CLOSED-CHEST CARDIAC MASSAGE

W. B. Kouwenhoven, Dr. Ing., James R. Jude, M.D.
and
G. Guy Knickerbocker, M.S.E., Baltimore

When cardiac arrest occurs, either as standstill or as ventricular fibrillation, the circulation must be restored promptly; otherwise anoxia will result in irreversible damage. There are two techniques that may be used to meet the emergency: one is to open the chest and massage the heart directly and the other is to accomplish the same end by a new method of closed-chest cardiac massage. The latter method is described in this communication. The closed-chest alternating current defibrillator that was developed in our laboratories has proved to be an effective and reliable means of arresting ventricular fibrillation. Its counter-shock must be sent through the chest promptly, or else cardiac anoxia will have developed to such a degree that the heart will no longer be able to resume forceable contractions without assistance. Our experience has indicated that external defibrillation is not likely to be followed by the return of spontaneous heart action, unless the counter-shock is applied within less than three minutes after the onset of ventricular fibrillation.

A study was undertaken of means of extending this time limitation without opening the chest. A method was sought that would provide adequate circulation to maintain the tone of the heart and the nourishment of the central nervous system. This method was to be at once readily applicable, safe to use, and requiring a minimum of gadgets.

One of the first attempts at enhancing circulation in the arrested heart was a closed-chest method reported by Boehm in 1878. Working with cats, he grasped the chest in hands at the area of greatest expansion and applied rhythmic pressure. His results were quite striking in some series of tests. Tournade and co-workers reported that by an abrupt compression of the thorax of a dog in cardiac arrest blood pressures of 60 to 100 mm. Hg could be produced. No survival studies were given. Killkik and Eve reported that the rocking technique of artificial respiration, by which a patient is tilted about 60 degrees in each direction from the horizontal plane, will produce a change in the blood pressure at the atrium from 38 to 76 mm. Hg. Eve hypothesized that this change will produce sufficient blood flow to nourish the heart and the brain. In 1947 Gurvich and Yuniev found that a capacitor discharge sent through the chest of a dog would be followed by a resumption of the cardiac function if applied not later than one or one and one-half minutes after the onset of induced ventricular fibrillation. They reported that this time limitation might be extended to as long as eight minutes by rhythmical application of pressure on the thorax in the region of the heart. In tests which lasted 10 to 15 minutes 19 animals survived and 17 died. These authors, however, gave no specific information as to the method of application of the pressure. Rainer and Bullough treated cardiac arrest in children by lowering the head about 10 degrees, placing one arm underneath the patient's knees, and flexing the legs and buttocks against the chest. They reported eight successful resuscitations in patients ranging from 8 weeks to 13 years in age. Stout in 1957 reported the successful use of this method in one adult.

Experiment

With dogs used as the experimental animal, cardiac arrest in the form of ventricular fibrillation was induced. In the initial experiments more than 100 dogs, weighing from 5 to 24 kg. (11 to 52 lb.), were used in testing various methods of moving blood by massaging the intact chest. A safe and effective method of "massaging the heart" without thoracotomy was developed. Adequate circulation for periods as long as 30 minutes was easily maintained with the dog in ventricular fibrillation. A closed-chest defibrillating shock would result in the immediate return of normal sinus rhythm in such animals.

In fig. 1 are shown sections taken from the recording of the variations in blood flow, blood pressure, and electrocardiogram of a dog whose heart

* Lecturer in Surgery (Dr. Kouwenhoven), Resident Surgeon (Dr. Jude), and Assistant in Surgery (Mr. Knickerbocker), John Hopkins University School of Medicine.
was in ventricular fibrillation for eight minutes. Simultaneously recorded on a four-channel recorder were the blood flow in a carotid artery, the instantaneous and average pressures in a femoral artery, and the cardiogram. The tracings in the first column of figure 1 are the normal values of these respective phenomena immediately before fibrillation was induced by a 110-volt shock. The second column shows the build-up of blood flow and pressures that took place when closed-chest cardiac massage was started, one minute after the onset of fibrillation. The third column is a record of what took place about seven minutes later. Note that vigorous fibrillation has been maintained throughout the entire period. The fourth and last column shows the immediate return of normal sinus rhythm when the closed chest defibrillator shock was given. The electrocardiograph was temporarily disconnected when the counter shock was applied.

Method.—The method of closed-chest cardiac massage developed during these animal studies is simple to apply; it is one that needs no complex equipment. Only the human hand is required. The principle of the method as applied to man is readily seen by consideration of the anatomy of the bony thorax and its contained organs. The heart is limited anteriorly by the sternum and posteriorly by the vertebral bodies. Its lateral movement is restricted by the pericardium. Pressure on the sternum compresses the heart between it and the spine, forcing out blood. Relaxation of the pressure allows the heart to fill. The thoracic cage in unconscious and anesthetized adults is surprisingly mobile. The method of application is shown in figure 2. With the patient in a supine position, preferably on a rigid support, the heel of one hand with the

![Fig. 1.—Record of blood flow, pressures, and electrocardiogram of dog whose heart was in ventricular fibrillation for eight minutes. I: normal initial values; II: start of closed-chest massage; III: seventh minute of massage; IV: closed-chest defibrillation.](image1)

other on top of it is placed on the sternum just cephalad to the xiphoid. Firm pressure is applied vertically downward about 60 times per minute. At the end of each pressure stroke the hands are lifted slightly to permit full expansion of the chest. The operator should be so positioned that he can use his body weight in applying the pressure. Sufficient pressure should be used to move the sternum 3 or 4 cm. toward the vertebral column.

Closed-chest cardiac massage provides some ventilation of the lungs, and if there is only one person present in a case of arrest, attention should be

![Fig. 2.—Position of hands during massage of adult.](image2)

concentrated on the massage. If there are two or more persons present, one should massage the heart while the other gives mouth-to-nose respiration.

Clinical Application.—About nine months prior to time of writing, at Johns Hopkins Hospital, clinical application of closed-chest cardiac massage was successfully illustrated in a case of cardiac arrest. Initially, it was felt that the method might be useful in treating arrest in children, whose ribs are known to be flexible, but that it would not be effective in adults. This latter assumption was proved to be incorrect, since the chest of an unconscious adult was found to be remarkably flexible.

During the 10 months prior to writing this method alone has been applied to 20 patients aged from 2 months to 80 years. In 13 of these patients artifi-
cial respiration was applied simultaneously with the massage; the duration of the massage varied from less than 1 minute to 65 minutes. In seven cases records were obtained of either the blood pressure or of the electrical activity of the heart (by electrocardiogram) during the episode. Systolic pressures during massage ranged from 60 to 100 mm. Hg. Figure 3 shows the blood pressures recorded on an adult. The hearts of 3 of the 20 patients treated were in ventricular fibrillation, and all were defibrillated by a closed-chest A. C. defibrillator shock. All 20 patients were resuscitated and, at time of writing, 14 of them are alive without central nervous system damage and without undergoing thoracotomy.

Report of Cases

Four cases of cardiac standstill and one case of ventricular fibrillation are reported below.

Case 1.—A 35-year-old woman was admitted in July, 1959, through the emergency room, with acute cholecystitis. After premedication with 8 mg. of mor-

Figure 3.—Blood pressure produced in an adult by closed-chest cardiac massage.

Fig. 4 (case 5).—First defibrillation shock, followed by standstill and return of fibrillation.

phine sulfate, 0.4 mg. of atropine, and 100 mg. of pentobarbital (Nembutal), she was taken, one and one-half hours later, to the operating room where anesthesia was induced with thiopental sodium and succinylcholine. Intubation was attempted, but difficulty was encountered, with inability to ventilate the patient. She became pulseless and cyanotic and her respirations disappeared. External cardiac massage was instituted, without artificial respiration. After two minutes a strong transthoracic pulse developed, together with spontaneous shallow respirations. Blood pressure returned to 130/80 mm. Hg and pulse to 100 beats per minute. Intubation proceeded thereafter, with some difficulty but no further cardiac problems. The patient underwent a cholecystectomy for acute hydr. of the gallbladder and had an uneventful recovery. She was discharged five days later without neurological signs or symptoms and has been entirely normal on subsequent follow-up examinations.

Case 2.—A 9-year-old boy with chronic mastoiditis was admitted and on Nov. 5, 1959, had a mastoidectomy. Postoperatively the patient was very cyanotic. Respirations stopped in the recovery room but a weak heart beat was obtainable. The child was given mouth-to-mouth respiration and cardiac assistance with external cardiac massage for about 30 seconds. He responded to this with good return of all functions and had no further difficulty. On Nov. 17, 1959, the patient was again returned to the operating room for a left mastoidectomy, after preoperative medication with 60 mg. of pentobarbilal and 0.25 mg. of scopolamine. The patient was vomiting continuously on arrival in the anesthesia room, and his pulse was irregular. The induction of anesthesia was stormy because of the patient's nausea. He was given open-drop anesthesia with fluothane and intubation was performed with ease. At this point his pulse suddenly disappeared, as did the blood pressure and apical beat. Closed-chest cardiac massage was carried out for one minute and the patient responded with a good return of pulse, blood pressure, and respirations. The operation was canceled, and the patient returned to the ward. He had no further difficulties and no central nervous system damage.

Case 3.—An 80-year-old woman was admitted with a large tumor of the thyroid and had a tracheostomy with biopsy of the thyroid. She was returned to the operating room three days later for a definitive procedure after premedication with 100 mg. of pentobarbital and 0.5 mg. of atropine. She was given anesthesia with thiopental sodium and fluothane. Succinylcho-

line in divided doses was also given. Intubation was performed through the tracheostomy. A few minutes thereafter the blood pressure became unobtainable and the administration of fluothane was immediately stopped. There was no apical or peripheral pulse. External cardiac massage was begun immediately and carried out for a period of two minutes. Mephenetamine (Wyamine), 30 mg., and phenylephrine (Neo-Synephrine) hydrochloride, 1 mg., were given intravenously. A good pulse and
Case 4.—A 12-year-old boy developed sudden cardiac arrest on Jan. 22, 1960, while undergoing an excision of a verrucous linearis of the scalp. Under thiopental and fluothane anesthesia the patient became anoxic, with an irregular pulse followed by arrest. Local infiltration with epinephrine-saline solution may have contributed. The pupils dilated and the patient was pulseless and without respiration for at least one minute before external massage was begun. After one minute of massage a good pulse and pressure returned. The operation was completed without difficulty. Postoperatively the patient had transitory blindness and bilateral Babinski reflex. Nystagmus was also present. Over 36 hours the neurological findings returned to normal. The remainder of the postoperative course was uneventful.

Case 5.—A 45-year-old man was brought to the emergency room of the hospital with excruciating substernal chest pains radiating down both arms on Jan. 6, 1960. He was conscious when admitted. While removing his clothing, preparatory to examination, he fell to the floor. His respirations ceased, and there were no heart sounds and no pulse. The house officer immediately began closed-chest cardiac massage. An electrocardiogram showed the heart to be in ventricular fibrillation. The patient began to breathe spontaneously. Ten minutes after the start of external massage artificial respiration by endotracheal tube was first begun. External heart massage and artificial respiration were continued for 20 minutes, while a closed-chest A. C. defibrillator was being brought to the emergency room.

Two defibrillator shocks were given; the first (fig. 4) temporarily arrested the fibrillation. After the second shock (fig. 5) the heart resumed natural beats. An electrocardiographic tracing (fig. 6) taken two hours later showed an anterior myocardial infarction. Subsequent tracings confirmed the diagnosis.

The patient had no sign of central nervous system damage, except amnesia for the period of cardiac massage plus two hours. He has followed, without incident, the usual course of treatment for myocardial infarction.

Summary

Closed-chest cardiac massage has been proved to be effective in cases of cardiac arrest. It has provided circulation adequate to maintain the heart and the central nervous system, and it has provided an opportunity to bring a defibrillator to the scene if necessary. Supportive drug treatment and other measures may be given. The necessity for a thoracotomy is eliminated. The real value of the method lies in the fact that it can be used wherever the emergency arises, whether that is in or out of the hospital.

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References