How to do it

A simple and flexible blood cardioplegia delivery system

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Abstract

We describe a simple technique for the delivery of high haematocrit blood cardioplegia. The system allows for a user defined, variable concentration of warm, tepid or cold solution to be delivered. The concentration can be varied based upon the pressure regulated flow of blood, and is manipulated by a four variable equation calculated by a spreadsheet formula stored in a hand-held computer. The system provides a very accurate and rapid method of titration and administration of the cardioplegic solution. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

The preparation and delivery of cardioplegic solution varies widely among different cardiac centres. Following the extensive experimental work of Buckberg, [1] many surgeons now employ blood cardioplegia. The temperature, conditions and rate of delivery remain controversial. We have developed a simple method of titration, preparation and administration of the cardioplegic solution based on a known system of continuous blood cardioplegia administration [2,3]. The technique allows the use of high haematocrit blood and facilitates the manipulation of temperature and constituents while ensuring predictable delivery and air removal.

2. Technique

The cardioplegia (CP) delivery system is comprised of a 0.25 inch PVC tubing length with a silicone pump insert (Fig. 1). The heat exchanger is placed distal to this tubing length. Our current system utilises either the Sorin CSC14 (Sorin Biomedica, West Sussex, UK) or the Medtronic Cardiotherm (Medtronic, MN). A Graseby syringe infusion pump (Graseby Medical Ltd., Herts, UK) is used to deliver the solution to the circuit through a luer connector placed distal to the heat exchanger.

The determinants of cardioplegia are a known concentration of potassium and a suitable substrate that allows delivery. The technique employs high haematocrit blood (i.e. undiluted). The patient bypass haematocrit is targeted as greater than 18. Blood is drawn from the arterial line, distal to the oxygenator, by a calibrated occlusive roller pump. The blood passes through the heat exchanger prior to the introduction of the cardioplegic solution. The rate of cardioplegic infusion ($q_{cp}$) is determined by the four variables, depicted by a simple spreadsheet program stored in a hand-held computer (Hewlett Packard 200 LX).

- Desired $K^+$ level in cardioplegic solution − $[K^+]_{bc}$
- Serum $K^+$ level − $[K^+]_b$
- Blood cardioplegia flow rate − $Q_{bc}$
- Cardioplegic solution − $[K^+]_{cp}$

The program is utilising basic mathematics of chemical solutions and flow dynamics

The calculation of the syringe pump rate is based on the following equation

$$q_{cp} = Q_{bc} \times \frac{([K^+]_{bc} - [K^+]_b)}{[K^+]_{cp}}$$ (l/min)

To convert this to ml/h multiply by 60 000.

3. Cardioplegia administration

The cold, arrest-inducing dose of 20 mmol/l is followed by a maintenance dose of 10 mmol/l, given at regular inter-
vals antegrade and/or retrograde. Finally a warm (37°C) reperfusion dose is given prior to the removal of the cross-clamp (Table 1) [4]. Aortic root and coronary sinus pressures are continuously monitored in order to regulate flow.

4. Discussion

This method has the advantage of an instantaneous accurate delivery of the required cardioplegic solution. The infusion can be stopped, re-titrated and immediately re-infused with no need to waste or store any of the blood or the cardioplegic solution. Unlike other systems [5] it can ensure a high haematocrit with no additional dilution of the blood cardioplegia. However, with the addition of the pressure isolator and heat exchanger it can be used to titrate and deliver cold or warm cardioplegia with tepid or any other concentration of haematocrit [6]. The potassium level targeted is not the standard concentration in the cardioplegia solution but the actual level of potassium in the patient’s blood. The set-up of the system is very simple as it only includes a common syringe pump and a line connected to the main CPB (cardiopulmonary bypass) arterial line. The cost of setting the system up is low (less than 60GBP for the disposables). Although the mathematics of the calculation are simple, the availability of a small portable calculator/computer where the program has been loaded, allows for an easier and more reliable calculation of the desired infusion rate. This provides a simple method by which to manipulate the syringe infusion rate based upon fluctuations in the blood flow rate which in turn are dependent on the circuit pressure. This has proved to be a robust, user friendly system, which has been used in over 2500 patients undergoing adult heart surgery in this hospital.

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Table 1
The cardioplegia delivery scheme

<table>
<thead>
<tr>
<th>Dose</th>
<th>Volume</th>
<th>K⁺</th>
<th>Temperature</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Induction</td>
<td>600 ml antegrade</td>
<td>20 mmol/l</td>
<td>6–8°C</td>
<td>Aortic root 60–80 mmHg</td>
</tr>
<tr>
<td>Maintenance</td>
<td>300–400 ml retrograde</td>
<td>10 mmol/l</td>
<td>6–8°C</td>
<td>Coronary sinus 20–35 mmHg</td>
</tr>
<tr>
<td>Reperfusion</td>
<td>600 ml retrograde</td>
<td>10 mmol/l</td>
<td>37°C</td>
<td>Coronary sinus 20–35 mmHg</td>
</tr>
</tbody>
</table>
References