Cardiac Arrest

Report of Application of External Cardiac Massage on 118 Patients

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Cardiac arrest is the sudden and unexpected cessation from whatever cause of circulation producing cardiac activity. This term once applied only to the sudden death associated with anesthesia and surgery. In the last decade attempts at resuscitation from sudden cardiac arrest have been made outside of the confines of the operating and recovery room areas. Successes have been reported. The desire to do something effective in such unfortunate situations has engendered the interest of many medical disciplines and even extended beyond the limits of the hospital.

Cardiac arrest may occur as primary cardiac collapse or secondary to failure of pulmonary ventilatory function. It may occur from many causes such as (1) vagovagal stimulation, (2) anesthesia, (3) hypoxia, (4) adverse reaction to drugs, (5) cardiac catheterization, (6) radiographic dye injection, (7) myocardial infarction, (8) electric shock, (9) drowning, and (10) diseases such as Adams-Stokes. The sudden cessation of circulation may take the form of cardiac asystole, ventricular fibrillation, or profound hypotension. While the final treatment of each may vary, the immediate aim is prompt restoration and maintenance of the oxygenation system by artificial ventilation and artificial circulation.

History

Cardiac arrest first became a problem of major concern following the introduction of general anesthesia in 1842. Studies on its etiology have subsequently been made and preventive and therapeutic measures outlined. The basic steps in treatment have been altered but little since the first attempted resuscitation by Niehaus in 1880. Widespread acceptance of mouth-to-mouth artificial respiration has, however, simplified the method of providing ventilation, and Beck et al. in 1947 reported the first successful open chest defibrillation of a human heart by a technique developed by Hooker, Kouwenhoven, and Langworthy in 1933.

Various methods of artificially providing circulation have been investigated. Schiöll in 1874 performed the classical experimental work. His approach was to perform a thoracotomy and circulate blood by intermittent compression of the dog's chloroform arrested heart. Boehm in 1878 provided circulation with moderate success by intermittent compression of the external thorax of the cat. Igelsrud in 1901 applied Schiff's method of direct cardiac massage through the open chest in the first successful resuscitation of a stilled human heart. The use of a direct approach through the diaphragm was later reported. Crile and Dolley in 1903 maintained circulation in the dog for brief periods of time by pressing rhythmically on the intact thorax and ribs over the heart. Crile also restarted a human heart by this technique. Ranter and Bulloch and Stout had clinical success in applying forceful thrusts of the legs against the chest hoping thereby to have increased venous return and stimulated cardiac action. Tournaire et al. in 1934 described the experimental application of a method of intermittent compression of the thorax for movement of blood. Gurvich and Yuniev applied this method on dogs with survival of up to 8 minutes of cardiac arrest in ventricular fibrillation. Reports of very forceful positive pressure respira-
tion causing cardiac compression and circulation have been made.\textsuperscript{23}

Attempts to stimulate cardiac activity from a standstill have been made by the use of forceful blows over the precordium or by plunging a needle into the myocardium.\textsuperscript{24,25} The external electric pacemaker has been applied to the well-oxygenated myocardium for acute heartblock arrest such as occurs with Stokes-Adams attacks.\textsuperscript{26}

\textbf{Resuscitation Problem}

The major requirement in cardiac resuscitation is rapid diagnosis followed by immediate reinstitution of the oxygenation system by artificial means. Speed is the factor of greatest importance here more than in any medical emergency. Only 3 to 5 minutes are available before irreversible brain damage occurs.\textsuperscript{27} Because of the extent and nonreversible nature of open chest cardiac massage, procrastination for absolute proof of diagnosis has often been prolonged to dangerous limits. The rapid application of an effective and easy method of pulmonary ventilation, providing the first part of the oxygenation system, is readily made. The second part of the oxygenation system, circulation, has required the use of open thoracotomy and direct cardiac massage. Trained medical personnel, specific equipment, and appropriate location and time have been necessary. General acceptance and wide use of this therapy have thus been delayed or prevented. A less drastic method of artificial circulation and one more socially acceptable in any surroundings would avert these and other criticisms of the open chest treatment. The possibility of immediate application of cardiac massage would prevent the fruitless consequences of delayed treatment. It would open the door to resuscitation of the drowned, the electrocuted, and the victim of sudden death from coronary thrombosis. A second chance would thereby be given a large group otherwise doomed by inadequate, late, or no therapy.

\textbf{Method and Material}

A new method of cardiac resuscitation by external cardiac massage has previously been reported.\textsuperscript{28,29} During the experimental development of a closed chest defibrillator, it was discovered that dogs could be kept viable while in ventricular fibrillation for as long as 30 minutes by intermittent compression of the lower sternum against the thoracic spine. This was termed "closed chest cardiac massage" or "external cardiac resuscitation."

The effectiveness of closed chest cardiac massage in man is based upon the location of the heart (Fig. 1), and the flexibility of the mid-thorax of the unconscious individual. The heart fills most of the space between the lower sternum and the thoracic spine and is restricted from lateral motion by the pericardium. It is compressed during rhythmic downward thrusts of the lower sternum (Fig. 2).

With exact placement of pressure on the lower sternum the relaxed thorax gives at the costochondral and chondrosternal junctions. Some motion occurs in the ribs themselves and in the costovertebral ligaments. With 60-80 intermittent compressions per minute, adequate circulation can be maintained to sustain viability of the brain and other vital organs.

The negative intrathoracic pressure created between compressions by the resilient expansion of the intact thorax enhances the cardiac venous filling phase.\textsuperscript{30,31} Although pressure is exerted on the venous system with each compression, because of the heart valves the resultant pressure differential is forward.

In the past 2\% years the applied therapy for sudden circulatory arrest at The Johns Hopkins Hospital has been that of closed chest cardiac massage.
Because of the employment of this simple method early treatment has been the rule. There were 138 cardiac arrests in 118 patients. Thirty-five arrests were of the classical type in the operating and recovery room areas. An additional 28 arrests occurred in pre- and postoperative cardiac surgery patients, but none during cardiac surgery were considered. Twenty-four arrests were in patients with acute myocardial infarctions, and 51 were in a miscellaneous group with arrests anywhere in the hospital from the emergency room to diagnostic laboratories to the patient’s room.

**Results**

About 30% of the arrests were in the form of ventricular fibrillation. About 44% of the cardiac arrests were documented by electrocardiographic or arterial blood pressure recordings or direct palpation of the heart or a major intra-abdominal blood vessel. In the nondoncumented cases the same criteria were used as if open chest massage were to be applied. In such instances the absence of carotid or femoral pulse, audible heartbeat, and respiration indicated arrest of circulation. Seventy-eight percent had cardiac action restored, but only 60% were resuscitated. The criterion for successful resuscitation was the return of the patient’s prereast central nervous system and cardiac status.

The arrests summarized in Table 1 are discussed by the type of patient as follows: operating and recovery room patients, pre- and postoperative cardiac surgery patients, myocardial infarction patients, and miscellaneous patients.

**Operating Theater and Recovery Room.—** This group of 35 arrests in 31 patients includes those with cardiac arrest due to vagovagal stimulation, adverse reaction to anesthesia, postoperative hypoxia, or a combination of these together with blood loss or other less common factors. Immediate resuscitative measures were instituted with use of artificial respiration, external cardiac compression, and cardiotonic drugs. Response was immediate in most instances with the duration of compression lasting from 1 to 10 minutes in 27 cases of arrest. Six others required 15 to 20 minutes of massage, 1 required 30 minutes, and 1 required 65 minutes. Of the 22 cases occurring immediately preceding or during surgery, only 4 had the operative procedure delayed. Three were subsequently operated upon and without incident. Five arrests occurred in the form of ventricular fibrillation but all were readily externally defibrillated.

All but 3 patients in this group returned to their prearrest central nervous system and cardiac status. Of the failures, 1 died of persistent cardiovascular collapse after 8 hours without completely awakening; 1 succumbed without awakening 20 hours after resuscitation due to intracerebral hemorrhage following removal of a cerebellar hemangioblastoma; and 1 initially awakened with only slight evidence of cerebral damage but one week later gradually became decerebrate. Eight patients succumbed in the postoperative period from their primary disease. Two patients showed transitory central nervous system changes but did not require specific treatment.

**Pre- and Postoperative Cardiac Surgery.—** There were 21 patients undergoing 28 arrests in this group. This type of patient is more likely to develop cardiac arrest because of the frequent presence of a failing myocardium with low cardiac output. Evidence of arrest was present by electrocardiographic tracing or arterial pressure in all but 3. Time of cardiac massage varied from 1 to 75 minutes. Nineteen were massaged 10 minutes or less. In 4, permanent defibrillations could not be accomplished. While 19 (68%) were revived to their prearrest central nervous system and cardiac status, only 2 (10%) survived the postoperative period. The low ultimate survival was considered to be due to the magnitude of the surgery and the severity of the primary cardiac disease.

**Myocardial Infarction.—** Potentially one of the most valuable applications of the closed chest massage technique is in the case of sudden, unexpected death from coronary vascular disease. In such a situation it was used on 24 patients with 24 arrests. All had the electrocardiographic pattern or good history for an acute myocardial infarction before the sudden arrest of the oxygenation system. The age of this group varied from 40 to 82 years with 17 being 60 years of age or older. Twenty-one arrests were in sudden ventricular fibrillation, and 3 were in asystole. External massage was performed.

### Table 1.—Summary of Cardiac Arrests Treated with External Cardiac Massage

<table>
<thead>
<tr>
<th>Patients</th>
<th>21</th>
<th>31</th>
<th>38</th>
<th>35</th>
<th>50</th>
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<td>30</td>
<td>10</td>
<td>50</td>
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<td>100</td>
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<tr>
<td>Resuscitated arrests</td>
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<td>20</td>
<td>10</td>
<td>50</td>
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<td>Aysotole</td>
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<td>60</td>
<td>30</td>
<td>50</td>
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<td>100</td>
</tr>
<tr>
<td>Ventricular fibrillation</td>
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<td>10</td>
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<td>50</td>
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<td>100</td>
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<td>Proof of arrest</td>
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<td>30</td>
<td>20</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Cardiac action restored</td>
<td>30</td>
<td>10</td>
<td>70</td>
<td>30</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Leaving hospital (patients)</td>
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<td>40</td>
<td>60</td>
<td>20</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

* Seven arrests during anesthesia induction and 11 during surgery.
for from 2 to 120 minutes. In 23 arrests it was continued over 20 minutes, and in 17 it was continued over 30 minutes. There was EKG evidence of arrest in all but one. All those in ventricular fibrillation were at least temporally externally defibrillated requiring 1 to 10 attempts. Five patients (20%) were resuscitated to their prearrest central nervous system and cardiac status, and 3 patients (13%) left the hospital. Temporary cardiac activity lasting up to 9 hours was obtained in 7 other patients. Five patients had the massage initiated by ambulance attendants outside of the hospital. One of these survived. Attempted application of the pacemaker was made in 2 patients, and this resulted in delay in artificially reestablishing the oxygen system in one of these.

Miscellaneous.—In extending circulatory resuscitation outside of the operating theater it was inevitable that a sizable number of patients with cardiac arrest would be found who could not be specifically classified. Of 51 arrests in 42 such patients, 36 were felt to be secondary to hypoxia, 3 to hyperkalemia, 9 to acute cardiovascular collapse, and 3 to myocardial irritability. The hypoxia was due to numerous causes, the most common of which were convulsions or severe cerebral depression. The length of massage varied from 2 to 90 minutes with 18 being over 10 minutes in duration. Although 25 of the arrests (55%) were reverted to the prearrest central nervous system and cardiac status, the ultimate long-term survival was very low due to the irreversibility of the inciting condition. Only 3 patients (7%) encompassing 4 arrests had long-term survival.

One patient with cardiac arrest, early in the series had his chest opened and internal massage performed after a brief 4-minute period of external compression during which no cardiac drugs had been employed. With the use of epinephrine and internal massage, cardiac action was restored. This child had had a long unknown period of total anoxia and died of cerebral damage 3 weeks later. Seven others all had obvious central nervous system damage occurring after prolonged periods of total anoxia. Death followed in 2 to 48 hours except for one patient who died after 10 days.

Several patients in the miscellaneous group had multiple arrests due to the unrelenting nature of their disease. Although repeatedly resuscitated to their prearrest central nervous system and cardiac status, ultimate death usually resulted.

This simple technique of cardiac resuscitation opened a virtually untapped field of use outside of the operating theater area. The decision as to whom these methods were to be applied was difficult. In the early application of this new procedure its indications perhaps were much broader than they now are. Many of this miscellaneous group, although fitting into the criterion of sudden death, were not entirely unexpected to suddenly expire. Many had irreversible underlying diseases with little chance for even a brief relatively normal existence.

Comment

Terminology.—Application of the term "external cardiac massage" has been made to the method of artificial circulation described here. This has been done to equate it with the similar objective of internal cardiac massage. While the term "massaging" does not readily describe either procedure, it is one which has been widely applied for almost a century. A more descriptive term would be "cardiac compression," but for consistency the term "cardiac massage" is employed.

Steps in Cardiac Resuscitation.—The initial steps in resuscitation from cardiac arrest are (1) rapid diagnosis, (2) artificial ventilation, and (3) artificial circulation. A plateau is arrived at with the accomplishment of these first 3 steps, whereby the central nervous system is protected. Time is then available to pursue the following steps at a more leisurely pace: (4) drug therapy, (5) electrocardiogram, (6) defibrillation if necessary, (7) continued cardiovascular and pulmonary support, and (8) postresuscitation therapy. These steps and other important points will be elaborated upon.

Indications and Contraindications for Resuscitation.—Not all dying patients should have cardiopulmonary resuscitation attempted. Some evaluation should be made before proceeding. The cardiac arrest should be sudden and unexpected. The patient should not be in the terminal stages of a malignant or other chronic disease, and there should be some possibility of a return to a functional existence. The rigid time limit of 3 to 5 minutes since the onset of arrest of cardiac output should not be exceeded. In regard to the latter when there is a genuine question of the duration of arrest, resuscitation should be attempted.

Diagnosis.—The literature on cardiac arrest has repeatedly emphasized that the most common denominator in the unsuccessful resuscitation attempts is that of delay. With the use of external cardiac massage delay is unnecessary. There is no need for 100% proof that arrest is present as this method of resuscitation, if properly applied, is not dangerous even if the heart is normally contracting. Rapid diagnosis, by checking the major pulses, precordial heart beat, pupil constriction, and respirations can be made in 15 to 20 seconds. Their absence indicates the presence of functional cardiac arrest and calls for immediate application of artificial respiration and circulation.

Pulmonary Ventilation.—Revival from cardiac arrest also requires ventilation. Circulation of unoxegenated blood does not protect the central nervous system or oxygenate the myocardium. Resuscitation should always be considered as cardiopulmonary resuscitation.
Satisfactory ventilation of the lungs can be provided by the technique of expired air resuscitation (mouth-to-mouth or mouth-to-nose). The body is well oxygenated by this simple method when used together with cardiac massage. After the oxygenation plateau has been reached, tracheal intubation may be performed and positive pressure bag breathing or an automatic respirator used. It is important to remember that the central nervous system must be reoxygenated within 3 to 5 minutes, and therefore time should not be taken to attempt tracheal intubation until the brain has been protected.

With certain types of cardiac arrest spontaneous respiration may resume and continue as long as oxygenated blood is circulated to the brain stem. In such cases only cardiac massage may be necessary. In other situations even though spontaneous cardiac action has resumed, respirations may not have returned or be very weak. Continued ventilatory assistance may be necessary. A tracheostomy is very valuable if respiratory assistance is maintained beyond 24 hours.

**Anatomical Considerations.**—External cardiac massage has been employed on patients ranging in age from the newborn to 82 years. Only slight pressure on the lower sternum with 1 or 2 fingers is necessary in the newborn or infant. Use of the heel of one hand is sufficient for older children. Both hands transmitting pressure through the heel of the one placed against the lower sternum are required in the adults. External cardiac massage is performed more efficiently if the patient is on a solid surface.

The anatomical construction of the patient's chest determines the pressure that is necessary for adequate artificial circulation. A thin person with a short anterior-posterior diameter of the thoracic cage can have external cardiac massage applied simply. The barrel chested individual with emphysema requires more pressure on the sternum but otherwise poses no problem. Only in one case in this series was the thoracic cage so fixed from old, calcified, pulmonary tuberculosis and consolidation that external cardiac compression was impossible. Attempts at emergency thoracotomy in this patient likewise met with no success due to the fixed ribs, underlying pleural synphysis, and solid pulmonary parenchyma.

**Criteria of Effectiveness of Cardiac Massage.**—Evidence that effective oxygenated circulation is present can be obtained by observation of the patient. His color will improve and his pupils become constricted. Spontaneous gasping respirations may occur. There may be swallowing and movement of the extremities. When resuscitation is stopped for a few minutes, the pupils will often dilate. With each cardiac compression a second person should be able to palpate a pulse in the carotid, femoral, or brachial arteries. Likewise the blood pressure with each compression can be determined by a blood pressure arm cuff or intra-arterial cannula and should be in the range of 90 to 150 mm. Hg systolic (Fig. 3).

**External Massage vs. Internal Massage.**—An opportunity for comparing the methods of internal and external artificial circulation has occasionally presented itself. This has usually been due to the lack of an external defibrillator and the need for open defibrillation. Although pressure tracings have not been obtained in this hospital, personal communication with others32,33 show that external cardiac massage provided arterial blood pressure as high as direct internal massage in the same patient.

The pathological changes occurring in the heart with direct internal massage have been well outlined.34 Severe ecchymosis and muscle bruising may result and are thought to be detrimental to good myocardial function. Hearts with external massage applied for periods of up to 120 minutes have been studied in the laboratory. No gross or microscopic damage has been seen except for rare slight bruising and occasional petechiae at the site of needle puncture.

Cardiac venous filling is considered to be enhanced by the maintenance intact of the pleural integrity with external massage. With relaxation following each external compression the sternum recoils outward increasing intrathoracic negative pressure and thereby aiding in the venous filling phase of the heart. This point is considered to be of great importance in providing a good cardiac

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**Fig. 3.**—Examples of arterial blood pressure developed with external cardiac massage. Age and size of chest did not greatly affect ability to obtain good blood pressure.
output in the arrested heart. Experimental studies have substantiated this thesis.\textsuperscript{39, 51}

If evidence of adequate circulation is absent during use of external cardiac massage, the resuscitator may desire to open the chest and apply direct massage. When the chest is already open during surgery, direct massage is applied if necessary. There are definite indications for open thoracotomy and direct cardiac massage. Such is the case where cardiac action ceases after severe blunt or penetrating trauma to the thoracic cage. The etiology of arrest may then be tension pneumothorax, cardiac puncture, pericardial tamponade, or laceration of a major blood vessel.

\textbf{Drug Therapy.}—Proper utilization of intracardiac or intravenous cardiotonic, vasopressor, and antacid pharmacological agents will greatly aid cardiac resuscitation. They may make the difference between success and failure.

Epinephrine, 0.5 mg. intravenously or directly into one of the chambers of the heart is given as soon as possible. If ventilation and circulation have been initiated immediately, the heart will be sufficiently oxygenated so that the possibility of ventricular fibrillation resulting will be very small. This or other cardiotonic drugs (25-50 mg ephedrine; 45 mg. mephenetermine; 2-3 mg. phenylephrine hydrochloride; or 0.1-0.2 mg. isoproterenol hydrochloride) may be used. Continued massage will distribute the drug evenly throughout the myocardium and the rest of the body. An elevation of the systolic and diastolic massage pressure will occur with resultant improvement in perfusion (Fig. 4).

Calcium chloride or calcium gluconate is beneficial if weak cardiac action returns. One-half or 1 gm. of the 10% solution is given intravenously or into the heart blood.

Continued cardiac arrest, even though the circulation is artificially maintained, will result in metabolic acidosis. Sodium bicarbonate is beneficial in maintaining blood pH close to the normal value. Forty-four mEq. (3.75 gm.) can be given intravenously every 5 to 10 minutes if necessary in adults. One-half this dose is used in children. Cardiac action and responsiveness to vasopressors are improved.

Continued infusion of strong concentrations of metaraminol (Aramine) bitartrate or levartenol bitartrate may be necessary to support blood pressure after cardiac action is restored. In cases of difficulty in defibrillation or maintaining defibrillation, quinidine gluconate or procainamide hydrochloride are valuable adjuncts.

\textbf{Electrocardiogram.}—In every case of cardiac arrest an electrocardiogram should be obtained as soon as possible. Time is available to obtain this when, after providing artificial ventilation and circulation, the plateau of a protected central nervous system is reached. The EKG will indicate the type of arrest present and whether continued massage and drugs alone are necessary or if defibrillation must be performed. Later the EKG will show the return of electrical activity or give evidence of cardiac death. Since the chest is not open, the EKG becomes the eye of the resuscitator as to cardiac electrical activity.

\textbf{Defibrillation.}—Thirty per cent of the cardiac arrests in this series were with the heart in ventricular fibrillation. This group required a special procedure to defibrillate the heart before spontaneous cardiac action could be returned. External electrical defibrillation developed by Hooker and Kouwenhoven\textsuperscript{35, 57} was first applied to man by Zoll\textsuperscript{28} in 1952. The efficacy of this procedure is well established. The fibrillation must be vigorous and rapid in order for defibrillation to be successful in restoring normal heart action. This will occur with a well oxygenated myocardium. Epinephrine also will improve the quality of the fibrillations. Four-hundred and forty volts A.C. applied across the longitudinal axis of the heart for 0.25 seconds has proven the most effective for external electrical defibrillation.

In certain circumstances the likelihood of ventricular fibrillation being present is very great and an EKG may not be immediately available. Since the prognosis is dependent to a large part upon the rapidity with which spontaneous cardiac output can be resumed, it is desirable to reestablish cardiac action as soon as possible. Experimental studies on dogs have shown that 440 volts alternating current shocks for 0.25 seconds have not had any detrimental effect on the normally beating heart. It is possible that the blind application of the defibrillating shock may prove valuable when cardiac action has not resumed after 5 or 6 minutes of good ventilation, external massage, and drug therapy. Because an EKG could not be immediately obtained, this was performed on 3 patients in this

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig4.png}
\caption{Effect of epinephrine on blood pressure developed during external cardiac massage in dog. External massage was delivered with consistent pressure by mechanical device. Femoral arterial pressure before intravenous injection of 0.5 mg. epinephrine was 110/40 mm. Hg. Two minutes later it was 190/60 mm. Hg.}
\end{figure}
series with immediate resumption of cardiac action in all of them. Also, 2 of the authors have accidentally received the full voltage without incident.

Criteria for Cessation of Efforts at Resuscitation.—In this series efforts at resuscitation were continued as long as 120 minutes. Successful return to the prearrest central nervous system and cardiac status occurred up to 90 minutes. Artificial circulation by external massage is stopped when there is a return of a strong spontaneous pulse and blood pressure of 70 mm. Hg or greater. Intermittent support of circulation by massage may still continue to be necessary. Artificial respiration is continued until spontaneous respirations are adequate and not tiring to the patient.

When resuscitation is unsuccessful criteria for discontinuing artificial respiration and circulation are evident by signs of cardiac or central nervous system death. Cardiac death is evident by absence of return of any electrocardiographic activity within one hour of continuous support of the oxygenation system. It is also evident by deterioration of the electrocardiographic complex such as widening of the QRS and slowing of the electrical activity. Central nervous system death is evident by dilated, fixed pupils and by loss of signs of viability such as gasping respirations.

Cardiac resuscitation will be only partially successful with the return of a good heart beat and cardiac output. The patient may still have evidence of brain damage and need to be treated intensively with hypothermia and support of the respiratory system. If after 72 hours of such treatment there are no signs of improvement in the central nervous system, further attempts at resuscitation can be considered fruitless. Any sign of the central nervous system regaining function, however, can be considered favorable and worthy of continued support. Failure of the myocardium in the recovery period is evident by gradual fall in the blood pressure unresponsive to intensive vasopressor therapy. Only sudden cardiac rearrest should have all resuscitative steps reinstituted.

Postresuscitation Therapy.—Continued treatment is important even though the patient has been resuscitated. The extent of this care will depend on the etiology of the arrest and on how long it lasted. The primary disease problem must be treated so that a recurrence of the arrest will not occur. The patient is closely observed, and the EKG is monitored in an intensive care unit. Continued artificial respiration and support of the cardiovascular system are given as necessary.

If there is any evidence of damage to the central nervous system, further cerebral edema must be prevented. Some brain damage is evident if the patient does not immediately awaken. More severe damage is evident by dilated, fixed pupils or persistent apnea. In such cases the body temperature is lowered to 32° to 34° C. (89.6° to 93.2° F.) and maintained for 72 hours or until there is no further evidence of cerebral deterioration. 20

Criteria for Successful Resuscitation.—The steps in cardiac resuscitation are directed to get the body to spontaneously support its own oxygenation system. When properly applied soon enough it is hoped to return the patient to his prearrest status in respect to both his heart and central nervous system. This was the object in this series and was 60% successful. The aim thereafter is to insure survival by treating the inciting disease by specific medical therapy. The patient with cardiac arrest who suddenly loses his ability to support his cardiovascular system indicates the seriousness of his condition. In a large group of attempted resuscitations long-term survival may not be frequent. The act of resuscitation itself cannot be expected to cure the inciting disease. It is successful and fulfills its objective if the patient returns to the prearrest cardiac and central nervous system status.

Data on ultimate survival are included in Table 1. Patients who had their arrest in the operating room or recovery room had a high rate of long-term survival. These patients usually had curable diseases, and the etiology of the arrest was readily corrected. Cardiac arrests in postoperative cardiac surgery patients and in patients in the medical wards, in the emergency room, and in other locations of the hospital usually were a reflection of the seriousness of their disease process. The resultant ultimate long-term survival rate was small since the primary disease frequently could not be permanently alleviated.

Complications.—The method presented is not free of side effects. Application of sternal pressure in the proper location, however, will usually avert most side effects (Fig. 5).

<table>
<thead>
<tr>
<th>Author</th>
<th>Operating Room Survived</th>
<th>Outside of Operating Room Survived</th>
<th>Total Survived</th>
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<tr>
<td>Coute</td>
<td>200</td>
<td>412</td>
<td>612</td>
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<td>Dale</td>
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<td>Stephenson et al.</td>
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<td>37</td>
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</tr>
<tr>
<td>Jude et al.</td>
<td>52</td>
<td>32</td>
<td>84</td>
</tr>
</tbody>
</table>

1. Breakdown into location of arrest not reported.
2. Includes 21 pre- and postoperative cardiac surgery and recovery room patients.

Table 2.—Results of Internal and External Cardiac Massage.

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Fractured or cracked ribs are the most common complication. Only when they are so numerous that a flail chest results are they of major concern. In this situation the loss of the elastic recoil of the thoracic cage decreased cardiac venous filling and thereby cardiac output with massage. Rib fractures can be avoided or at least the number decreased by applying pressure on the lower sternum only and not on the ribs. Relaxation of the costochondral and chondrosternal junctions then occurs, and they become the main points of motion.

Pneumothorax must be checked for whenever transpleural injections into the ventricles of the heart are made. The injections were the etiology of this complication in 2 patients. One other had an apparent rupture of an apical pulmonary bleb. All responded well to chest catheter drainage.

Subcapsular liver hematoma or rupture may result from placement of pressure over the xiphoid or epigastrium. This has been seen only twice in this series. In experiments on the dog, however, because of the high lying diaphragm and liver and the long anteroposterior diameter of the thoracic cage, this complication was not infrequently observed. In infants and young children this possible complication must be kept in mind.

A fractured sternum has been seen once. This complication occurs due to placement of pressure high on the sternum near the sternal angle. In this location the sternum is depressed only by fracturing it.

Rupture of the heart itself has not been observed in this series. However, at autopsy a 67-year-old woman with multiple pulmonary infarcts was found to have a tear of the inferior vena cava at its junction with the right atrium. Such complications might occur from massive pressure as they are also known to occur with direct manual massage.

Trauma to pulmonary tissue has not been observed. Some intercostal muscle hemorrhage, however, has not been an unusual finding. Hemopericardium or hemothorax have not been seen. Bone marrow emboli to the pulmonary arteries has been found in over 50% of those patients coming to autopsy.

**Ancillary Equipment.**—The cardiac pacemaker has been suggested for use as the primary treatment of cardiac arrest. It may be effective if immediately applied to the heart in vagovagal arrest and is valuable with heart block in Stokes-Adams attacks. However, the pacemaker will not be effective on a hypoxic myocardium. Time should not be taken to apply a pacemaker until the oxygenation system of the body has been reestablished.

Mechanical devices to replace the human hand in external cardiac massage are under development and study. Their place in cardiac resuscitation is not yet established. While they are not likely to be the primary approach in reestablishing blood flow, they may form a secondary or supportive role. Clinical and experimental observations have shown them to be very effective in maintaining circulation.

**Comparison of Results With Those of Internal Massage.**—Table 2 shows the results of internal massage in several series and those of this paper with external cardiac massage. It is difficult to compare published statistics since the exact definition of arrest and location are not always well defined. Only a few series are available that give data on cardiac arrests outside of the operating theater. Our previous experience with open chest massage away from the operating room provided no survivals except in the emergency room and recovery room areas.

**Summary and Conclusions**

External cardiac massage was the primary form of artificial circulation in 138 cardiac arrests in 118 patients. Sixty per cent of the patients were returned to their prearrest central nervous system and cardiac status. Twenty-eight patients (24%) were long-term survivals with well functioning central nervous systems.

The technique of resuscitation used, incorporating effective artificial ventilation and artificial circulation, provided an immediate protective plateau of a functioning oxygenation system. Restitution of spontaneous cardiac and respiratory action was then accomplished by drug and other specific therapy if needed.

This simplified technique of cardiac resuscitation is available to anyone, at anytime, and in any location.

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References are available from the authors upon request.