SHORT COMMUNICATIONS

MECHANICAL HEART MASSAGER*

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CARDIAC ARREST occurs not infrequently during the course of general surgery and cardiac surgery. Many factors which may precipitate the onset of cardiac arrest are beyond the scope of this article. When cardiac arrest occurs, it is imperative that blood be sent to the brain and other vital organs within three minutes. To accomplish this, the heart has either to be started again or manual massage begun. When manual cardiac massage is properly performed it is possible to resuscitate an arrested heart and keep the patient alive while the heart is being revived.

Experience has shown that there are great variations in the ability of different surgeons to obtain a satisfactory blood pressure from manual cardiac massage. Sometimes the heart may be restored but because of inadequate cerebral circulation during the period of massage the brain suffers irreparable damage and the patient dies.

In other instances the surgeon is able to maintain proper cerebral blood pressures but the heart fails to revive and manual massage has to be discontinued because of fatigue. Such was the situation in October 1955, when a patient suffering from angina decubitus caused by coronary artery disease was given an anæsthetic for internal mammary artery implantation.

When the left chest was opened there was a sudden onset of left ventricular fibrillation and the heart stopped. The pericardium was quickly opened and defibrillation accomplished. Manual heart massage was then performed continuously for eight hours, at the end of which time the patient was still alive. During the hours of manual massage the blood pressure was maintained at 60 mm. Hg or better and the patient required the intermittent administration of nitrous oxide to keep him asleep. Unfortunately the heart did not revive.

This man was kept alive by a pair of hands. His life was literally in the hands of the operator. Each time the surgical resident attempted massage there was no blood pressure and the pupils became dilated. At the end of eight hours manual massage was discontinued because of fatigue, and the patient died.

This was a most disturbing experience, particularly since the patient was alive until the last minute, requiring nitrous oxide to keep him asleep. The autopsy failed to show any evidence of a fresh coronary occlusion or infarction. If cardiac massage had been more adequate and could have been maintained longer, there is a possibility that such a heart might have recovered. After this experience, work was begun upon a mechanical apparatus adapted to apply resuscitation and massaging action to the human heart.

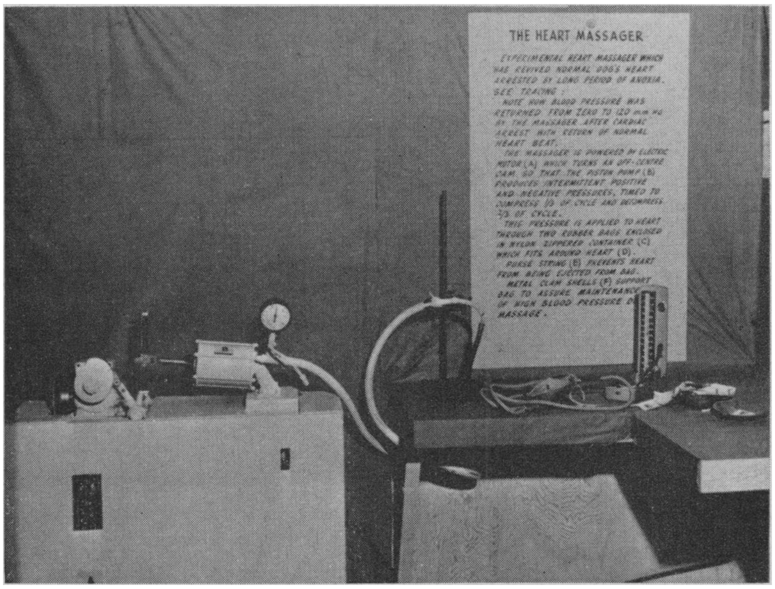

Fig. 1a.—Photograph of mechanical heart massager displayed at Canadian Medical Association Annual Meeting, June 1956. On the table the part which fits around the heart surrounded by metal cups is shown surrounding a balloon which was attached to a sphygmomanometer, showing a type of pressure obtainable when the massager was demonstrated.

The apparatus to be described has two major parts, the mechanical massager and the pumping power unit.

1. *Mechanical massager*—The part of the mechanical heart massager which has been the most difficult to design is the part applied to the heart. The shape of the heart makes it difficult to apply mechanical pressure without damaging the myocardium or coronary vessels. In June 1956 the apparatus was exhibited at the Annual Meeting of the Canadian Medical Association (Fig. 1a).

The main element of the apparatus consists of a flexible pouch or sac (10) which is provided along one side with a zipper closure (12) and along the open top with a drawstring (14). A pair of flexible diaphragms (16a) (16b) are sewn to the interior walls of the flexible pouch (10), so as to constitute an airtight flexible

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The pumping mechanism was planned and made by Electrodesign, Montreal.

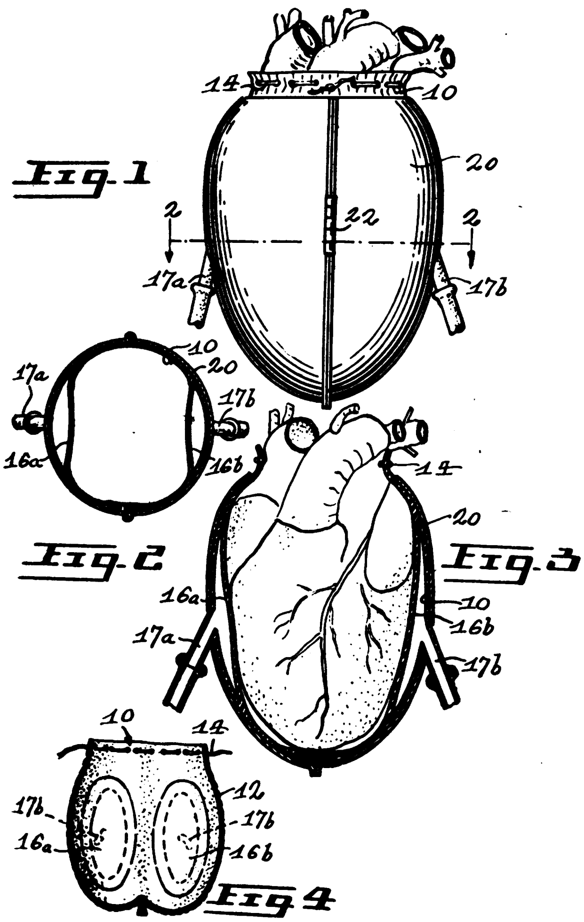

Fig. 1.—Metal shells were used at first to maintain pressure on heart. These were difficult to apply and subsequently found not to be necessary. Fig. 2.—Cross-section of construction of sac and diaphragms. Fig. 3.—Vertical sections of sac and diaphragms. Fig. 4.—Sac opened, showing position of flexible diaphragms and purse string.

membrane which can be expanded or contracted by the application and release of fluid pressure, i.e. air. The material used for the sac was nylon and the flexible membranes were made of rubber. The membranes (16a) (16b) are connected to conduit portions (17a) (17b) which are attached to the source of fluid pressure. In use the sac or pouch (10) was placed beneath the heart; that is, one side was placed beneath the heart and the other side folded over by the zipper closure (12). The sac envelopes the heart as shown in Fig. 3. The open top is constricted through the use of a drawstring (14) so as to prevent a portion of the heart being forced out through the top when pressure is applied.

In order to exert the pressure applied by the flexible membranes (16a) (16b) against the walls of the heart, the pouch (10) was surrounded by a hollow shell (20) made of rigid material. This was shaped to follow the heart contour. The shell (20) as it was at first was hinged but later was made of two separate halves which were held together by clamps. The ends of the conduit (17a) (17b) pass through suitable openings provided in the walls of the shell (20) where pulsations of fluid pressure are applied through the membranes (16a) (16b). Because of the rigid nature of the outer shell (20) the pressure in the membranes is directed against the walls of the ventricles individually and simultaneously. By this apparatus it was possible to maintain blood pressure and revive the animals' hearts which had been arrested by stopping the artificial respiration pump. The outer shells were difficult to apply and in some animals there was difficulty with venous return because of constriction at the base of the heart caused by the metal shells. Because of this a complete revision of the massaging part of the apparatus was carried out (Figs. 4a and 4b). It was realized that the metal cups were not necessary if smaller diaphragms were made.

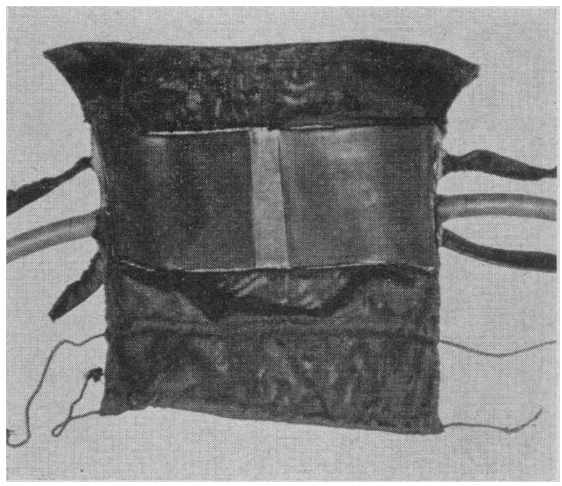

Fig. 4a.—New massager showing 2″-square siliconised rubber diaphragms connected by a piece of rubber placed on the inside of nylon cloth which has drawstrings at both ends; nylon cloth strips on its opening sides are used to tie the massager in position. Attached to the outer surface of the flexible diaphragms are similar conduits as shown in Figs. 1, 2 and 3.

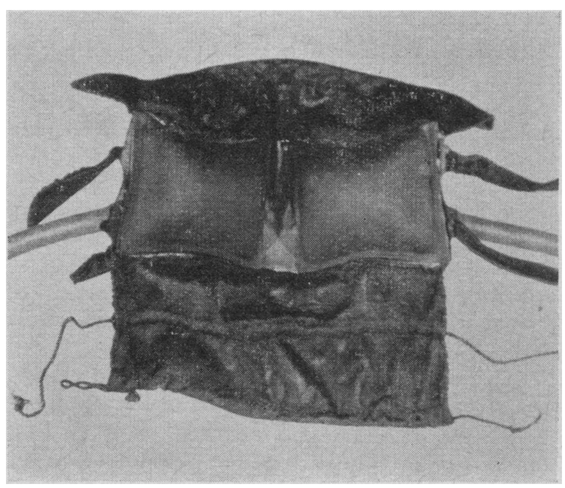

Fig. 4b.—Diaphragm inflated.

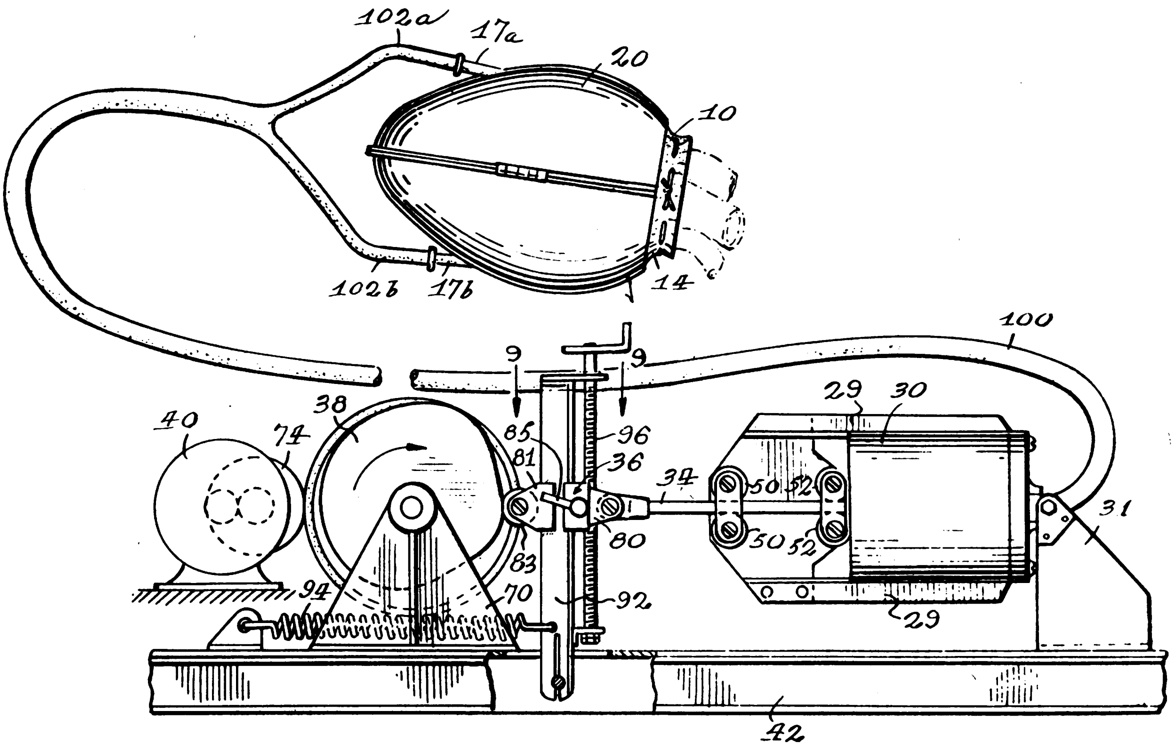

Fig. 5.—Diagrammatic sketch showing the mechanism of the pump—the off-centre cam (38) which permits a one-third compression stroke of piston (30) and two-thirds diastolic stroke run by an electrical motor.

The sac is made of non-stretchable cloth, nylon, open at the top and bottom and on one side. The top and bottom parts are controlled by drawstrings after the sac is placed around the heart. The open part of the sac is closed by tying the strips of non-stretchable cloth attached to the wall of the sac on each side of the opening. Sewn to the *inside wall* of the sac are two 2″-square rubber diaphragms which are connected to the same conduit as in the original massager. By placing the diaphragm on the inside of the non-stretchable sac it has been possible to do away with the hollow metal shells (20) used in the original apparatus. This model can be quickly applied to the heart and is adjustable to hearts of different sizes. Further, it is easy to open it, apply defibrillating electrodes and, when defibrillation has been accomplished, quickly close the sac and resume mechanical massaging. It is planned in later models to incorporate defibrillating electrodes in the walls of the sac.

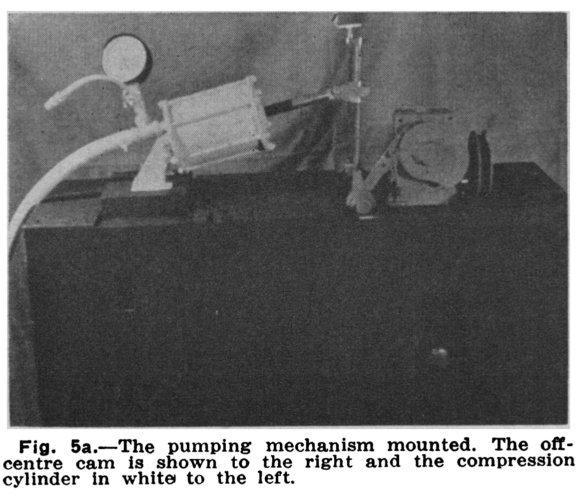

Fig. 5a.—The pumping mechanism mounted. The off-centre cam is shown to the right and the compression cylinder in white to the left.

2. *Pumping mechanism* (Figs. 5 and 5a)—The pulsating fluid pressure supplied to the interior of the flexible diaphragms is produced by means of a double acting air pump having a direct connection to the conduit leading from the flexible diaphragms. The double acting air pump is controlled by a cam (38) having a predetermined contour so that the pressure fluctuation of the flexible diaphragms is divided into: (1) a one-third pressure stroke, and (2) a two-thirds suction stroke per revolution, which corresponds to the one-third systolic contraction and two-thirds diastolic relaxation of the normal heart cycle. The speed of the pump can be varied (see Fig. 5).

TEST OF MECHANICAL HEART MASSAGER

In medium-sized dogs the blood pressure has been recorded continuously on a drum by canulasition of the carotid artery. The left thorax is opened and the artificial respiration pump stopped. The course of the blood pressure as recorded is shown in Fig. 6. Anoxia at first causes the blood pressure to rise, and then it gradually falls until the heart ceases to beat.

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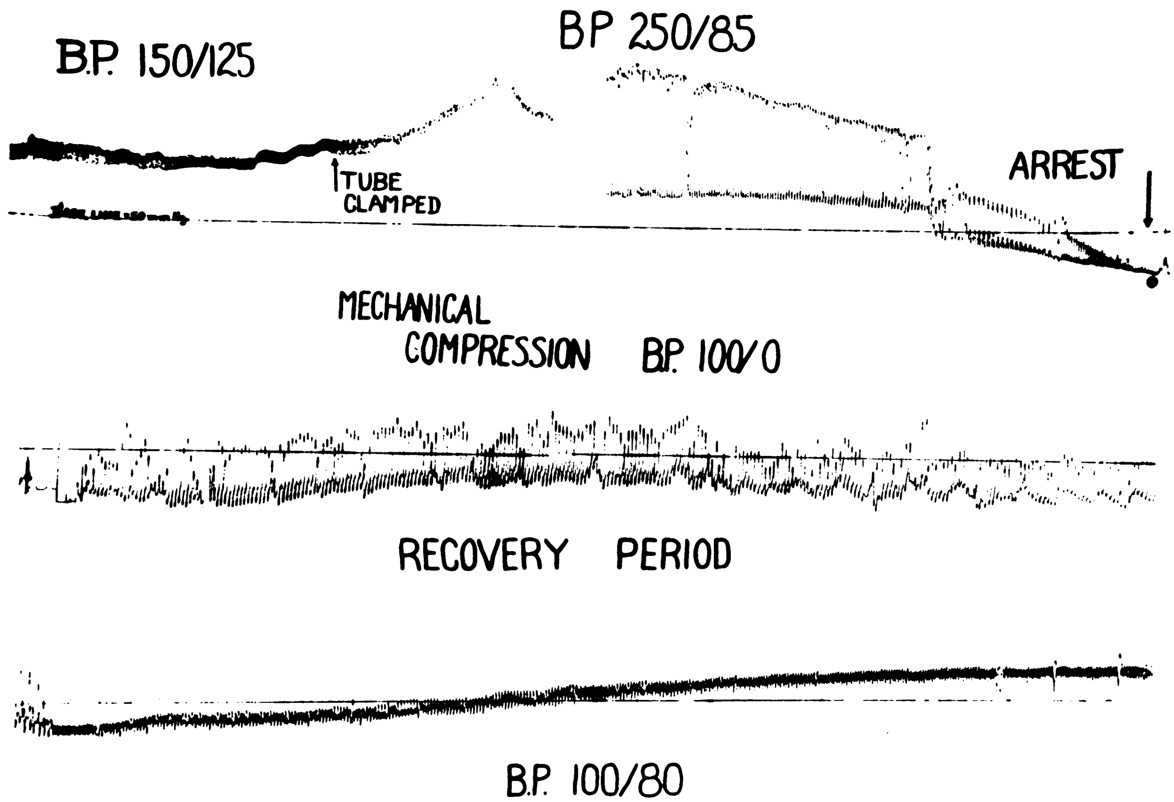

Fig. 6.—Record of the carotid blood pressure of dog showing a blood pressure of 150/125. Baseline was 50 mm. Hg. Artificial respiration tube was clamped. Blood pressure rose to 250/85 and finally dropped to zero with cardiac arrest. Ten minutes after the commencement of anoxia and two minutes after total arrest, mechanical compression of the heart was started, with return of blood pressure to 100. During the massaging the blood pressure was maintained between 60 and 100. Fifteen minutes after commencement of massaging, the heart re-started with return of blood pressure to 100/80, and complete recovery of animal.

This takes about eight minutes. Two minutes after there has been no recorded blood pressure, with no evidence of heart beats (usually from 8 to 10 minutes after the starting of the anoxic period), the cardiac massager is applied to the right and left ventricles through an open pericardium. The effect of the cardiac massager on the blood pressure is immediate. It has been possible in all animals to maintain a blood pressure above 80 mm. Hg. The blood pressure can be kept at this level without difficulty until the heart starts to beat, as has happened in all five of the animals thus treated. All have had complete recovery. In one instance the heart was massaged 15 minutes before it started to beat again. In no case has there been any evidence of coronary artery, myocardial or gross epicardial damage. The shape of the myocardial massager with its 2″ square inflated diaphragms corresponds roughly to the surface of the palms of the hands, which are frequently used during manual massage.

This is a preliminary report. Much more study on animals must be carried out and further refinements have to be made on both the massager and the pumping mechanism. However, it is now safe to say that an arrested heart may be massaged by a mechanical apparatus which maintains an adequate blood pressure during the period of cardiac resuscitation resulting in a return of cardiac action and survival of the animal.

STUDY OF BLOOD CHOLESTEROL LEVELS IN OBESE DIABETICS USING PHENMETRAZINE (PRELUDIN)*

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BLOOD CHOLESTEROL is a factor worthy of consideration in the problem of diabetes mellitus. Hypercholesterolæmia is often implicated in the degenerative complications of diabetes. One is concerned about the fact that the percentage of diabetics with degenerative complications is the same as that of diabetics with hypercholesterolæmia, namely about 85%.

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