine 1 m and 100 mg of secobarbital 1 m).

On the other hand, Lown does not entirely share this opinion. He stated that with the present equipment and unless the use of larger electrodes allows a reduction in the effective amount of the energy needed, general anaesthesia would still be indicated for cardioversion, especially in very anxious patients, those with significant cardiomegaly and long-standing arrhythmias, and patients in the immediate postoperative period following valvular surgery.

Therefore, the question which remains to be answered is whether to give those patients a large dose of a sedative, the prolonged and unforeseen effects of which can bring about a dangerous depression of vital functions, or rather to submit

those patients to a light, even, and short anaesthetic without endangering a cardiorespiratory system which is already precarious. The second solution seems definitely the more satisfactory of the two.

We feel, therefore, that light general anaesthesia consisting of a mixture of halothane-nitrous oxide-oxygen, without muscle relaxation, offers the greatest margin of safety and comfort to the patient with chronic atrial fibrillation to be treated by cardioversion.

SUMMARY

A technique of light general anaesthesia without muscle relaxant using halothane-nitrous oxide-oxygen has been described for atrial defibrillation by external direct-current shock. Atropine was omitted from the pre-anaesthetic medication. Endotracheal intubation was not performed.

Twenty-four cardiac patients in chronic atrial fibrillation have been anaesthetized by this technique with satisfactory results. Most of them have been operated upon previously for mitral stenosis and were found to be refractory afterwards to treatment with quinidine. There was no complication in connection with anaesthesia or atrial defibrillation.

The advantage of halothane over repeated doses of thiopental, either alone or associated with succinylcholine, have been evident in our study, especially in cases when additional shocks were necessary, or prolonged haemodynamic studies had to be done. With halothane, it was easier to maintain a light and steady level of anaesthesia without fear of serious cardiorespiratory depression. In our opinion, this technique of light general anaesthesia without muscle relaxation provides the greatest margin of safety and comfort to the patient who needs cardioversion for atrial fibrillation.

RÉSUMÉ

Nous vous avons présenté une technique de narcose légère sans curarisation avec le mélange protoxyde d'azote-oxygène-halothane pour la défibrillation électrique des oreillettes par voie externe. L'atropine a été supprimée de la pré-médication et l'intubation n'a pas été pratiquée.

Vingt-quatre malades fibrillants, qui avaient été pour la plupart opérés antérieurement pour sténose mitrale à cœur fermé et qui étaient par la suite restés réfractaires au traitement par la quinidine, ont été endormis selon cette technique avec des résultats satisfaisants. Aucune complication liée soit à l'anesthésie, soit à la défibrillation électrique n'est survenue.

Le grand avantage de l'halothane sur le penthobarbital seul ou associé à la succinylcholine, c'est qu'il permet d'assurer sans crainte de complication cardiorespiratoire le maintien facile d'une anesthésie légère, sans à-coups, chaque fois qu'il est nécessaire d'administrer plusieurs chocs ou de recueillir des données hémodynamiques sur la défibrillation auriculaire elle-même. De plus, cette méthode d'anesthésie générale légère semble offrir à notre avis un plus grand confort et une plus grande sécurité au malade.

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