A SIMPLE METHOD FOR INDUCING HYPOTHERMIA*

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THE CURRENT STATUS of intracardiac surgery might be compared accurately to the position of intrathoracic surgery before effective control of intrapleural and intrapulmonary pressures was made possible by anesthetic technics.

Courageous and ingenious surgeons have developed methods to help patients with mitral stenosis and other intracardiac lesions. Existing technics, however, require violation of a cardinal principle of surgery—adequate exposure. Most intracardiac manipulations are, in fact, "Braille" or tactile. It is safe to predict that the current methods will, in a few years, seem crude and, in retrospect, amusing as the Sauerbruch's pressure chamber and other efforts to control breathing during intrathoracic operations.

The basic issue is protection of the brain, kidneys and hind quarters during exclusion of the heart from the circulation. All other problems are details of technic, which probably can be solved without too much difficulty.

The tireless and courageous investigations of Gibbon,[6] Dennis,[4] Potts[9] and others in the search for a safe and practical extracorporeal pump will in time yield one of the most brilliant contributions in the history of surgery. This prediction is made without regard of the success or failure of any particular apparatus. The ramifications of their research and the settlement of many basic fundamental problems will eventually bring a satisfactory solution.

Until an adequate heart pump is available, another technic may be helpful—hypothermia. Perhaps in the future, the combination of a pump and hypothermia may make open operations on the heart safe and easy.

The purpose of this presentation is to describe a method for the production of hypothermia, which may have the advantages of safety and simplicity. Before justifying the method, however, it will be necessary to review certain physiological principles involved in the production of hypothermia.

Probably the only advantage of hypothermia in surgery is the reduction of oxygen consumption. Bigelow,[1] Swan[11] and others have shown that the brain of the really cold animal can endure 15 to 20 minutes after excluding the heart from the general circulation. Compared to the three to five minutes allowable at normal temperatures the possibilities become obvious. Temperature, oxygen consumption and heart rate decrease as linear functions.

Despite lowered tissue oxygen demands, hypothermia in the human is dangerous. The threat is ventricular fibrillation. Ventricular fibrillation may result from tissue anoxia regardless of the amount of oxygen in the circulation blood—in other words, anoxia without anoxemia. Haldane and Priestley,[7] and many others, have emphasized this physical law. As body temperature decreases in the safe ranges of hypothermia for the human, oxygen dissociation

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from the blood stream to the tissues decreases (Fig. 1).

The dangers of hypothermia, therefore, depend upon the delicate balance of tissue anoxia in the myocardium. If oxygen dissociation decreases too rapidly or below a critical level, ventricular fibrillation will surely result.

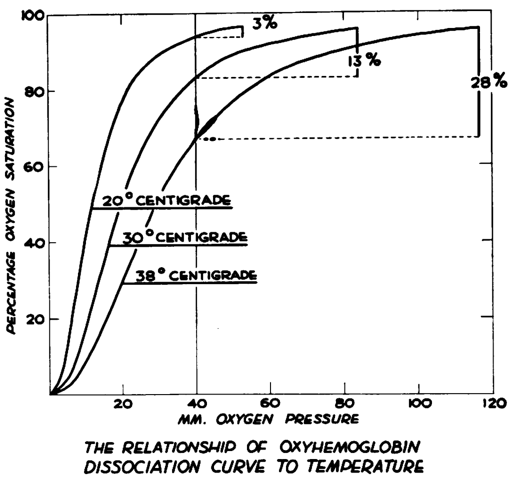

FIG. 1. Oxygen dissociation as effected by temperature change.

Ripstein[10] has reported four deaths in humans during hypothermia. All were due to cardiac arrythmias.

Other factors may be important. Swan[11] has emphasized the changes in potassium metabolism and also noted the difficulty in defibrillating experimental animals under hypothermia unless potassium was given. Bigelow[1] does not concur entirely with Swan's conclusions; in fact, he believes that sometimes potassium levels increase during hypothermia. Data obtained from our experimental animals parallel Swan's observations. Experience with one human adult, however, revealed no significant change in potassium metabolism.

Oxygen dissociation and tissue anoxia may rule and predict the changes in potassium metabolism and other electrolyte balances. Moreover, unless a deliberate accumulation of carbon dioxide is allowed or another acid is administered during hypothermia, the pH of the blood stream increases. A paradox is developed since as the temperature is decreased and the blood becomes more alkaline, oxygen dissociation to the tissues becomes more difficult.

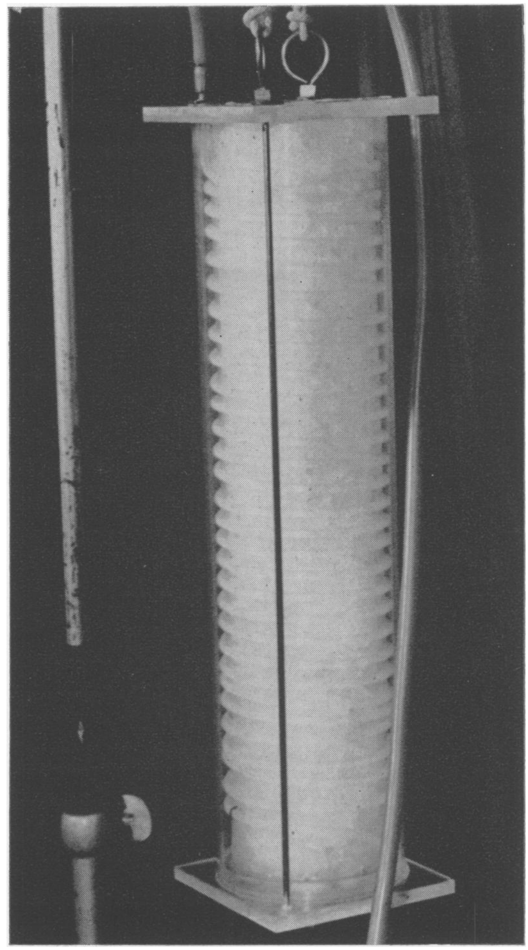

FIG. 2. Apparatus for chilling and maintaining a constant flow of saline.

Tissue anoxia of the heart can be detected before irreversible changes have occurred. Lange, Weiner and Gold[8] have described electrocardiographic changes characteristic of impending disaster during hypothermia. These consist of inverted T waves and prolongation of the condition time. Injections of hydrochloric acid or glutonic acid in experimental animals reversed the electrocardiographic changes.

A realistic approach, until the basic physiologic problems are solved, would be a technic of hypothermia which can be reversed quickly if signs of tissue anoxia are present and, if ventricular fibrillation should occur, immediate treatment instituted.

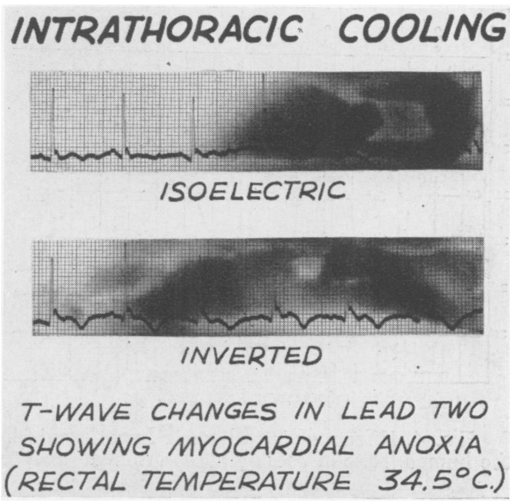

FIG. 3. Changes of myocardial anoxia reflected in electrocardiograms.

METHODS

Common technics for the production of general hypothermia are skin cooling and direct cooling of the blood stream.

Fay[5] first employed general hypothermia by packing the extremities and trunk in ice. The method was employed in patients with far-advanced carcinoma, in hopes the cold might destroy not only the primary lesion, but effect metastatic foci. A significant mortality rate was recorded attributed to heart failure and cerebral edema. There can be little doubt that most of these deaths were the result of ventricular fibrillation.

Ice water baths, cold rooms and ice water blankets have recently been used for the production of hypothermia by skin cooling.

In 1950, Boerema[2] described direct cooling of the blood with a refrigerated cannula which was connected to the femoral artery and vein. Later, Delorme[3] studied this technic and cited the following advantages: Reduction in the time required to produce effective hypothermia and less intense neuromuscular responses.

Blood passing through cardiac pumps has been chilled in an effort to furnish double protection. This combination may be helpful in the future.

By far the most commonly employed technic has been skin chilling, either with the cold room or ice water bath. There are certain disadvantages—transference from bath to table after cooling, difficulty in immediate detection of ventricular fibrillation while the patient is immersed in ice water or packed in ice, and finally, the move from table to bath for warming.

If ventricular fibrillation does occur, the delay from tub to table before the chest is opened and treatment begun may be dangerous or disastrous.

The cannula method may have certain disadvantages. Violation of major vessels in the human for sufficient periods of time to produce hypothermia might produce complications. Moreover, the chest would have to be opened after the onset of real or impending ventricular fibrillation.

Intrapleural Cooling for the Production of Hypothermia. The method we offer does not solve the basic problems of oxygen dissociation and ventricular fibrillation. It does, however, provide a technic which is more rapid than skin cooling; cooling can be temporarily discontinued if electrocardiographic changes indicate anoxia of the myocardium and immediate diagnosis and treatment of ventricular fibrillation is possible.

The technic consists of directly cooling the circulating blood by allowing cold physiological saline to bathe the pulmonary vascular bed of the lung, the aorta and the pleura. The overflow is siphoned off. The cold solution is in contact with a large surface and therefore cools a major portion of the circulating blood (Fig. 2).

The method was first employed in a series of 15 mongrel dogs. Physiological saline was chilled in cracked ice to a temperature of from one to three degrees Centigrade. This was allowed to flow into the open hemithorax of the animal. The rectal temperatures in these animals dropped from 39 to 26 degrees Centigrade in an average of 67.8 minutes. This corresponds to Delorme's rate of cooling of about one degree Centigrade to five minutes when the cannula method is employed. Once the cooling is well established, levels may drift to one degree lower after the flow of the cold solution is stopped.

Warming is accomplished by reversing the process. Saline warmed to 45 degrees Centigrade is allowed to flow over the lungs and into the pleura. In general, the warming period requires from one-half to two-thirds the time necessary to cool the animal. This method requires from one-half to one-third of the time compared to the more conventional technic of placing the animal or patient in cracked ice or in ice water baths.

The technic has been employed in one human case, a 25-year-old male with an aneurysm at the arch of the aorta.

During the cooling, changes in the electrocardiograms indicated myocardial anoxia on nine different occasions (Fig. 3). The flow of the cold saline was discontinued temporarily and the inverted T waves reverted to normal after nine or ten beats of the heart. Cooling was then resumed. After completion of the operation, warming was accomplished by irrigations of saline at 45 degrees Centigrade (Fig. 4).

The body temperature was lowered to 30 degrees Centigrade by intrathoracic cooling, which required two hours and 35 minutes. Warming required one hour and 55 minutes.

The aortic arch was cross clamped, sparing only the innominate artery. The aneurysmorrhaphy required 18 minutes.

The patient's postoperative course was uneventful and he was discharged from the hospital 11 days after the operation. No ill effects from transthoracic cooling were evident. Potassium levels did not alter during or after operation.

The preoperative diagnosis was incorrect in this patient, who was thought to have a

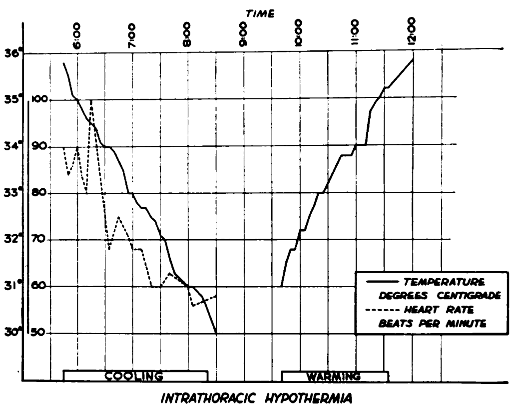

FIG. 4. Effects of intrathoracic hypothermia in the human. Rate of cooling and warming.

mediastinal tumor. Intrathoracic cooling was begun as soon as the correct diagnosis was established. There was no necessity for redraping, closing the chest to employ skin cooling, or any similar delay. This represents another advantage of the method.

SUMMARY AND CONCLUSIONS

1. A simple technic for producing hypothermia is presented.

2. The method has the advantages of rapid induction of effective hypothermia and rapid warming as compared to skin cooling and warming.

3. Anoxia of the myocardium can be detected on the electrocardiogram, and cooling temporarily discontinued until the condition is improved.

4. If ventricular fibrillation does occur, immediate treatment can be instituted.

5. Need to transfer the patient from bath to table is eliminated.

6. In instances of incorrect diagnosis without preparation for hypothermia, the cooling can be begun without delay.

7. With a method which offers control of myocardial anoxia and immediate treatment of ventricular fibrillation should it occur, the dangers of hypothermia in adults and older age groups may be reduced.

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Discussion.—Dr. William H. Muller: This has been a most interesting presentation by Dr. Blades and Dr. Pierpont. We recently had occasion to use a similar method to elevate the temperature in a 35-year-old man upon whom we performed about two years previously Dr. Swan's procedure of invaginating the auricular appendages to close an inter-auricular septal defect. Since the patient had developed subacute bacterial endocarditis, which would not respond to antibiotic therapy, we planned to remove the buttons and the suture which passed through the auricles.

The patient's temperature was lowered to approximately 20° C. and ventricular fibrillation developed just as the skin incision was being made. Electric shock and other means failed to arrest the fibrillation. We thought that the elevation of temperature, and especially differential warming of the heart, might be helpful in this instance, so we employed a constant flow of warm saline into the right neural cavity.

After more than 90 minutes of cardiac massage the fibrillation was arrested and regular rhythm developed. He regained consciousness, responded verbally and appeared rational, but suddenly died about 12 hours later, as he was being returned to the ward.

I would like to ask Dr. Pierpont if he has employed this method on the right side, and if so, has he observed any direct effect on cooling of the sino-auricular node itself, such as cardiac arrhythmias and T-wave inversion?

I wish to thank the Association for the privilege of the floor.

Dr. Henry Swan, Denver, Colorado: I arise primarily to congratulate the authors on this very fine piece of work, and this very nice technic for cooling. We believe it is important to cool as rapidly as possible when this method is used for intrathoracic procedures.

This technic appears to warm rapidly, and it would be particularly valuable, I should think, as Dr. Muller mentioned, when one is in trouble with an arrhythmia of the heart which one is unable to overcome when the patient remains at a cold temperature.

We, too, have had the experience of having to undertake prolonged manual compression of the heart in order to supply a circulation with which to warm the patient, and have used warm saline in