CLINICAL PROGRESS

The Resuscitation Problem

By Hamilton Southworth, M.D.

Resuscitation is best defined as the restoration of life after apparent death. From prehistoric time death has been considered to be the permanent cessation of breathing, and resuscitation up to 20 or 30 years ago consisted of artificial respiration. Modern medicine, however, has recognized the primacy of the heart beat. Death is now generally determined by cessation of the heart beat, even though it is well known that individual tissues, and even the heart itself, may be capable of full function and therefore of revivification for minutes or hours after legal death. In the dissolution of the total organism it makes little difference whether cardiac arrest or respiratory arrest occurs first; the other is bound to follow rapidly. If both have occurred, the individual is technically dead and resuscitation involves an attempt to restore life, which is different from the physician’s usual efforts to preserve life. By the same token, resuscitation should not be regarded as either cardiac or respiratory but as a combined operation best defined by the term cardiorespiratory.

History
Schiff in 1874 first recorded the successful restoration of the heart beat in experimental animals by cardiac massage. Niehau5 5 years later is quoted as the first to attempt massage of the human heart after cardiac arrest, but success was not reported until Starling and Lane in 1902 resuscitated by subdiaphragmatic massage an individual who suffered an arrest during an abdominal operation. In 1904 Crile3 brought back to life a 12-year-old girl whose heart had apparently stopped during brain surgery. An adrenalin solution was perfused into the brachial artery, and when Crile held the bottle high over his head there was a sudden violent shaking of the chest and spurting of blood into the bottle. The operation was finished uneventfully. In 1926 Chevalier Jackson successfully resuscitated a man by cardiac massage who suffered cardiac arrest during gallbladder surgery. Since then in operating rooms all over the world cardiac massage with assisted respiration has been progressively recognized as the basic technic for resuscitation. The first successful defibrillation of the human heart by electric shock seems to have been performed by Beck and his associates in 1947.4

Physiologic Basis
The term cardiac arrest is generally used to mean the cessation of any effective heart beat. The commonest form is cardiac standstill, in which no ventricular contraction of any type occurs. This may be initiated by sinus arrest with no subsequent idioventricular activity or there may be only ventricular standstill with continuing atrial beats but complete atrioventricular block. Somewhat less common is ventricular fibrillation, in which the rapid and completely disorganized contraction of individual groups of ventricular muscle fibers is totally ineffective in producing any forward movement of the blood. A third type is occasionally seen, in which the heart is found to be beating very feebly but in a coordinated manner without appreciable effect on the circulation.

From the Department of Medicine, College of Physicians and Surgeons, New York, N. Y.
Regardless of the type of arrest involved, cessation of circulation leads to death of the body’s tissues through hypoxia. Most susceptible to oxygen deprivation are the higher centers of the brain, with the adrenal glands, liver, kidneys, and lower brain centers probably following in that order. Numerous experiments on various animals have shown that cessation of brain circulation for more than 5 minutes generally leads to irreparable damage, while restoration of circulation short of this time limit is followed by a high incidence of complete recovery. Individual and species differences exist, but clinical series in man suggest that 3 to 5 minutes, and perhaps the average figure of 4 minutes, represents the critical time limit for restoration of full cerebration. Thus Cole and Corday\(^5\) report that out of 132 cases of attempted human resuscitation, all of the 33 that resulted in complete recovery were initiated within 4 minutes of the arrest. Success, moreover, is directly correlated with the speed with which cardiac massage and proper ventilation are begun.

In both animals and human beings, it is possible at times to reestablish cardiac and respiratory function in the face of serious brain damage. Thus in Cole and Corday’s series 44 patients revived only to die days, weeks, or months later in various degrees of decerebration, and 2 survived with apparently permanent cerebral impairment. Happily, most of those individuals who are revived after the safe time limit die within a few days, but the few who linger on and the 1 to 2 per cent who become institutional cases are ample warning of the danger of resuscitation once the critical time limit has passed.

Instances of fully successful human resuscitation have been reported after cardiac arrest of 5 minutes or more and raise the question as to how safe it is to be arbitrary about a 4-minute limit. Most of the earlier cases can be dismissed because the delay was measured as the time from the arrest until the heart began to contract spontaneously rather than from the arrest until massage was commenced. In others the accuracy of the time estimation may be questioned in view of the stress and excitement of the moment. But there probably are real variations. Thus in many an operating-room case there has been hypoxia preceding the actual arrest and brain metabolism may already be impaired. And in those cases in which effective pulmonary ventilation is established an appreciable time before cardiac massage can be started, the safe limit may be slightly longer. Thompson has shown that mechanical methods of ventilation in asphyxiated dogs cause a slow advance of blood through the circulation presumably by means of alternate dilatation and contraction of the pulmonary capillaries. Recently, moreover, some evidence has appeared\(^7\) that individuals resuscitated after 5 to 8 minutes of standstill and with apparent severe brain damage may make complete recoveries if promptly subjected to hypothermia that is continued for 2 or 3 days. The rationale underly- ing this maneuver is the theory promoted by Sheldon and co-workers\(^8\) that many of these patients die of cerebral edema rather than of brain-cell necrosis at the time of the initial anoxia. If these results are substantiated, however, the presumption is that the critical time limit will still exist, though it may be lengthened. Whether the incidence of mentally mutilated survivors will be increased or decreased by hypothermia is as yet unknown.

**Resuscitation in the Operating Room**

The great majority of the reported cases of cardiac resuscitation have occurred in the operating room. In this setting the equipment and the trained personnel for cardiac massage and assisted respiration are at once available. Furthermore, surgical procedures under modern anesthesia provide a not inconsiderable incidence of cardiac arrest. Large hospital series suggest that arrest may occur as often as once in every 2,000 anesthetics\(^9\) and that therefore there may be 5,000 instances each year. The rising incidence up to 1952 seems attributable to the increase both in the complexity and the daring of surgery and in the multiplicity of anesthetic agents and associated medications. Basically, however, the precipitating factors in the susceptible indi-
vidual are generally a combination of hypoxia and vagal stimulation. Special emphasis has therefore been placed on prevention. As Flagg has stated,10 "Present emphasis on surgical treatment of cardiac arrest has obscured the fact that cardiac resuscitation is in reality a final desperate supplement to respiratory resuscitation . . . Emphasis should be shifted . . . to the prevention of hypoxia." These statements apply to the situation as generally observed under anesthesia.

Beck has divided the treatment of cardiac arrest into 2 steps: 1. The reestablishment of the oxygen system (the emergency act) by assisted breathing and cardiac massage. 2. The restoration of the spontaneous heart beat. This division is important because it emphasizes the emergency of getting oxygenated blood flowing through the circulation by mechanical means and leaves other considerations, such as defibrillation of the heart, resumption of spontaneous cardiac contractions, and reawakening of the respiratory center, for subsequent consideration. It is beyond the scope of this article to discuss techinics in detail, but the essential steps of the emergency act are (1) to reestablish pulmonary ventilation, preferably by intubation and manual breathing using a bag and 100 per cent oxygen and (2) to open the chest and reestablish the blood circulation by cardiac massage. Once the oxygen system has been reestablished, the heart that was in standstill tends to resume its sinus rhythm but may need manual assistance for a period if the contractions are weak. If fibrillation is present or appears during massage, defibrillation is best carried out after a few minutes by electric shock across the ventricles applied by specially designed electrodes and repeated until the fibrillation is broken. Intracardiac injection of drugs is usually of secondary value. Administration of epinephrine (3 to 5 ml. of a 1 to 10,000 solution) strengthens ventricular contraction and may help to initiate spontaneous contraction when the heart in standstill has been massaged for several minutes. In ventricular fibrillation it is useless by itself, as it increases the tendency to fibrillation, but it has been reported as of value after electrical defibrillation in strengthening ventricular contraction. Procaine (3 to 5 ml. of a 1 per cent solution injected into the right ventricle) is indicated in the attempt to terminate ventricular fibrillation if electrical shock seems ineffective.

The emergency of cardiac resuscitation is such that even in the operating room sterile technic is not attempted. While the anesthetist establishes the airway and begins ventilation with 100 per cent oxygen, the surgeon quickly opens the chest, usually by an incision between the fourth and fifth ribs on the left. If the heart is truly in arrest there will be no bleeding. Massage may be carried out with either one hand or two depending on the size of the heart and the surgeon's training. Subsequently, a rib spreader is introduced, and hemostasis as well as sterile technic becomes desirable. Proper surgical closure is not carried out until both heart beat and respirations have proved their ability to continue spontaneously.

In certain surgical patients known to have cardiac disease an increased risk of cardiac arrest during anesthesia can be anticipated. The use of a continuous monitoring electrocardiographic lead during surgery may prove most useful and external electrical stimulation (to be discussed later) is possible in association with it. In hospitals where the surgical staff and operating-room personnel have been well indoctrinated, successful resuscitation in the operating room has been reported in up to 75 per cent of cases.11 In 1950 under the aegis of the Cleveland Area Heart Society a 2-day postgraduate course in resuscitation was initiated by Beck and Hosler. The influence of the now over 1,500 graduates of this course and of the manual written by Hosler9 has been felt over the country. Many surgeons have become protagonists for cardiac massage and urge its use outside the operating room.

Resuscitation Outside the Operating Room

In 1950 there appeared the report12 of a young woman who had developed ventricular fibrillation during cardiac catheterization,
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and who survived after thoracotomy, massage, and defibrillation. Since then at least 7 other cases\textsuperscript{13} have been published of successful resuscitation in various parts of hospitals distant from the operating room. These often astonishing revivals have led to a school of thought which, in its extreme form, advocates that all interns be equipped with sharp penknives and be trained to perform a thoracotomy on any case that stands a chance of being salvageable. The complications that could result from the overuse of cardiac massage by inadequately trained personnel can easily be imagined. The overenthusiasts fail to recognize the difference in the setup between the operating room and the ward or clinic. In the operating room all needed surgical equipment is at hand, trained surgeons are at work on the patient, an anesthetist is watching his breathing, and arrest should be immediately apparent. Outside the operating and perhaps the recovery room, any or all of these favorable factors may be missing. In addition, the first physician on the scene may well be unfamiliar with the case and also impeded by the presence of family or other patients.

When confronted with an apparent case of sudden exitus not in the operating room, the first duty of the physician is to confirm that cardiac arrest has really occurred. This is best accomplished by deep palpation of the abdomen for aortic pulsations. Time should not be wasted listening for more than a moment for heart sounds or applying a blood pressure cuff but it is most important that syncope and that repetitive attacks of the Stokes-Adams type be differentiated.\textsuperscript{*} Next, the physician should glance rapidly at his watch and record the time. If he feels there is any chance this may be one of the rare medical instances where cardiac resuscitation is indicated, he should then shout for trained assistance, for it is obvious that one person cannot both massage a patient's heart and breathe for him at the same time. At least 2 trained persons must be present from the very start.

A simple technic occasionally effective in resuscitation is pounding on the anterior chest. One good pounding can do little harm but repetitive efforts waste time. Needling of the heart, on the other hand, is generally not to be recommended. It is rarely efficacious (one success out of 40 attempts in Bailey's series\textsuperscript{15}) and should only be considered in cases where circumstances make thoracotomy impracticable.

More recently, resuscitation through the use of an external electrical stimulator has been advocated and has achieved some fair success.\textsuperscript{16,17} This is now the method of choice in Stokes-Adams attacks, which tend to be repetitive and where a monitoring electrocardiographic lead can be set up with a warning device when standstill occurs. But external electric stimulation is not as effective in other forms of cardiac standstill as cardiac massage, except perhaps during the first half minute or so of arrest, and wastes invaluable time if thoracotomy subsequently has to be performed. Furthermore, it is totally ineffective in the considerable proportion of cases caused by ventricular fibrillation. To meet this last objection Zoll and associates have devised an external electric defibrillator.\textsuperscript{18} The success of this instrument so far has not been great, presumably because it is difficult to defibrillate a heart, even with shocks applied under direct vision to the myocardium itself, until the heart has been "pinked up" with oxygenated blood by massage together with assisted respiration. It is likely that the usefulness of external electrical methods will increase, as technics improve, in severe cardiac patients in whom arrest may be anticipated and who therefore have a pacemaker-defibrillator constantly at their bedside, perhaps with a monitoring lead attached. But at the present time it seems wise to reserve external stimulation and external defibrillation for Stokes-Adams attacks and perhaps

\textsuperscript{*}It has been suggested that, if the physician has an ophthalmoscope with him, a quick look at one fundus may be of value to see if the retinal arteries have become emptied of blood and if beading or segmentation has occurred in the retinal veins.\textsuperscript{14} Slow forward movement of blood in the retinal veins can, however, continue for 10 or more minutes after death.
for certain other cases in which cardiac massage seems inadvisable.

**Indications for Cardiac Massage Outside the Operating Room**

To help the physician, confronted with an instance of cardiac arrest, to decide whether or not to attempt cardiac massage, the following 4 questions have been proposed.\(^4\) It is recommended that he run them rapidly through his mind before making his decision—a process that should take but a few seconds. 1. Has the patient the fundamental health to justify restoration of life? Obviously one would not wish to resuscitate a patient who had a hopeless prognosis. 2. Is it reasonably certain that there is still time to institute massage and that the critical time limit (4 minutes) during which full restoration is still possible has not passed? 3. Has the physician the training, the equipment, and the assistance necessary to undertake both cardiac massage and assisted respiration and to carry them through to a successful conclusion? Here the first emphasis is on the need for at least 2 people who are reasonably trained. The initial equipment need only be a scalpel, for the physician assisting in the breathing can start with mouth-to-mouth respiration. But proper rebreathing apparatus must be available by the time the chest has been opened, and eventually a skilled surgical closure in the operating room is needed. Once massage is under way, and especially if there is resumption of effective cardiac action, there will be brisk bleeding. It is therefore inadvisable to attempt cardiac massage, except under extraordinary circumstances, in a patient’s home or in the usual doctor’s office outside a hospital. 4. Is the arrest iatrogenic? If the arrest occurs during cardiac catheterization or from an overdose of digitalis, the physician feels a personal responsibility that must affect his actions. Also, he is more liable to a claim of malpractice. It seems generally accepted that the lay press has publicized cardiorespiratory resuscitation to a degree that makes any malpractice claim unlikely against a physician who attempts massage under any reasonable circumstances. There has been one instance of legal action against a physician because he failed to perform a thoracotomy. This case was dismissed by the presiding judge.

At the present time it would seem to be only the rare case occurring outside the operating and recovery rooms that would fulfill the requirements raised by the first 3 questions listed above. Stokes-Adams attacks, as already mentioned, constitute a special category and are best treated by external electrical methods. It is therefore unlikely that the physician, rather than the surgeon, will often be called upon to massage a heart. Certain special situations, however, may present an especial challenge. One of these is the patient with coronary heart disease, either with angina at rest or with a relatively small myocardial infarction, in whom the risk of cardiac arrest is a definite one and where the prognosis otherwise is reasonably good. It has been suggested\(^1\) that such cases may in time be grouped in hospitals in a way to make constant observation possible and a trained physician and nurse immediately available for resuscitation. Endoscopies of various kinds and cardiac catheterizations constitute another special group in which there is increased risk of arrest. Certain intravenous medications, and especially the injection of agents that may be necessary in spite of suspected hypersensitivity, form another group. And further removed from the hospital and the internist, one can list anesthesias in dental offices, drownings at public beaches, and accidental electrocutions at power stations. If cardiorespiratory resuscitation is ever applicable for any of these groups, it must be because special setups have been devised that make it possible to satisfy the special requirements.

Because the occasional case may justify cardiac massage, it is recommended that each internist and general practitioner, as well as each surgeon, think through the problems of cardiorespiratory resuscitation and decide what criteria he believes must first be met. It is also recommended that all physicians be
trained in the simple methods of assisted respiration, and if possible also have the experience of successfully massaging a dog's heart back from standstill. In this way they may be able to help carry through a successful resuscitation, if a case with the proper indications ever comes their way.

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