

Original Article

Alleviating Heat Loss Associated with Modified Ultrafiltration

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Abstract: Modified ultrafiltration (MUF) has been described and utilized for the removal of extracellular water in the immediate postcardiopulmonary bypass (CPB) period. This technique has been associated with improved hematological status and hemodynamic stability post cardiopulmonary bypass. Hypothermia during the MUF period has been described as a complication associated with this technique. Decreased patient temperature may be associated with increased bleeding causing an increase in time to sternal re-approximation, OR time, decreases in cardiac function, peripheral vascular perfusion, and an increase in blood product utilization. These complications may reduce some of the benefits described with the use of MUF. The purpose of this study was to evaluate the use of a heated MUF infusion line to reduce the heat loss associated with this technique in a pediatric population. After obtaining Committee for Protection of Human Subjects exemption, a retrospective review to evaluate the efficiency of the hot MUF infusion line was undertaken. Twenty patients under 10 kg who underwent MUF before the change to a heated infusion line were retrospectively identified and matched to patients undergoing MUF with a heated infusion line

with regard to weight, lesion, procedure, surgical staff and technique, and disposable equipment. Groups were evaluated for temperature and hematocrit change during the MUF period, blood loss and transfusion postprotamine in the OR and 24 h, and time to sternal re-approximation postprotamine. Statistical significance was seen between the two groups in temperature (-0.24 ± 0.72 vs. $-1.58 \pm 0.89^\circ\text{C}$; $p < .0001$) with the HotLine group having little change post MUF. Significance was also seen in the last OR temperature recorded (37.0 ± 1.2 vs. $36.0 \pm 1.0^\circ\text{C}$; $p = .01$) with the HotLine group having the higher temperature. There were no significant differences in hematocrit levels at 24 hours, last in the OR, or the change after the MUF period. No significant difference was found in blood transfused postprotamine in the OR, 24-h blood transfused, 24-h chest tube loss, or sternal closure. The study suggests that the use of a heated MUF infusion line safely reduces the heat loss associated with MUF in the immediate post-operative period. **Keywords:** modified ultrafiltration, hypothermia, blood transfusion, cardiopulmonary bypass, pediatric. *JECT. 2002;34:88-91*

In the early 1990s, Naik et al. (1) described the use of modified ultrafiltration (MUF) for the removal of extracellular water in the immediate post-CPB period. This technique utilizes the CPB circuit and a hemofilter in an arterial-venous (A-V MUF) shunt. The patient's blood is removed using the arterial line, shunted through a hemofilter wherein extracellular fluid is removed, and the concentrated volume is then returned to the patient on the venous side. The residual blood volume in the CPB circuit

is slowly transferred into the MUF circuit and returned to the patient. This technique returns nearly all the blood in the CPB circuit to the patient and increases the post-CPB hematocrit (HCT) to preoperative values, resulting in decreased blood product utilization. With this technique, total body water (TBW) content increase is reduced from 18 to 6% in the post-CPB period. MUF has also been associated with a decrease in 24-h total blood loss, presumably from an increase in fibrinogen and total plasma protein concentrations and an increase in mean systolic and diastolic pressures (49 and 28 mmHg, respectively) (2-5). Further investigation of this technique showed a marked increase in cardiac index, no change in systemic vascular resistance, and a decrease in heart rate and pulmonary

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vascular resistance. MUF has also been shown to increase myocardial contractility and to reduce myocardial wall thickness (6). Still further investigation showed that MUF increases pulmonary compliance and arterial oxygenation and decreases pulmonary hypertension, intrapulmonary shunt fraction, and the incidence of pleural and pericardial effusions (7–11). Studies of the increase in systolic and diastolic pressure reveal that MUF improves left ventricular function and diastolic compliance while reducing inotrope requirement in the early postoperative period (12, 13). The use of MUF has also been associated with shorter hospital stay and, consequently, an over-all cost reduction. (11).

Modified ultrafiltration is not without its complications. Hypothermia during the MUF period and entrainment of air into the CPB circuit (on the arterial side, across the membrane of the oxygenator) have been reported. In smaller patients, there have been reports of arterial cavitation caused by obstruction of the aortic cannula by the aortic wall during extraction, as well as aortic obstruction by the arterial cannula itself (14). Decreased patient temperature may be associated with bleeding causing an increase in time to sternal reapproximation and OR time, decrease in cardiac function and peripheral perfusion, and an increase in blood product utilization. These complications may reduce some of the benefits described with the use of MUF.

Although the residual blood and the crystalloid used to clear the CPB circuit are continuously heated with the heat exchanger of the oxygenator while slowly being transferred into the MUF circuit, the volume only represents a small portion of the entire volume of the MUF circuit. Most of the heat lost during the MUF period is caused by the extracorporealization of blood traveling from the arterial line, through the hemofilter, and into the MUF return line, all of which is unheated in a system not incorporating the heat exchanger of a blood cardioplegia device. In an effort to reduce the heat loss associated with MUF, a circuit was designed in which the infusion line was replaced with a sterile, modified level 1 (Sims Level 1, Inc., Rockland, MA) blood line (HotLine). Previously, standard IV tubing was utilized in this position.

MATERIALS AND METHODS

After obtaining Committee for Protection of Human Subjects exemption for obtaining informed consent from the parents of these patients, a retrospective study to evaluate the efficiency of the hot MUF infusion line against the previous system was undertaken. Two groups were evaluated: Heated MUF infusion line ($N = 20$) and nonheated MUF infusion line (Control; $N = 20$). Twenty

patients under 10 kg who underwent MUF before the change to a heated infusion line were retrospectively identified and matched to patients undergoing MUF with a heated infusion line with regard to weight, lesion, procedure, surgical staff and technique, and disposable equipment. The two groups were evaluated for temperature change during the MUF period, blood loss postprotamine in the OR and 24 h postoperatively, blood transfusion postprotamine in the OR and 24 h postoperatively, time to sternal reapproximation postprotamine, and hematocrit change during the MUF period and at 24 h after surgery.

MUF Procedure

Patients were separated from CPB in normal fashion, clamping the venous line, and filling the patient until adequate hemodynamics were achieved. A pre-MUF ABG was drawn from the patient, and pre-MUF datapoints were collected. The venous line was then drained of blood and replaced with crystalloid. Immediately post-MUF, an ABG was drawn, and hemodynamic data were recorded before cannulas were removed, along with filtrate volume removed and amount of time taken to MUF. The inlet of the MUF circuit was connected to the luer connector on the “Y” of the venous cannula, and air was removed. Blood was removed from the patient and into the MUF circuit via the arterial cannula and line (Figure 1). MUF was begun by running the filtration pump at a rate tolerated by the patient, 10–30 mL/kg/min. The effluent volume removed from the patient was replaced by slowly running the arterial pump head, displacing the residual blood volume from the A–V circuit into the MUF circuit, chasing through the CPB circuit with crystalloid. When the patient require volume, the filtration pump rate was lowered, and the arterial pump head rate increased, transferring volume to the patient through arterial line. MUF was continued until the priming and reservoir volume of the CPB circuit were removed or the circuit was clear of blood. The only procedural difference between the two groups was in the use of the HotLine or standard IV tubing, both being the same length and 1/8-in diameter.

Data Analysis

Data were collected and entered into a spreadsheet for analysis and reported as mean \pm standard deviation of the mean. Differences between the groups were analyzed with one tailed *t*-test to identify statistical significance, and $p < .05$ was accepted as significant.

RESULTS

There were no significant differences between the Hot MUF group and the Control group in hematocrit levels at 24 h, last in the OR, or after the MUF period, or sternal

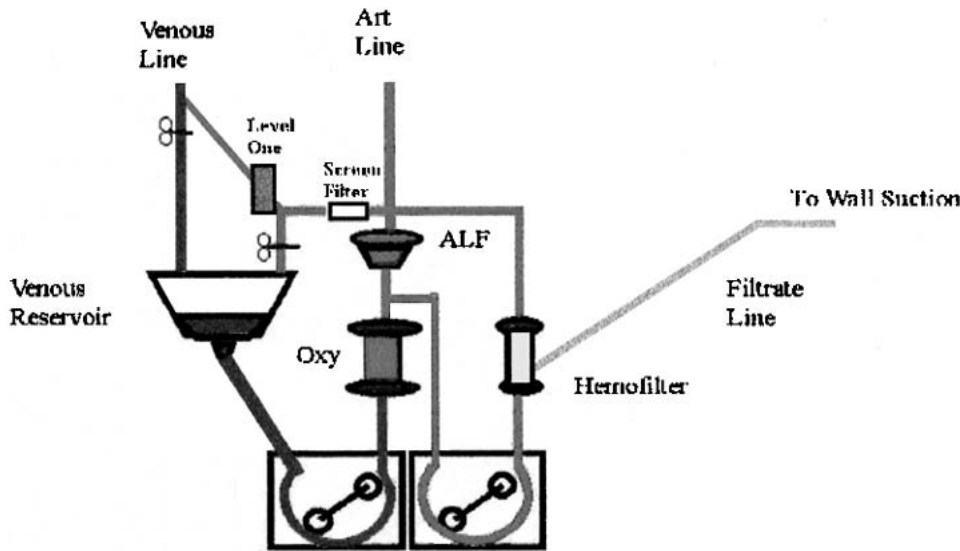


Figure 1. A-V MUF circuit incorporating Level 1 HotLine.

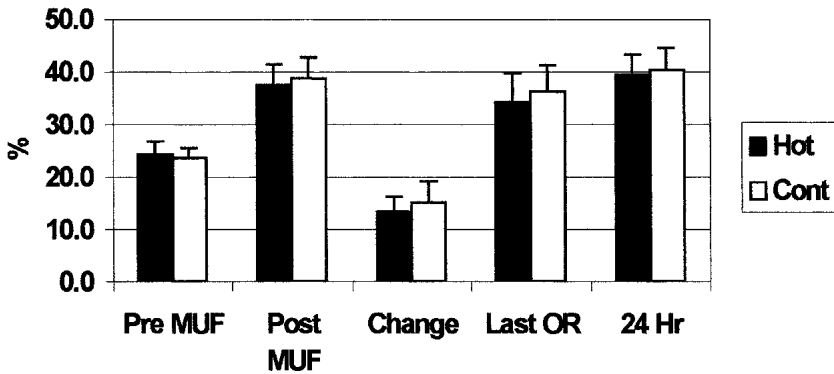


Figure 2. Hematocrit differences between Hot MUF and Control group.

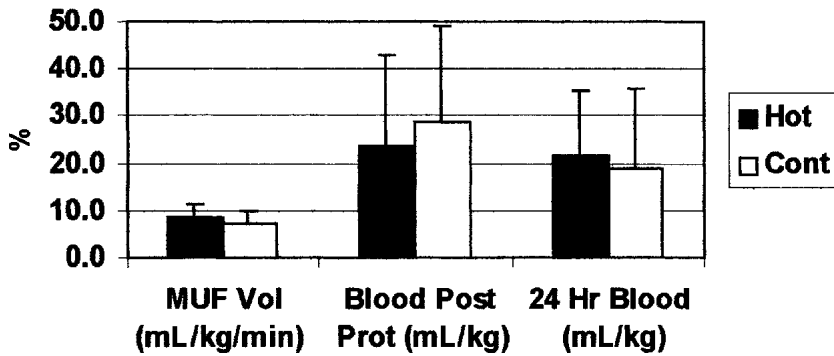


Figure 3. Fluid comparisons between Hot MUF and Control group.

closure postprotamine (Figure 2). No significant differences were found in MUF volume, blood transfused postprotamine in the OR, 24-h blood transfused, or 24-h chest tube loss (Figure 3).

Statistical significance was seen in comparing the heat lost during the MUF period between the two groups (-0.24 ± 0.72 vs. -1.58 ± 0.89 °C; $p < .0001$) and last OR temperature recorded (37.0 ± 1.2 vs. 36.0 ± 1.0 °; $p = .01$) favoring the Hot MUF group in both (Figure 4).

DISCUSSION

The technique of incorporating a HotLine into the MUF circuit was first described by Davis in a letter to the editor published in 1995 (JECT. 1995;27). The purpose of incorporating a HotLine into the MUF circuit was an attempt to alleviate the core temperature reduction seen in the smaller patient population undergoing CPB during this period. Our aim was to reduce such hemody-

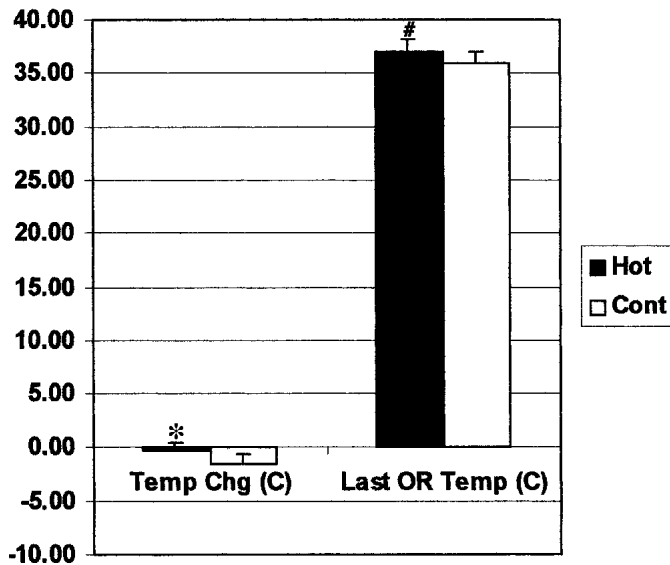


Figure 4. Temperature change from pre to post MUF and last OR temperature comparison between Hot MUF and Control group. * = $p < 0.0001$; # = $p < 0.01$.

dynamic instabilities associated with this reduction as post-protamine bleeding, blood gas and electrolyte imbalances associated with blood replacement, and continued heat loss associated with blood transfusion. With the innumerable variations on modified ultrafiltration currently being practiced, many of which incorporate the heat exchanger of a blood cardioplegia device, the method described would benefit most those centers not incorporating a heating device within their MUF circuit.

Evaluation of the data suggests that the objective of reducing the heat loss associated with MUF was achieved using the modified HotLine. The last OR temperature of the Hot MUF group was statistically significant, being higher than the control group probably as a result of reducing that which was lost during the MUF period. Neither of the two groups experienced any further heat loss during the remainder of the surgical procedure post MUF. The control group did receive more blood in the OR post-protamine administration however, not a statistically significant amount. No differences were seen in the first 24 h after surgery in the amount of blood transfused or chest tube output, suggesting that the benefits of the Hot MUF infusion line are limited to the immediate post-operative period.

CONCLUSION

This study suggests that the incorporation of a Hot MUF infusion line into the MUF circuit does significantly reduce the heat lost when this technique is used. Evalua-

tion of the data in this patient population suggests that other measured variables were not significantly affected by reducing the heat loss associated with MUF, although there was more blood transfused in the control group in the immediate post CPB period. There were no other significant findings in the first 24 h following surgery, suggesting that the benefits of the Hot MUF infusion line are limited to the immediate postprotamine period. Further studies into this technique should be limited to a population of smaller patients, perhaps under than 5 kg, which would benefit even further from this heated infusion circuit.

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