Evaluation of a Topical Myocardial Cooling Device and Comparison of Technical Modalities for Maintaining Myocardial Hypothermia

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Abstract

A technically simple, water-filled envelope with cold fluid recirculation was compared to topical cold lavage with respect to the maintenance of myocardial hypothermia during aorto-coronary bypass operations. In order to compare the efficiency of the two methods it was necessary to derive the percentage rewarming (PR), of the myocardium toward body temperature for each. Rewarming of the interventricular septum was slower using the cooling device. There were no complications attributable to the use of the topical cooling device.

Introduction

The maintenance of hypothermia is an important aspect of myocardial protection. Numerous methods have been described for induction and maintenance of local cardiac hypothermia (1). Commonly used techniques include single or multiple trans-coronary infusions of cold solution and topical applications of cold solution with or without systemic hypothermia (2, 3, 4, 5).

Favorable results have been reported for a variety of methods (6). However, means of objectively comparing efficacy of methods for maintaining myocardial hypothermia have not been reported (1, 6).

We describe the clinical evaluation of a cooling device that was designed to help maintain local cardiac hypothermia. A method of comparing hypothermia techniques is presented and the efficacy of the cooling device is compared to a widely used method of topical lavage.

Methods

All patients in this study underwent multiple aorto-coronary bypass operation. On a random basis, patients were assigned to one of two groups. Group I consisted of twelve patients in whom a topical cooling device (TCD)* was used. (Figure 1) Group II consisted of ten patients in whom cold topical lavage, without the use of the TCD, was employed to maintain cardiac hypothermia.

Standard cardiopulmonary bypass techniques were used. The superior and inferior vena cavae were cannulated separately, and the cannulae were secured by tourniquet tapes around the cavae. The left heart chambers were vented using a catheter** placed through the right superior pulmonary vein. Oxygenated blood was returned to the ascending aorta. The proximal ascending aorta was cannulated*** for infusion of cardioplegic solution into the coronary arteries.

Systemic hypothermia to 24° or 28° centrigrade,

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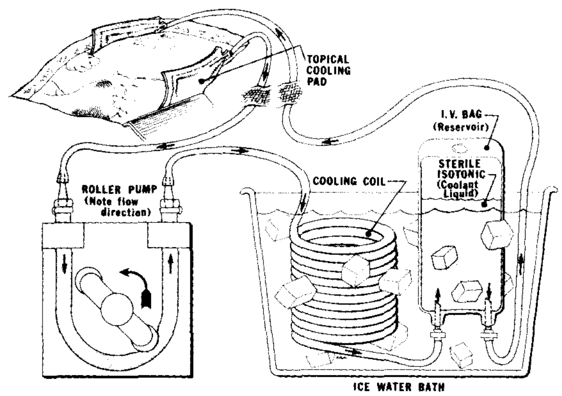

FIGURE 1. Operation of the Topical Cooling Device. Isotonic sterile coolant circulated in the manner indicated by the arrow.

ascertained by tympanic membrane temperature, was employed in each case.

In all patients, hypothermic cardioplegia was induced by cross-clamping the aorta and infusing 500 to 700 ml of cold (approximately 5°C) Ringer's solution containing 5% glucose and 40 mEq KCl and 44 mEq Na HCO_3 per liter. Cold isotonic saline solution was intermittently poured into the pericardial well in order to serve as a topical coolant. For the twelve test patients, little or no lavage was used after the heart was placed on the TCD.

Following arrest of the heart, a needle thermistor probe**** was introduced into the mid-interventricular septum 1 to 2 centimeters to the right of the anterior descending coronary artery. In both groups of patients, cardioplegia solution was reinfused when septal temperatures rose above 20°–22°C.

Tympanic membrane temperature and mid-interventricular septal temperatures were recorded immediately following the infusion of cardioplegia solution and at five minute intervals throughout the duration of cardiac arrest. In order to evaluate the rewarming that had taken place at any given time, percentage rewarming (PR) was calculated using the following formula:

$$PR = \frac{1 - (Tb - Th) \times 100\%}{(Tb_i - Th_i)}$$

where Tb − Th was the difference of temperatures between body and heart at the given time, and $Tb_i - Th_i$ was the body minus heart temperature immediately following the infusion of cold cardioplegia solution.

**** Model T27101, Yellow Springs Medical Instrument Co., Yellow Springs, Ohio 45387

TABLE I

Data Name	Without TCD (N = 10)	With TCD (N = 12)	P
Ischemic Time	68 ± 20 min.	73 ± 21 min.	N.S.
Total Vol. Cardioplegia	813 ± 151 ml.	654 ± 208 ml.	N.S.
Total Vol. Cold Lavage	1730 ± 489 ml.	250 ± 158 ml.	<.03
# Pts With Positive HIS	0	0	0
# Pts With Positive ECG	0	1	N.S.
CPK/MB 1st	1.9 ± 2.4 IU	3.3 ± 4.2 IU	N.S.
CPK/MB 2nd	31.7 ± 19.5 IU	29.3 ± 17.3 IU	N.S.
CPK/MB 3rd	7.2 ± 8.3 IU	9.3 ± 8.6 IU	N.S.

Listed data were compared using student's two-tailed two sample T test. The heart infarct scan (HIS) was performed two days postoperatively using pyrophosphate tagged with technetium. The appearance of new Q waves was considered to represent electrocardiographic evidence of perioperative infarction. Electrocardiogram, CPK-MB determinations were made approximately two hours, 16 hours and 28 hours postoperatively.

Results

The amount of cardioplegia solution used in the two groups of patients was similar. The duration of cardiopulmonary bypass, duration of myocardial ischemia, and postoperative creatine kinase MB isoenzyme measurements were also similar (Table 1). There was no apparent difference between Group I and Group II patients with respect to the complexity of the operations or techniques employed to initially arrest the heart.

One patient in the TCD group suffered a perioperative myocardial infarction on the fourth postoperative day. There were, however, no complications attributable to the use of the TCD or the septal thermistor probe. There were no deaths in either group.

At all times following arrest of the heart, myocardial rewarming was less in the group in which the topical cooling device was used (Figure 2). The application of cold lavage did not produce a change in ventricular septal temperatures. On the other hand, aortic root perfusion significantly reduced septal temperatures (Figure 3). Less topical lavage was employed (1730 ± 489 ml vs. 250 ± 158 ml. P <.03) when the topical cooling device was in place than in those patients where lavage alone was used to cool the surface of the heart.

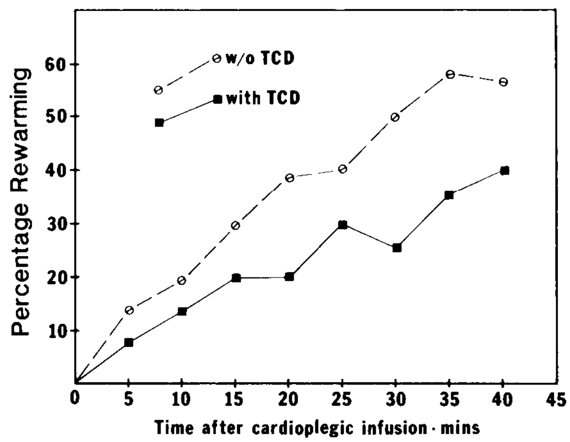

FIGURE 2. Percentage rewarming of the ventricular septum using the TCD (12 patients) compared with cold lavage in the absence of the TCD (10 patients) following infusion of cold cardioplegia solution through the coronary vessels. Systemic hypothermia from 24°C to 28°C was employed. The data presented do not include the terminal phase of cardiopulmonary bypass when core temperature exceeded by 3°C or more the core temperature at the time of cardioplegic infusion. With each infusion, time was "reset" to zero.

Discussion

The topical cooling device was designed to help maintain myocardial hypothermia during cardioplegia. Previous animal experimentation with the TCD has indicated that the device slows rewarming of the hypothermic heart in the areas of the interventricular septum and left and right ventricular free walls (1). Our observations have indicated that the cooling device was more effective than the intermittent lavage which was used.

Slower rewarming with the TCD is probably related to reduced heat transfer to the heart from extra-cardiac structures that would otherwise be in contact with the heart. The cooling pad holds the heart away from the pericardium, providing an insulating effect in the pericardial well. There was less accumulation of fluid in the pericardial well in the patients in whom the TCD was used.

Following two or three uses, the operating team adjusted to the use of the TCD. It is easily implemented and requires only periodic observation to ascertain that it is operating correctly. We did not encounter interference with the surgical procedure once the device was placed beneath the heart.

We used a single septal thermistor probe in this clinical study. No conclusion can be drawn about the uniformity of cardiac cooling or differential rates of myocardial rewarming that may have occurred in our patients. It is likely that separate caval cannulation and venting the left heart chambers reduces heat transfer between cardiac and extra-cardiac structures and thereby reduces variations in regional rewarming (2).

Body core temperature is probably the most significant factor contributing to the tendency of the myocardium to rewarm following initial hypothermic arrest. Core temperature influences the temperature of thoracic structures near and in contact with the surface of the heart, the temperature of blood returning to the right heart during incomplete caval isolation, blood returning to the left heart from the pulmonary circulation, and non-coronary collateral blood flow. All of the foregoing produce rewarming if core temperature is greater than myocardial temperature.

Despite efforts to maintain constant core temperature, variations in body temperature occur to some degree during the period of cardiac arrest and also vary from patient to patient. Morever, the degree of cardiac hypothermia achieved varies from one patient to another. In order to compare the efficacy of the means chosen for maintaining myocardial hypothermia, it was necessary to consider myocardial temperature in relation to body core temperature. Accordingly, the "percentage rewarming" was employed.

The extent of cardiac rewarming is less when body core temperature is colder, when cold cardioplegic solution is reinfused at frequent intervals and when the ischemic period is short. On the other hand, when warmer body temperatures are maintained, when infusions of cold cardioplegic solution are infrequent, or when ischemic times are long, the importance of maintaining cold temperatures surrounding the heart assumes a more significant role. In such situations, the

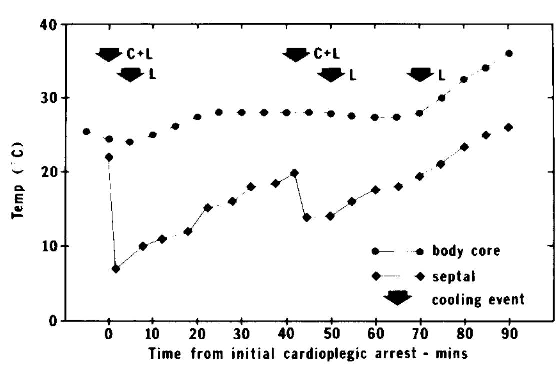

FIGURE 3. Core temperature and ventricular septal temperature during 90 minutes of cardiac ischemia using hypothermic cardioplegia infusion and topical lavage (Group II patients).

cooling properties of the topical cooling device would offer some advantage over the use of topical lavage. The relatively dry operating field afforded by the TCD has resulted in the preference for this device by some surgeons during even short periods of ischemia.

Topical lavage that is discarded carries away heparinized blood from the pericardial well and contributes to blood loss during operations. The use of the topical cooling device and elimination of lavage may well aid in conservation of blood during open heart operations. Evaluation of the potential for the TCD to contribute in this way has yet to be carried out. Further studies attempting to evaluate the optimum combination of body core temperature, hypothermic coronary perfusates and topical cooling measures are required before the optimum combination of hypothermia methodology can be defined.

1. The placement of water-filled flexible envelope in the pericardial well and through which cold solution is constantly circulated (topical cooling device), has been more effective in *maintaining* myocardial hypothermia than intermittent topical lavage.

2. In order to compare means of maintaining myocardial hypothermia, it is helpful to relate the degree of rewarming of the myocardium to body temperature at various times following the induction of hypothermia.

3. In order to determine optimum combination of body temperature, cardioplegic infusion and maintenance of cold surface temperatures, additional studies are required.

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