Technique

Veno-Arterial Modified Ultrafiltration in Children after Cardiopulmonary Bypass

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ABSTRACT

A method of performing veno-arterial modified ultrafiltration is described that utilizes conventional blood flow through the aortic and venous cannulae. A dual-pump blood cardioplegia console is adapted to aspirate blood from the cardiopulmonary bypass venous line. The blood is ultrafiltered, sent through the cardioplegia heat exchanger, and returned to the aorta via the cardioplegia needle.

Veno-arterial modified ultrafiltration has produced no visual evidence of air entrainment in the cardiopulmonary arterial line. This method allows the immediate resumption of cardiopulmonary bypass without the need for the surgeon to recannulate or alter tubing. Thirty-five children underwent veno-arterial modified ultrafiltration; the results show significant increases in postoperative hematocrit, early extubation, and improved rheology.

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INTRODUCTION

Modified ultrafiltration (MUF) is a procedure to remove excess plasma water from patients after cardiopulmonary bypass (CPB). The patient’s blood is pumped through an ultrafilter composed of a semi-permeable membrane. Plasma water, low molecular weight solutes, and certain inflammatory mediators cross the membrane as effluent and are discarded (1). Ultrafiltered blood is returned to the patient. MUF has been shown to reduce tissue edema, improve myocardial performance, and attenuate dilutional coagulopathy (2, 3).

Naik produced the original work on MUF in 1991 (2,4). In 1994, Groom improved upon Naik’s original design by incorporating a blood cardioplegia heat exchanger into the MUF delivery circuit (2,4,5). To date, vascular access for MUF has been either the arterio-venous (A-V) or veno-venous (V-V) approach. Of those pediatric centers using MUF, 86% use A-V MUF, which basically aspirates blood from the aorta via the CPB arterial cannula, ultrafilters the blood, and returns it to the right atrium (6).

However, aspirating blood from the aorta can entrain air into the CPB arterial line. For example, a small aorta is apt to occlude an end-hole aortic cannula producing cavitation, air may be pulled into the CPB arterial line through an open aortic root, or air may be sucked across an oxygenator’s hollow fibers into the arterial blood phase. According to one recent study, 68% of centers performing pediatric A-V MUF have experienced air entrainment in their CPB arterial lines (6). The risk of arterial embolization posed by A-V MUF appears to have prompted some cardiac teams to abandon MUF altogether (6). Veno-arterial (V-A) MUF (Figure 1) is an attempt to avoid the risk of air entrainment associated with A-V MUF. The V-A technique siphons systemic venous blood from the right atrium via the CPB venous cannula and returns ultrafiltered blood to the aortic root through the cardioplegia cannula.

MATERIALS AND METHODS

The basic components of the system are: the CDS41 blood cardioplegia system; the dual pump Sorin Blood Cardioplegia Console (BCC); the Minimax/Maxima Oxygenators; and the HPH-400 Hemoconcentrator. During circuit assembly, a short length of 1/4 in tubing is spliced between the venous line and the line supplying arterialized blood to the cardioplegia unit. This bridge remains clamped during CPB.

As preparation is made to separate from CPB, an ultrafilter primed with Normosol® is inserted into the cardioplegia circuit as shown. The BCC blood mixture knob is rotated to the blood only position, deactivating the pump that blends cardioplegia admixture into the perfusate base. After CPB is terminated, tubing clamps are positioned as shown, and the aortic, venous, and cardioplegia cannulae remain in-situ.

MUF begins within one to three minutes after separation from CPB. The process begins as the BCC aspirates systemic venous blood via the CPB venous cannula. The BCC then pumps this blood through the ultrafilter, followed in series by the cardioplegia heat-exchanger. Blood flow is maintained between 10 and 15 ml/kg/min. A 100 mmHg vacuum is applied to the ultrafilter. Warm, ultrafiltered venous blood returns to the aortic root via the cardioplegia cannula. Peripheral arterial oxygen saturations are continuously monitored. The slow removal of plasma water causes a loss of intravascular volume. Cardiac fill-
ing pressures are maintained by transfusing perfusate via the CPB arterial line. CPB arterial line infusion pressures and CDS41 infusion pressures are continuously monitored. The remaining blood in the venous reservoir is transfused first. When exhausted, we add 500 ml of Normosol to the reservoir (MiniMax group). MUF is continued until the venous reservoir is empty.

The venous cannula is then removed, and the blood in the CPB venous line is siphoned, ultrafiltered, and transfused as well. When finished, the CPB circuit remains primed with Normosol. The aorta is decannulated and protamine administered. The concentrated blood remaining in the CDS41 is aspirated into ml syringes and later transfused.

**RESULTS**

Thirty-five children underwent veno-arterial MUF during a 10 to 15 minute period after CPB. The patients weighed between 4.6 and 43 kg, with a mean weight of 14.8 ± 10 kg (standard deviation). Paired t-tests were used to examine increases for each patient in post ultrafiltration blood pressure and hematocrit. The mean hematocrit at the end of CPB was 22 ± 1% (standard error) and increased to 34 ± 1% (standard error) following MUF and was statistically significant (p < 0.0001). Mean arterial blood pressure increased from 61± 2 mmHg to 84 ± 2 mmHg and was statistically significant (p < 0.0001). No technical difficulties were encountered in this series. Twenty patients were extubated immediately or within one hour of arrival in the Intensive Care Unit after completion of surgery. Of the 19 patients weaned from CPB with inotropic and vasopressor support from dopamine (5 mg/kg/min), all had that support decreased or weaned off during the MUF period. After MUF, no patient required further blood transfusions during the operative period.

**DISCUSSION**

Veno-arterial MUF has two obvious potential risks: air embolization and arterial oxygen desaturation. V-A MUF shares with A-V MUF the risk of air embolization, though the source of embolization is different for the two methods. Veno-arterial MUF avoids the negative pressures generated in the CPB arterial circuit during arterio-venous MUF. Excess negative pressure pulls air into the CPB arterial line, where it remains a potential source of embolism. In contrast, the pressure in the CPB arterial circuit during veno-arterial MUF remains positive, thus air entrainment and embolism is unlikely. In veno-arterial MUF, however, micro-embolism from the cardioplegia delivery system is possible. We believe this risk is minimized by CO2 flushing and meticulous de-airing of the ultrafilter and cardioplegia system during priming. The CDS41’s external blood path allows visual inspection for air during operation. Blood passes through a large bubble-trap just prior to leaving the device. There is also the potential for arterial oxygen desaturation during veno-arterial MUF. However, pulse oximetry showed no significant arterial oxygen desaturations in this series.

With the in-line systemic venous oxygen saturation (SvO2) and hematocrit (hct) meter, we can observe the patient’s hematocrit rising during ultrafiltration (Figure 1).

Veno-arterial MUF utilizes conventional blood flow through the aortic and venous cannulae and probably avoids the risk of air entrainment observed by some in the arterio-venous approach. Our results compare favorably with those published by other investigators (2,5). It allows the immediate resumption of CPB without the need for the surgeon to recannulate or alter tubing. Further studies to investigate the effects of veno-arterial modified ultrafiltration are suggested.

**REFERENCES**