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Classic Pages of the *Journal of ExtraCorporeal Technology*

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A Hemodilution Cardioplegia and a Proposed Delivery System

Dyson CW, Emerson RC, Buckberg GD. A hemodilution cardioplegia and a proposed delivery system. J Extra Corpor Technol. 1980:12(4);86–89. [UCLA Medical Center, Los Angeles, California]

BLOOD CARDIOPLEGIA

President Stammers presented AmSECT's Gibbon Award to Gerald Buckberg in Orlando, Florida, on April 12, 2008. Listening to Dr. Buckberg's award acceptance address to AmSECT attendees prompted the JECT Editor to ask me to point to two classic articles by Dr. Buckberg and his perfusionist lead author Charles Dyson (1,2).

Searching the keyword "cardioplegia" in the JECT database reveals 44 articles. The first article listed chronologically in the search is this JECT issue's classic article authored by Dyson, Emerson and Buckberg (2). Chuck Dyson presented the manuscript at the 1978 AmSECT Conference and their second paper (2) subsequently in 1980 at the International Conference in Philadelphia.

In their classic articles, Dyson and coworkers share the vision of a single-pump blood cardioplegia system—the single pump system used by many of us today. The one-pump system was creative in its simplicity and yielded a 1:1 blood to crystalloid ratio with two equal ID tubing segments loaded in the pump. You will recognize the list of crystalloid cardioplegic solution dilutent components that have not changed substantially in more than 27 years. Buckberg and his research team even recommended a low level of calcium in the crystalloid component, presumably to help avoid stone heart syndrome (3).

Our classic article references four articles for which Dr. Buckberg is the common author. In reading Dr. Buckberg's CV (4) it is easy to understand why he was selected for this year's Gibbon Award Recipient. Many millions of patients have benefited from the blood cardioplegia technique that Dr. Buckberg developed in his laboratory at UCLA and subsequently lead its translation into clinical practice. Dr. Buckberg graciously acknowledged the contribution of perfusionists with whom he has been associated with over the years as clinicians and research collaborators. This JECT classic is a perfect example of Dr. Buckberg's professional collaboration and communication with perfusionists that earned him our highest professional award in honor of Dr. John H. Gibbon (5).

Dr. Buckberg receiving the Gibbon award from President Al Stammers.

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5. John Heysham Gibbon. About.com. Downloaded from http://inventors.about.com/library/inventors/blheartlungmachine.htm (accessed 05/25/08).

Intraoperative Myocardial Protection III. Blood Cardioplegia

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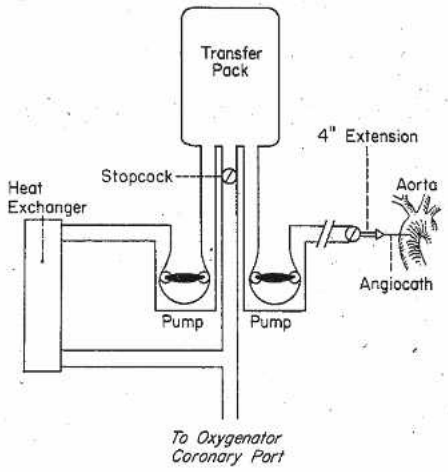
Until 1976 we at UCLA Medical Center used the beating non-working heart with intermittent ischemia as our method of intraoperative myocardial protection. Even though we recognized the great technical advantage of operating on an arrested heart we were unwilling to accept the amount of myocardial injury that accompanied prolonged periods of ischemic arrest. For these reasons we, over the past several years, developed a pharmacological method of arrest. We favored a cardioplegic solution made up of the patient's own blood because of the following reasons. First, our laboratory research showed it to be the best method of producing safe, prolonged pharmacologic arrest. Using this technique hearts had normal function following two hours of cross clamping. Second, the heart is stopped in an oxygenated environment and thus continues to derive its energy stores from the oxidative pathway rather than the anerobic glycolysis pathway. Third, because the solution is blood based we can replenish the substrates at regular intervals without causing profound anemia.

The principles behind each of the modifications to the patient's blood are as follows. The potassium chloride depolarizes the resting cell membrane thus producing an immediate arrest. The blood supplies the oxygen substrate. The CPD (citrate phosphate dextrose) solution (this is the preservative found in blood bags) binds the ionized calcium. This is important because ischemic damage is characterized by calcium precipitation in the cells (stone heart) by binding most of the ionized calcium we feel that the heart's metabolic rate but it also reduces the chance that electrical mechanical activity will occur. THAM (Tromethamine) buffers the hydrogen ions produced during arrest. Also, we feel that myocardial performance is improved post arrest when the storage medium is alkalotic. The blood is modified in the following ways to produce one liter of the cardioplegic solution: first, the blood is cooled to 16° C then potassium chloride 30mEq, THAM 50 ml, citrate phosphate dextrose 20 ml are all added.

Figure 1



The cardioplegic solution is prepared in the system shown in Figure 1. All tubing is 1/8" I.D., the temperature is regulated by a disposable heart exchanger, the medications are introducehe system via a three-way stopcock, the cardioplegic solution is stored in a 1000 ml transfer pack, a 14 gauge angio cath is sutured into the aorta and four inch arterial extension with stopcock is used to connect the injection line with the angiocath. The coronary perfusion

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heads on our heart–lung machine are used to draw, circulate and inject the cardioplegic solution.

The blood for the cardioplegic solution is drawn up and recirculated as shown in Figure 2. To draw the recirculation line is clamped and the blood follows the path of the open arrow. To circulate, mix and cool the cardioplegic solution the clamp is moved to the withdrawal line and the blood follows the path of the solid arrows. The transfer pack is hung on a backing plate with lines corresponding to 250, 500, 750 and 1000 ml volumes drawn on it so that the volume of the cardioplegic draw can be accurately determined. To infuse the cardioplegic solution a separate pump head is turned on and the blood is pumped directly into the aortic root at a known flow rate.

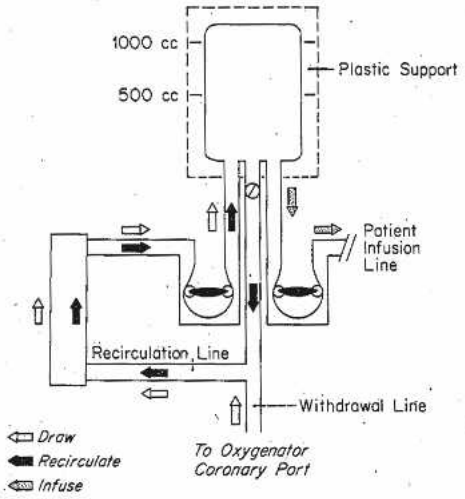

Figure 2

The blood cardioplegia is used with the following protocol. In the bypass period before the heart is arrested we start cooling the patient to a systemic temperature of 28–30° C as measured by a rectal temp probe. The patient is hemodiluted to a hematocrit of not less than 22–25%. A perfusion pressure of 80 Torr is maintained by first increasing the pump flow up to a maximum of six liters/min and then adding a vasopressure as necessary to achieve the desired pressure. For the initial infusion of the cardioplegic solution we rapidly drop the arterial blood temperature to 20° C for about one minute, then the cardioplegic solution is started at a flow of 300 cc/minute. Only after the cardioplegic infusion has started do we cross clamp the aorta. In this way, the competency of the aortic valve is guaranteed and it is not necessary to turn off the left ventricular vent. If, in fact, the cardioplegic solution is perfusing the heart, total arrest should occur in one minute or less. In the great majority of adult cases we inject 500 cc of cardioplegic solution initially. However, 250 cc more is used if we are dealing with a hypertrophied heart. We also measure the myocardial temperature and will infuse more than the 500 cc if the heart temperature does not go below 24° C. In the past we paid a lot of attention to the arterial pressure. Now when the patient is cooled and the heart is arrested, we are concerned only that the arterial pressure is over 50 mm Hg and the flow is greater than 40 cc/kh/min.

Finally, to prevent the heart from being rapidly rewarmed by the patient's body during the time of arrest the systemic temperature is kept at or below 30° C until near the end of the expected cross clamp period. Because the cardioplegic solution is washed out of the heart by noncoronary collateral flow, we reinfuse the heart every 20 minutes. We deviate from this time period only if the heart rewarms above 24° C or if the EKG shows the return of electrical activity before the end of the 20 minute period. Our reinfusion is 250cc of cardioplegic solution. When the surgeon determines that the cross clamp will be removed within the next 20-minute period, rapid rewarming is begun and 500cc of blood is drawn up and 25cc of THAM is added to adjust the pH. This is reperfusion solution and is given immediately prior to the removal of the cross clamp. The reason for the reperfusion solution is merely to reduce the chance that some degree of reperfusion injury will occur if the heart has incurred any ischemic insult during the period of cross clamping.

After the cross clamp is removed, spontaneous electrical rhythm usually returns within 2–3 minutes. The perfusion pressure is again kept at 80 Torr. Complete rewarming usually takes another 15 minutes and bypass is discontinued. A definitive report of our clinical results are being presented elsewhere.[1] However, in our hands, for the last one and one-half years blood cardioplegia has proven to be superior to any other method of myocardial protection we have tried.

REFERENCE

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