

CARDIAC RESUSCITATION DURING OPERATIONS FOR PULMONIC STENOSIS*

DENTON A. COOLEY, M.D.

BALTIMORE, Md.

FROM THE DEPARTMENT OF SURGERY OF THE JOHNS HOPKINS UNIVERSITY
AND THE JOHNS HOPKINS HOSPITAL

THIS REPORT DEALS with attempts at cardiac resuscitation during operations on a large group of patients with pulmonic stenosis at the Johns Hopkins Hospital. From November 29, 1944, until October 1, 1949, Dr. Alfred Blalock and his associates operated on 878 patients with a preoperative diagnosis of pulmonic stenosis. Forty-eight of these individuals form the basis of this study.

These patients manifested the usual signs and symptoms associated with pulmonic stenosis. All were cyanotic with arterial oxygen saturations ranging from 30 per cent to 85 per cent at rest. The details of surgical treatment (1) and anesthetic management (2) of these patients have been published elsewhere.

CLINICAL MATERIAL

Cardiac massage was employed in all of the patients discussed in this report. In a few instances the heart was still beating feebly or irregularly at the time massage was begun, while in most cases complete arrest, as determined by inspection, had occurred before beginning treatment.

All cases are considered together since there is no way, except by clinical judgment, of determining the necessity for cardiac massage. Even with electrocardiographic recording one may be misled by a normal tracing in a heart whose action is obviously inefficient. While admittedly inexact, the fact that massage was employed in these cases is taken as evidence that its use was necessary to maintain circulation. Some patients might possibly have survived without this maneuver, but its use by a surgeon with experience in cardiac surgery may be accepted as a reliable indication of complete or imminent cardiac arrest.

The 48 patients represent 5.5 per cent of the 878 patients operated on for pulmonic stenosis during this period. In 33 instances the surgeon was successful in restoring effective cardiac function. Of the 33 patients in whom heart beat was restored following the resuscitative attempts 18 lived for 12 hours or more. Twelve of the patients were discharged from the hospital with improvement in cyanosis and may be considered as good results. Two of these, however, had evidence of neurologic damage from anoxia. Six patients died in less than 72 hours after operation. In four of these, death was attributable to cerebral anoxia during the period of cardiac arrest. The cause of death in the remaining two patients was undetermined.

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During more than 700 operations the patient has been connected to the direct writing electrocardiograph and tracings have been taken at frequent intervals throughout the operation. This permits immediate electrocardiographic evaluation if there is any visible change in heart action or deterioration in the patient's general condition.

DISCUSSION

Cardiac emergencies under anesthesia may be divided into two main types, cardiac arrest and ventricular fibrillation. Although no instance of ventricular fibrillation has been encountered in this series, the management of this condition will be included in this discussion. Because cardiac arrest is much more frequent it will be considered first.

Cardiac Arrest. The largest group of patients with cardiac arrest has been reported by Hamilton Bailey.³ In 40 such patients he employed cardiac massage during general surgical procedures. Ruzicka and Nicholson⁴ and others⁵ have also reported cardiac resuscitation by massage. The effectiveness of this procedure in maintaining circulation has been borne out experimentally. Gunn⁶ demonstrated that a dye injected into the right ventricle of the arrested heart of a dog appeared in the lungs and carotid artery after rhythmic cardiac compression. Dripps and his co-workers⁷ maintained a systolic blood pressure of 60 to 70 mm. of mercury by cardiac massage in animals.

Thompson *et al.*⁸ found that artificial respiration would maintain measurable circulation in dead dogs which had been heparinized and injected with radioactive tracer substances. Pollock⁹ had shown experimentally that there are minor fluctuations in the blood pressure and pulse during rhythmic insufflation of the lungs. Critical analysis of these reports shows that one may expect little benefit from the circulation resulting from insufflation alone.

The subject of myocardial stimulants is controversial. Bailey was unable to initiate myocardial contractions by giving epinephrine into the heart in 40 cases of cardiac arrest. Moreover, in the presence of cardiac arrest, epinephrine may precipitate ventricular fibrillation. However, when massage has been successful in eliciting a myocardial response, epinephrine may be useful to support cardiac contractions. In ventricular fibrillation epinephrine is contraindicated because it may perpetuate the arrhythmia. Fauteux¹⁰ advocates dilute solutions of barium chloride because of the stimulating effect of the barium ion on the myocardium.

Most investigators believe that the direct myocardial action of nikethamide is negligible. The stimulating effects of nikethamide in the unanesthetized patient may be lost during anesthesia.¹¹ The studies of Eckenhoff and Hafkenschiel¹² suggest that nikethamide may be harmful to the failing heart.

The value of procaine in diminishing the irritability of the myocardium has been established. Burstein¹³ showed that procaine protects the hearts of dogs against fibrillation during cyclopropane anesthesia and that procaine may restore the heart to normal rhythm even when paroxysmal tachycardia has occurred.

From the experience with 48 instances of cardiac arrest at the Johns Hopkins Hospital certain observations are evident. The duration of cerebral anoxia is particularly significant in the cyanotic patient because the oxygen supply to the vital centers is already impaired. Whereas in normal individuals a three to five minute period of cerebral anoxia will ordinarily be tolerated, a much shorter interval of oxygen deprivation in cyanotic patients may lead to irreversible cerebral damage. We have seen severe neurologic residua after less than 60 seconds of cardiac arrest. It is apparent that resuscitative measures must be employed promptly if complete recovery is to be expected. The most important measure in resuscitation of the patient is cardiac massage. This maneuver is most effectively performed by grasping the heart in the hand and uniformly compressing or squeezing the ventricles. Frequently in children a less ideal technic of massage must be employed because of limited exposure of the heart and because the thoracic cavity may not admit the entire hand. Nevertheless one can usually place two fingers behind the heart and rhythmically compress the ventricles against the sternum. Such a method has been effective in a number of these patients. Optimal rate of massage in children is 50 to 60 times per minute.

Artificial insufflation of the lungs with a high percentage of oxygen is essential. Mechanical respirators have not been used in this clinic. While such devices offer a number of theoretical and practical advantages we have found manual compression of the anesthesia bag quite satisfactory.

Myocardial stimulants are used routinely. The dosage of drugs used in cardiac resuscitation varies widely because of the discrepancy in age and size of the patient. In the case of epinephrine the usual dose is 0.25 to 0.5 cc. of a 1 to 1000 solution. This solution is injected into the vena cava or auricles if preliminary massage has elicited a feeble response. The effect is usually favorable. If cardiac massage alone fails to produce any myocardial activity the combination of epinephrine and massage may be successful in initiating contractions.

Despite the well recognized injunctions against the use of epinephrine with cyclopropane anesthesia, we have noted no arrhythmia or fibrillary response in any of the many instances where these agents have been used together. The simultaneous use of procaine hydrochloride may account for the absence of undesirable side effects. The average dose is 8 mg. per Kg. of body weight of a 1 per cent aqueous solution of procaine hydrochloride.

Barium chloride solution (0.5 per cent) has been employed in a few patients and produced apparent increase in force and amplitude of systolic contractions. Certain other drugs cannot be recommended as resuscitative agents. Nikethamide was used regularly as a stimulant in the early group of patients with no definite beneficial effects, so that at present it is seldom employed. Caffeine sodium benzoate has been used in isolated instances without apparent benefit. Digitalis derivatives are not considered to be resuscitative medications in acute cardiac arrest. Lanatoside or digitoxin occasionally may be beneficial to sup-

port the resuscitated heart when additional strain is anticipated as the systemic-pulmonary anastomosis is opened.

Additional measures may contribute to the success of the resuscitation. The partial release or complete removal of the chest retractor is suggested as an aid to more adequate pulmonary ventilation. The Trendelenberg position favors cerebral circulation. Instruments occluding major vessels or distorting the position of the heart or great vessels should whenever possible be released. The adequate replacement of blood by transfusion or plasma infusion is obviously important.

Ventricular Fibrillation. As previously stated, no instance of ventricular fibrillation was encountered in these 48 patients with cardiac arrest. It is, therefore, assumed to be an uncommon occurrence in cyanotic patients. Nevertheless, a brief consideration of ventricular fibrillation is appropriate.

Electrical shock has been effective both experimentally¹⁴ and clinically¹⁵ in reverting fibrillating ventricles to a normal rhythm. According to Mautz¹⁶ procaine and metycaine applied topically or injected into the blood stream will defibrillate the dog's heart. By the combination of electrical counter shock with injections of procaine Beck¹⁷ was able to effect successful defibrillation in 50 consecutive dogs with experimentally produced ventricular fibrillation.

Cardiac massage is not usually recommended in connection with ventricular fibrillation. Lampson, Sheaffer, and Lincoln¹⁸ described a clinical case of acute circulatory arrest with ventricular fibrillation demonstrated electrocardiographically in which defibrillation and survival followed a combination of procaine injections and cardiac massage. The opponents of massage in ventricular fibrillation state that it will only perpetuate the rhythm by further stimulation of the hyperirritable myocardium. It is probably fair to state that massage should be less frequently and more cautiously used in cases of ventricular fibrillation than in patients with cardiac arrest. Cardiac massage must be employed to support cerebral circulation in the event that defibrillation has not been immediate.

Quinidine will prolong conduction time and increase the refractory period of the myocardium. These effects may abolish fibrillation. Physiologists have long known the effect of the potassium ion in depressing the myocardium, but this knowledge has had little clinical application because of difficulty in controlling the degree of myocardial depression.

A device (Fig. 1) has been constructed to apply electrical shock in cases of ventricular fibrillation. It utilizes a rheostat and specially constructed felt-padded electrodes (Fig. 2) to deliver a 1.0 to 1.5 ampere current from a 110 volt 60 cycle circuit through the heart. Before application to the heart, the felt surfaces of the electrodes are moistened with normal saline solution to obtain electrical contact and to prevent burning of the myocardium. Utilizing the techniques of Hooker *et al.*¹⁴ and of Beck¹⁵ with certain personal modifications the author has been successful in resuscitating dogs with electrically induced ventricular fibrillation. In these limited experimental trials the routine use of

procaine proved valuable. Supplemental cardiac massage was occasionally employed.

COMMENT

The incidence of cardiac arrest in a series of 878 patients undergoing surgery for pulmonic stenosis was 5.5 per cent. It was originally believed that with increasing experience the incidence of cardiac arrest would decrease. Now it is evident that the complication occurs largely in "poor risk" patients.

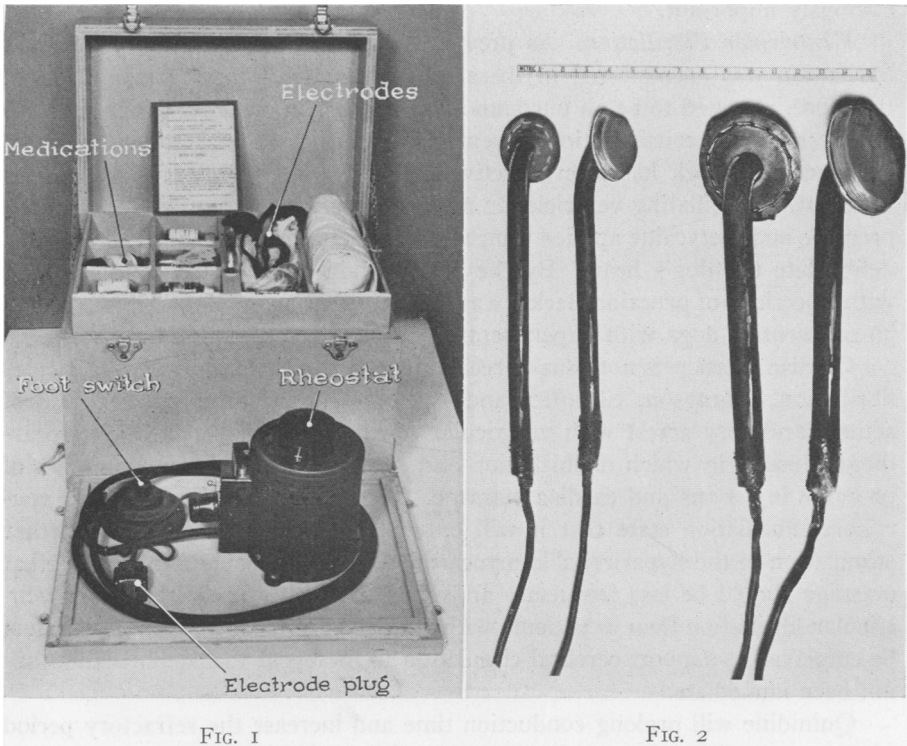


FIG. 1.—Cardiac Emergency Set. The base upon which the rheostat and foot switch is mounted fits into the box when not in use. The removable tray contains the electrodes and resuscitative medications (epinephrine solution 1 to 1000, procaine hydrochloride 1 per cent solution, quinidine lactate 10 per cent solution, barium chloride 0.5 per cent solution and lanatoside solution 0.4 mg. ampules).

FIG. 2.—Padded Electrodes. The diameter of the felt surfaces is 2.5 cm. and 4.5 cm. in the two pairs.

All patients with pulmonary stenosis have been accepted for operation regardless of the risk involved. In many patients it was believed unlikely that they would otherwise survive infancy. Unless such patients are denied the possible benefit of surgery this incidence of cardiac arrest will probably not be significantly reduced in the future.

Preventive measures will, of course, decrease the incidence of cardiac arrest in the poor risk patients. In Ziegler's¹⁹ study of electrocardiographic tracings

of 175 patients undergoing operation for pulmonic stenosis in this hospital it was noted that certain changes in cardiac activity precede cardiac arrest. Bradycardia of 30 to 40 beats per minute during anesthesia is the most serious of these changes. Unexplained tachycardia or extrasystoles may also serve as warnings. Prompt attention to such disturbances may prevent disaster.

Myocardial anoxia plays a major role in the etiology of cardiac arrest. The anesthetist can undoubtedly prevent many instances of arrest by constantly supplying as high a concentration of oxygen as is compatible with anesthesia. When an arrhythmia develops the depth of anesthesia is decreased and if cyclopropane is in use it is flushed out of the anesthetic system. A 100 per cent oxygen or an ether oxygen mixture is substituted. Bradycardia will often respond to complete inflation of the partially collapsed lung.

In most cases where bradycardia occurs during anesthesia atropine sulfate in a dose of 0.1 mg. per ten Kg. of body weight is injected intravenously. The heart rate will usually accelerate. Injections of the vagus nerve with procaine have not been as effective as atropine in eliminating this apparent vagal depression of the myocardium. Atropine is also a routine preoperative medication. If tachycardia or numerous extrasystoles appear, an intravenous injection of a 1 per cent procaine hydrochloride solution not exceeding 8 mg. per Kg. of body weight may elicit a favorable response. We have seen no unfavorable results from its use. In an occasional patient with known cardiac arrhythmia quinidine sulfate has been administered orally for several days in advance of operation in a daily dose of 1.0 Gm. for children and of 2.0 Gm. for adults. In these few instances, quinidine has been effective in preventing or suppressing arrhythmias during operation. Traction and torsion of the heart and great vessels should be minimized. Temporary release of the occlusive pulmonary artery may give a favorable response. If a patient does not tolerate the self-retaining retractor this may be only partially opened or hand retractors may be substituted.

If cardiac arrest occurs during anesthesia, and if resuscitation has been successful, the surgeon is faced with the question of whether or not to proceed. Important pulmonary collateral vessels may have been sacrificed in the mediastinal dissection. Thus, the arterial oxygen saturation has been further decreased in the already cyanotic patient. Without an anastomosis the prognosis for survival in the immediate postoperative period is poor. The surgeon is therefore obliged to continue with the anastomosis despite the apparent hopelessness of the situation.

SUMMARY

Cardiac massage has been required because of imminent or actual cardiac arrest during 48 of 878 operations for pulmonic stenosis.

In 33 instances it was possible to restore normal cardiac action, but only 12 of these patients survived to leave the hospital. In two of these 12 patients who were otherwise well, there were residual neurologic abnormalities as a result of cerebral ischemia during the cardiac arrest.

The management of cardiac emergencies during such operations has been discussed, and preventive measures have been outlined.

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