SUCCESSFUL CARDIAC RESUSCITATION DESPITE PERFORATION OF THE HEART DURING MASSAGE*

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RECENT WIDESPREAD interest in cardiac arrest has familiarized surgeons with the necessity for prompt recognition of this catastrophe and immediate institution of cardiac massage. In the following report, successful resuscitation of the heart was accomplished after three hours and 15 minutes of massage. This instance of successful resuscitation without evidence of cerebral damage is unique in that it was achieved in spite of perforation of a previously infarcted area of the right ventricle during cardiac massage. Until the last few minutes of massage there was very little indication that the attempt at resuscitation would be successful.

CASE REPORT

History. A 62-year-old man, Case No. 161722, was admitted to the Thoracic Surgery Service of the University Hospital on May 27, 1952, with active minimal, pulmonary tuberculosis of the right upper lobe for which he had been treated for 3½ years. In October, 1948, roentgenograms showed an increase in size in an old, previously noted and apparently healed, tuberculous lesion in the posterior portion of the right upper lobe. Tubercle bacilli were cultured from sputum obtained in November, 1948. Treatment consisted of a modified regimen of bed rest at home. Because there was an increase in the pulmonary lesions, the patient was admitted to the University Hospital in June, 1949, for a more rigid program of bed rest. A right primary temporary phrenic interruption was performed on June 9, 1949, and a secondary phrenic crush on May 31, 1950. Bronchoscopy was carried out on May 8, 1950, with negative findings. A fasting gastric specimen obtained in May, 1950, was subsequently found to be positive on culture. The patient was allowed to return to his home in June, 1950, since his progress had been considered satisfactory. He continued to observe a program of bed rest with very gradually increasing activities. A tertiary temporary phrenic interruption was performed on August 15, 1951.

Subsequent to the patient's discharge from the University Hospital following the tertiary phrenic crush, it was apparent that new areas of tuberculosis had developed in the right upper lung field. The patient was hospitalized again for 2 months on a regimen of modified bed rest with one bathroom privilege daily. Streptomycin, 1 Gm. 3 times weekly, and sodium PAS, 12 Gm. daily, were begun on September 13, 1951. This program was continued at home until the patient's subsequent readmission to the hospital in May, 1952. There was satisfactory regression of the new disease as well as of the more long standing tuberculosis. All gastric cultures were negative for tubercle bacilli following the positive culture of May, 1950.

Serious consideration was given to resection as a means of controlling the patient's tuberculosis, even though it was minimal in extent, because the disease had followed a discouragingly chronic course with 2 relapses during a period of 3½ years of treatment. Even with continued, intensive antimicrobial therapy, it seemed unlikely without pulmonary resection that the patient's tuberculosis could be controlled unless he was willing to restrict his activity markedly for an indefinite period of time. After considerable deliberation it was agreed that a segmental resection of the tuberculous lesions should be done.

Past History. In 1927 the patient underwent a cholecystectomy and appendectomy. In 1943 and again in 1944 he suffered episodes of coronary occlusion from which he recovered completely. The patient denied any recent symptoms suggestive of heart disease.

Physical Examination. Temperature was 98.6° F.; pulse, 100; respirations, 20; blood pressure, 114/84.

The patient was in good general condition but he appeared older than his age of 62 years. His

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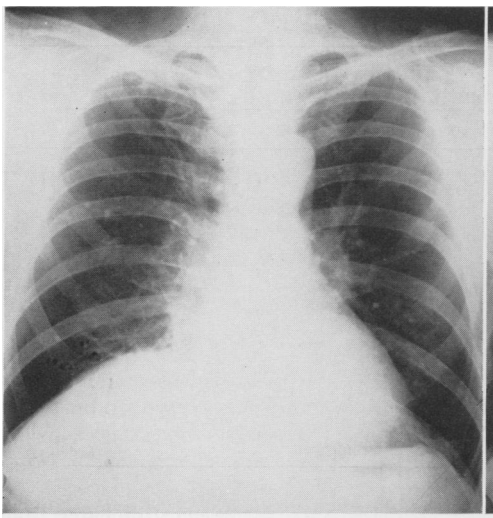

FIG. 1.

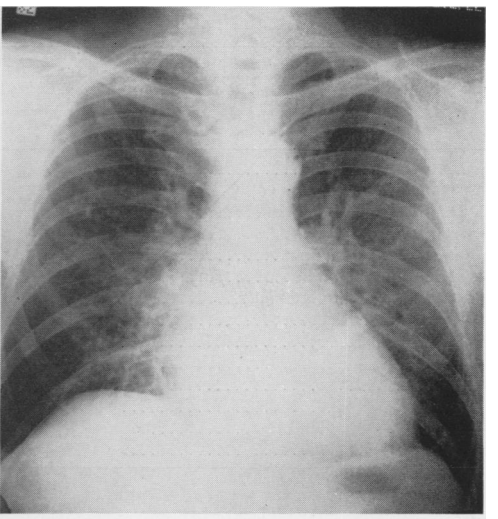

FIG. 2.

FIG. 1. Roentgenogram of the chest obtained February 26, 1952. The heart is not enlarged. There is minimal tuberculosis in the apex of the right lung. The right diaphragm is elevated.

FIG. 2. Preoperative roentgenogram of the chest obtained May 19, 1952. The minimal tuberculosis at the right apex is essentially unchanged. There has been a slight increase in the transverse diameter of the heart and increased vascularity in the lung fields.

chest was clear on auscultation except for a few crepitant rales at the right base. There was bilateral hyperresonance to percussion. The chest wall moved well bilaterally. There was elevation of the right hemidiaphragm. There was no evidence of cardiac enlargement. Heart sounds were normal and no murmurs were heard. There was a slight tachycardia and a gallop rhythm, but these had been present for several years. The remainder of the physical examination was essentially negative.

Laboratory Data. Hemoglobin was 15 Gm.; red blood cells, 4,700,000; white blood cells, 4,850 with 44 per cent polymorphonuclear leucocytes; hematocrit, 46; MCV, 98; sedimentation rate, 34 mm. per hour; Kahn, negative; urine, normal findings. After the administration of 25 mg. of ACTH intramuscularly the fasting eosinophil count fell from 90 to 20. The vital capacity was 3.4 liters and the maximum breathing capacity was 80.86 liters per minute.

Roentgenograms. Films exposed on May 19, 1952, showed persistent, stationary, noncalcified, conglomerate, tuberculous lesions located in the apical and posterior segments of the right upper lobe. There was slight descent of the previously elevated right hemidiaphragm during inspiration and fluoroscopic evidence of returning function. The cardiac silhouette seemed slightly enlarged when compared with previous films (Figs. 1 and 2).

Bronchoscopy. Bronchoscopy, performed on May 28, 1952, showed an essentially normal tracheobronchial tree except for slight narrowing of the right lower lobe bronchus and the superior division of the right lower lobe bronchus. There was no evidence of active tuberculous bronchitis.

Electrocardiogram. The tracing taken on May 27, 1952, showed that the heart rate was 95; the P-R interval, 0.14 seconds; and the QRS interval, 0.11 seconds. The limb leads showed a slight increase in the QRS interval, QRS changes suggesting old posterior myocardial infarction and flat T waves in leads I and II. They were much like previous tracings taken on April 5, 1949. Chest leads were also much like the previous ones, although V_4 showed QRS complexes of different form than those seen earlier, suggesting that a small anterior infarction might have occurred during the past 3 years. There was no evidence of recent infarction.

Operation. On May 29, 1952, the patient was taken to the operating room for resection of the tuberculous lesions in his right upper lobe. The preceding evening he had received 150 mg. of Seconal. The preoperative medication consisted of 100 mg. of Seconal at 6:30 A.M. and 75 mg. of Demerol with 0.5 mg. of scopolamine at 8:00 A.M. Anesthesia was induced at 8:27 A.M., with a total of 57.6 mg. of sodium pentothal. Laryngoscopy for attempted insertion of an endotracheal tube resulted in coughing. Cyclopropane and, shortly thereafter, ether were added as anesthetic agents. At 8:42 A.M. the patient's color was poor. He was quickly intubated with a #10 Portex tube. Marked

TABLE I. *Blood Chemical Determinations.*

	May (1952)				June (1952)							August (1952)
	28	29	30	31	1	2	3	10	12	15	18	5
NPN mg./100 ml.				68	75	89	66	36			31	30
Plasma CO_2 Combining Power vol. %		32	30	59	36	47	52					61
Plasma Chloride m.E.q./liter				97	85	88	96					98
Serum Sodium m.E.q./liter				125					121		134	
Serum Potassium m.E.q./liter		3.6		5.3		5.0						
Serum Calcium mg./100 ml.		11.8										
Inorganic Phosphorus mg./100 ml.		6.0										
Total Serum Protein										6.5		
Albumin										3.6		
Globulin Gm./100 ml.										2.9		
A/G Ratio										1.2		
Blood Sugar mg./100 ml.		269	90	108								
Serum Creatinine mg./100 ml.		1.7										
Prothrombin Time	64%		50%	50%	60%							

slowing of the pulse was noted. The patient was given 0.8 mg. of atropine sulfate intravenously without benefit. At 8:45 A.M. no cardiac action was present. The patient was wheeled immediately into the operating room and a left anterior thoracotomy was carried out through the fourth interspace. Cardiac massage was started at 8:46½ A.M. Inspection of the heart on entering the chest was cursory, but it was apparent that no effective cardiac contractions were present. It was the opinion of the surgeon that the dilated heart was in ventricular asystole.

Massage was started through the intact pericardium. The pericardium was then opened by a long, longitudinal incision anterior to the phrenic nerve. On so doing a small, superficial incision was made in the myocardium of the left ventricle. After three to five minutes of massage, weak but regular cardiac contractions were restored. With massage there was a perceptible peripheral pulse, but the cardiac contractions alone did not produce a palpable pulse. In an effort to stimulate the heart 0.5 cc. of epinephrine hydrochloride 1/20,000 was injected into the cavity of the right ventricle. The force of the cardiac contractions immediately improved. With massage the blood pressure was 80/60. Without massage it was 35/25.

At 9:05 A.M. a sudden hemorrhage occurred through the anterior surface of the heart. Inspection showed a laceration through the wall of the right ventricle. The laceration, 2.5 to 3 cm. in length, was located in a thin portion of the right ventricle, presumably the site of a previous myocardial infarct. This area, which lay beneath the sternum, had not been recognized by the surgeons carrying out the massage. The profuse bleeding was partially controlled by pressure on gauze packs placed over the laceration. The packs were held in place with one hand and massage was carried out with the other hand. This was continued for at least 30 minutes. Blood loss was replaced by massive intravenous transfusions which had been started soon after arrest occurred. Sutures of heavy silk were placed in the wall of the ventricle on two occasions in an effort to close the laceration but these tore out of the thin ventricular wall. Finally, in a desperate attempt to control the bleeding, a doubled suture of heavy catgut on a large needle was inserted at the caudal end of the laceration. On locking this suture it cut through the ventricular wall on one side of the laceration but held on the other side. The suture was then run as a continuous one throughout the length of the laceration, employing deep bites to prevent its tearing through the ventricular wall. The bleeding was completely controlled. With continued massage the heart beat feebly but would not sustain a beat which produced a palpable peripheral pulse. Intermittently, on numerous occasions, the massage was discontinued for intervals of 10 to 30 seconds to determine if spontaneous heart beats would continue. On each occasion, the heart beat became slower and more feeble as the heart dilated progressively. With resumption of massage, the heart beat in turn improved in rate and force of contraction.

At intervals, 4 or 5 cc. amounts of 1/20,000 epinephrine hydrochloride and 10 per cent calcium chloride were injected into the cavity of the left ventricle. Early in the resuscitative effort epinephrine hydrochloride resulted in improvement of the heart beat; later it was ineffectual, as were the other drugs in the amounts used. One intravenous injection of 50 cc. of 50 per cent glucose had no effect.

An impasse had been reached. Nothing which was being done produced any lasting improvement in the heart beat. It was then decided to massage the heart in rhythm with the heart's own weak

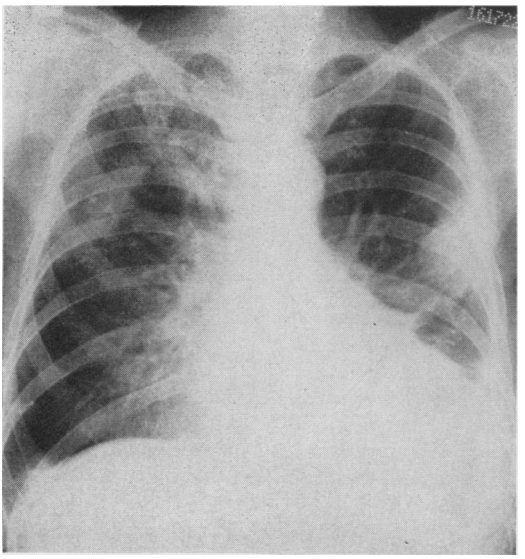

FIG. 3. Postoperative roentgenogram of the chest obtained August 5, 1952. There are bilateral pulmonary opacities. The transverse diameter of the heart is increased. There are pleural residuals of the left thoracotomy performed for cardiac massage.

contractions. As a result of this maneuver, or coincident with it, effective cardiac contractions began and a blood pressure of 118/110 was recorded at 12:04 P.M. This was maintained with the help of norepinephrine. The patient's color, which had been very poor throughout the period of resuscitation, now returned to normal.

With the re-establishment of effective cardiac contraction, the chest was closed, the pericardium being left widely open. Anterior and posterolateral pleural drainage tubes were inserted and these were connected to water-seal bottles. Large amounts of penicillin and streptomycin were placed in the pleural cavity. The ribs were approximated with interrupted sutures of heavy catgut. The extracostal muscles were closed with interrupted sutures of catgut and the skin with interrupted sutures of silk. Electrocardiographic recordings had been taken intermittently soon after the onset of cardiac arrest. At no time was there any evidence of ventricular fibrillation. The patient had breathed spontaneously throughout the period of resuscitation.

Postoperative Course. During the period following resuscitation, the patient for the most part maintained a blood pressure of 110/90, although there was one short period of hypotension at 1:37 P.M. when his position was changed. At 1:45 P.M. movement of the left arm was noted. Thereafter there were additional movements of other extremities and of the head. There was no hyperthermia, the temperature reaching 100.8° F. (R) at 11:00 P.M. The blood loss was calculated by measurement to be 5,369 cc., but it is believed that the loss was in excess of this amount. The patient received 6,340 cc. of whole blood as replacement. At 4:00 P.M. the following blood values were obtained:

hemoglobin	17.0 Gm.
hematocrit (corrected)	48.9 per cent
serum volume	3,348 ml., or 47.8 ml./Kg.
cell volume	2,728 ml., or 39 ml./Kg.
blood volume (corrected)	6,076 ml., or 87 ml./Kg.

Small amounts of Demerol intravenously were necessary to control the patient's restlessness. The intratracheal tube was removed at 4:45 P.M. By 9:55 P.M. he was asking questions and requesting that he be allowed to sit up.

Prior to this he had been making purposeful movements for some time. His general condition was better than one might have expected, although it was necessary to continue a slow infusion of norepinephrine in order to maintain a systolic blood pressure of 90-100. During the night the patient was sufficiently alert to discuss with a member of the staff the camera shutter speeds necessary to photograph birds in flight. At no time was there evidence of cerebral damage, in spite of the duration of cardiac arrest. Norepinephrine continued to be necessary intermittently for 4 days before the blood pressure stabilized at a systolic pressure of 100 or above.

Fluid balance was maintained for 2 days with intravenous fluids until the oral intake was adequate. Blood chemical determinations are listed in Table I. As the oral intake increased there was a steady rise in urine volume, with a corresponding fall in the elevated blood non-protein nitrogen values. The anterior drainage tube was removed on the third postoperative day and the posterior drainage tube on the sixth postoperative day, 2,000 ml. of bloody fluid having been drained from the pleural cavity. Repeated cultures of this fluid were sterile.

The patient had a febrile course, his temperature rising to 102.8° F. (R) 11 days following operation and gradually falling thereafter. Following operation he received streptomycin, 1 Gm. daily; penicillin (S-R), 400,000 units daily, and terramycin, 500 mg. intravenously daily. There quickly developed a severe stomatitis from which staphylococci and *C. albicans* were cultured. Antimicrobial therapy was altered but was finally discontinued on the sixth postoperative day except for streptomycin, 1 Gm. 3 times weekly. The stomatitis, which was thought to be a result of the intensive antimicrobial therapy, gradually cleared with local applications of aqueous gentian violet.

The patient raised small amounts of bloody sputum but his chest remained clear. Roentgenograms demonstrated small densities at the right base and later in the upper portion of the right lower lobe. It was felt that these represented pulmonary infarcts rather than a spread of tuberculosis. The areas of density later cleared partially.

The heart was definitely enlarged in the postoperative period and, 12 days following the cardiac arrest, dependent edema was noted for the first time. An active program of digitalis and diuretics was instituted, and this was followed by an immediate improvement in the patient's condition.

Two additional, short episodes of fever occurred. Fearing that these might be due to a spread of the tuberculosis, the administration of isonicotinic acid hydrazide was begun 5 weeks following operation.

Owing to the patient's desire to return to his home, he was discharged on July 18, 1952, approximately 7 weeks following the cardiac arrest. He continued on a modified regimen of bed rest at home and received streptomycin and isonicotinic acid hydrazide. The cardiac status was followed carefully. Roentgenograms of the chest on August 5, 1952, were interpreted as showing evidence of reactivation of the tuberculous lesions in the right apex. In addition there was a new subpleural density in the upper third of the right lung field laterally (Fig. 3). A probable, slight, additional increase in the size of the heart appeared. An electrocardiogram made on the same day showed that small QRS complexes of abnormal outline with slightly increased QRS interval and very flat T waves were present in all limb leads. Precordial leads showed occasional ventricular premature beats. QRS changes pointing to anterior myocardial infarction were present in V_4, V_{4-5}, and V_5. These records were quite similar to previous tracings. There was no clear evidence of recent infarction. During the night of September 11, 1952, following a day when he had been able to enjoy a brief period of outdoor activity, the patient had acute precordial pain and died within several minutes.

Postmortem Examination. Heart: The heart was flabby and weighed 550 Gm. There were dense fibrous adhesions over the anterior surface of the septal area. Multiple petechial hemorrhages were present on all the epicardial surfaces. An old infarct measuring 6 cm. in its greatest diameter in the anterior wall of the left ventricle near the apex also involved the anterior portion of the septum. There was another old infarct, 4 cm. in diameter, at the base of the heart posteriorly in the lateral and posterior walls of the left ventricle beneath the mitral valve ring.

A scarred area was observed in the endocardium at the base of the heart below the tricuspid valve and adjacent to the septum anteriorly. No sutures were identified grossly in this area of the right ventricle but suture material was seen on microscopic examination. The well-healed scar represented the site of perforation of the right ventricle. Farther below this area, toward the apex of the heart, there was a mural thrombus. The valves of the right and left heart were normal. There was advanced coronary atherosclerosis with practically complete obliteration of many areas in the anterior descending branch of the left coronary artery. The right coronary artery was atherosclerotic but appeared patent in all areas examined.

Lungs: In the apical portion of the right upper lobe there was active, chronic, caseating tuberculosis in scattered small foci. There were organizing emboli and thrombi in several small pulmonary arteries and multiple recent and older hemorrhagic infarcts in both lungs.

Other findings included acute exacerbation of chronic passive congestion of the lungs, liver and spleen, left hydrothorax, diverticulosis of the colon, and small abscesses in the thoracotomy scar. The brain was not examined.

DISCUSSION

Surgeons familiar with cardiac arrest have repeatedly stressed the importance of its immediate recognition, the rapid institution of cardiac massage and persistence in attempts at resuscitation even when there appears to be little possibility of a successful outcome.[2] Although there is uniform agreement regarding the necessity for prompt diagnosis and the institution of treatment, there is as yet insufficient knowledge regarding the length of time during which resuscitation measures might conceivably become successful. Beck[4] has emphasized that the surgeon should persist in his efforts until all possibility of resuscitation is exhausted. Ament, Popper and Rovenstine[1] recognize that the desirable duration of cardiac massage is not known but believe there can be little hope of successful resuscitation if the heart shows no response to massage and medication after 10 to 20 minutes. Murray,[9] in a recent editorial, has stated that no recoveries from cardiac arrest have been reported beyond 60 to 80 minutes of resuscitative efforts. In the reported cases of cardiac arrest, instances of successful resuscitation

after periods of massage lasting 53 minutes,[5] 70 minutes,[3] and 82 minutes[10] are recorded. Similarly, Ehrenhaft[6] noted that massage was carried out for two and one-half hours in one case of unsuccessful resuscitation. Lahey and Ruzicka,[8] in reporting their experience with cardiac arrest, describe a patient in whom massage was carried out for two hours and 45 minutes before attempts at resuscitation were abandoned. In these last two cases there was temporary return of cardiac action. Cardiac massage has been performed for periods longer than five hours in some instances of cardiac arrest at the University of Michigan Hospital before hope of successful resuscitation has been abandoned.

The readiness with which the previously infarcted right ventricle was perforated during massage should serve as a warning that the already damaged heart may easily receive additional trauma from vigorous cardiac massage. Hurwitt and Seidenberg[7] have reported a similar experience during cardiac massage. In our case attempts at closing the perforation of the right ventricle with interrupted sutures of silk failed because the sutures tore out of the thin ventricular wall. The perforation was successfully closed with a continuous suture of heavy catgut, which included within it large sections of the wall of the right ventricle. At postmortem examination the site of perforation of the right ventricle was well healed and was identified on inspection of the heart only with difficulty.

SUMMARY

Successful resuscitation of an arrested heart was accomplished after three hours and 15 minutes of cardiac massage, despite perforation of a previously infarcted area of the right ventricle during massage.

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