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A Simplified Approach to Pediatric Modified Ultrafiltration: A Novel Circuit Design

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Abstract: A simple intuitive approach to modified ultrafiltration (MUF) may improve the safety of this technique and enhance the adoption rate of MUF in pediatric and adult centers. This simplified technique is more easily implemented than the traditional MUF technique and will allow teams to adopt this technique successfully with ease. **Keywords:** modified ultrafiltration, perfusion education, pediatrics, international. *JECT. 2013;45:259–261*

OVERVIEW

With complex pediatric congenital heart surgery reaching all areas of the globe, the ability to provide modified ultrafiltration (MUF) has become crucial. MUF is practiced in over 70% of pediatric programs as a result of the positive benefits it provides for patients undergoing procedures using cardiopulmonary bypass (1). MUF has also been endorsed by the Society of Thoracic Surgeons recommending the use in adults as Class I Level of Evidence A, further escalating its clinical importance (2). As use of MUF becomes more widespread, a simplified technique using minimal equipment is warranted that will allow MUF to be carried out effectively with improved safety. This also poses an issue regarding disposables required to undertake the MUF procedure in the developing world, and the method described takes into account these limitations.

DESCRIPTION

Cardiopulmonary bypass (CPB) components and polyvinylchloride (PVC) tubing sets were chosen to match patient needs using standardized perfusion guidelines. The circuit includes an oxygenator, arterial raceway, and arteriovenous (AV) loop to satisfy CPB requirements. The cardioplegia (CP) delivery is accomplished using a simple ¼-inch internal diameter (ID) PVC length of tubing passed through a raceway of a separate roller pump to allow for flow control and delivery, because we do not use a manufactured CP delivery device (Figure 1). The tubing on the inlet end of the pump is connected to the refrigerated cardioplegia solution, primed, and completely deaired. The outlet end is connected to a cardioplegia cannula in the patient aortic root (Figure 1). Located in the CP outlet line to the patient is a ¼-inch straight connector with a luerlock (LL) to facilitate pressure monitoring during CP delivery (Figure 1). This system is run in an antegrade fashion during cardioplegia delivery and is not slaved to the arterial pump because no communication exists between the two circulations and therefore it has no safety benefit. Pressure limits and alarms remain activated to protect against overpressurization.

Before cross-clamp removal, the perfusionist removes the inlet portion of the CP line from the CP solution and replaces it with a hemoconcentrator (HC), which is connected to the venous reservoir (Figure 2). When the surgeon is ready to remove the cross-clamp, the CP pump is reversed to flow in a retrograde fashion, therefore venting the aorta and subsequently priming the HC. Care must be practiced to completely deair the HC because no air-removing device is present post-HC. Conventional hemoconcentration, if indicated, can now be performed until the cessation of CPB is complete.

While CPB is being discontinued, the CP/aortic root vent pump is stopped; however, the CP needle/aortic root

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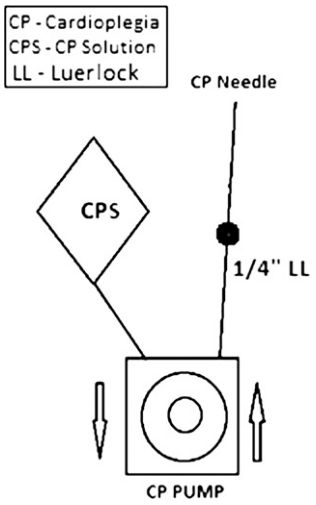

Figure 1. Cardioplegia delivery circuit.

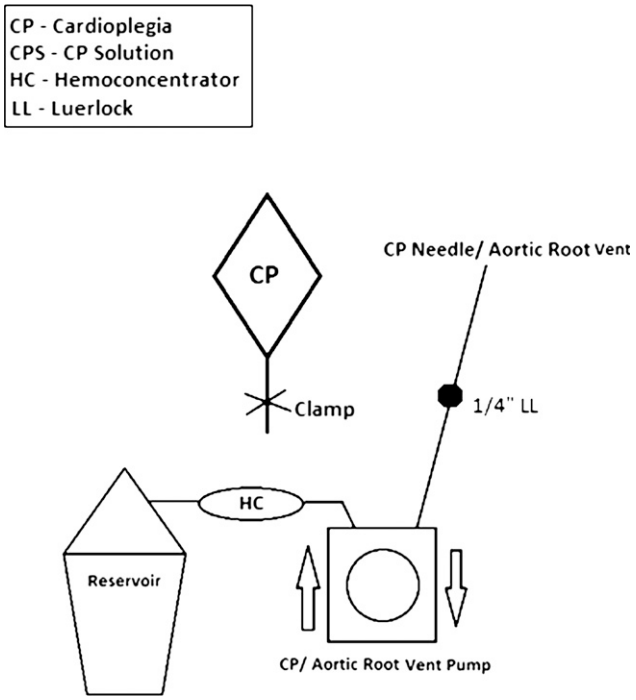

Figure 2. Cardioplegia circuit modified to aortic root vent/conventional ultrafiltration circuit.

vent needle is left in place and will become the removal point for the AV MUF circuit. The outlet of the HC is removed from the venous reservoir and connected to a dedicated MUF line, which is connected to the venous cannula through a LL connection (Figure 3). It is important to orient the HC in a vertical position with the inlet at the top and the outlet at the bottom to trap any air that might enter the circuit. This dedicated MUF line is passed from the sterile field to be connected and complete the AV MUF circuit. We used a simple 3/16-inch ID PVC length of tubing with male and female connections on

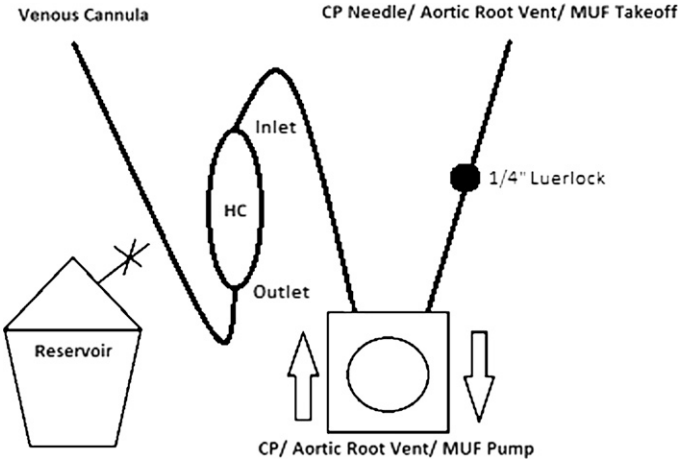

Figure 3. Aortic root vent/conventional ultrafiltration circuit modified to enable AV modified ultrfiltration.

opposing ends to attach to the HC and venous cannula LL, respectively.

CPB is terminated and venous line blood volume is chased with crystalloid into the reservoir to allow blood volume to be reinfused and MUF. This maneuver also allows us to protect the primed venous line and cannula for emergency institution of CPB if warranted. The aortic cannula also remains in place to enable transfusion of pump volume during the MUF procedure to maintain adequate volume status. As always with the MUF procedure, administration of protamine is delayed until complete.

Two separate circulatory systems are now in place. The first is the standard venoarterial (VA) circuit, which provides systemic circulation on standard CPB through the venous system to arterial system. This is used as the systemic transfusion route, which enables the pump blood to be warmed by the oxygenator heat exchanger post-CPB during MUF. The second system is the AV circuit, which provides MUF circulation through the CP needle/aortic root vent to venous cannula LL connection. This MUF circuit therefore runs independently and has no interaction with the systemic CPB circuit. MUF can therefore be manipulated easily by using one pump head to manage MUF flow and one to manage patient volume status completely independently. The ease of this circuit allows separate control of the MUF system alleviating the burden concerning negative pressures, clamping and unclamping of lines to transfuse, air, and general difficulty when integrated with the CPB circuit. Attention can be focused on the patient while managing volume with one pump and MUF flow with another rather intuitively.

DISCUSSION

MUF has been studied and proven beneficial on multiple occasions in regard to total body water reduction,

concentration of blood proteins, and some removal of cytokines (3,4). Furthermore, MUF has demonstrated additional benefits of superior hemodynamics and cardiac output maximization (3,5). Many circuit variations have been adopted with basically the same flow pattern and design either instituting a popular modified AV or less adopted VA circuit described by Buchholz in 1999 (6,7). Independent of flow patterns, the MUF circuit components can also vary, including MUF using blood cardioplegia devices (8). All circuits are designed for blood flow to leave the patient, pass through a HC and return to the patient in a closed loop that is also connected to the CPB circuit to facilitate pump volume to be salvaged, concentrated, and reinfused with total body water being decreased (9).

Issues regarding the MUF procedure include air entrainment in the arterial cannula, cavitation within the CPB circuit, disconnection of components resulting from overpressurization, hemodynamic instability, cerebral ischemia as well as a learning curve for perfusionists (7,9). This technical complexity that is added to the case can be decreased with the circuit configuration we have devised.

This technique has been successfully adopted at new programs in developing countries (10). Because MUF is so important in the pediatric population, we would like to perform the procedure on every patient we operate on (11); however, the capacity for some perfusionists to undertake MUF can be challenging.

Using this circuit allows patient filling pressure and blood pressure issues to be more readily recognized and controlled. Perfusionists are instructed to maintain an appropriate arterial blood pressure with the MUF pump and then maintain proper filling pressures with the systemic pump. Either pump can be turned up/down or off/on within reason and without regard to the other. There is no issue of air being pulled into the arterial cannula because it is flowing as designed, antegradely as the transfusion pump, which continues to remain a concern in other MUF circuits (12). There is no risk of pulling air across the oxygenator because there is no possible negative pressure applied as a result of the independent circuit and MUF pump. However, the MUF pump circuit is still able to create deleterious negative pressure within the system and cavitate, possibly entraining air into the system if not corrected.

Vigilance must still be practiced by the perfusionist in general both to ensure no air is entrained into the MUF pump through the MUF takeoff point and patient vital signs remain stable. The two separate circuits are run until MUF is complete to specifications warranted for the given procedure or institution/surgeon. Use of this circuit allows MUF to continue until blood in the circuit has been returned including blood in the arterial line and aortic cannulae. This allows more complete salvage of the CPB circuit.

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