

Novel Applications of Modified Ultrafiltration and Autologous Priming Techniques to Reduce Blood Product Exposure on ECMO

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Abstract: Patients needing the assistance of extracorporeal membrane oxygenation (ECMO) are at risk of hemodilution and, in some instances, may require exposure to large amounts of allogeneic blood products. Patient outcomes can be improved by taking steps to reduce transfusions and hemodilution. Currently, modified ultrafiltration (MUF) is used across the world to reduce hemodilution after cardiopulmonary bypass (CPB). Another common technique during bypass initiation is autologous priming. By applying modified versions of these techniques, ECMO patients may potentially benefit. Usually, patients requiring immediate transition from CPB to ECMO are not stable enough to tolerate MUF. Through alterations of the CPB and ECMO circuit tubing, MUF can be performed once on

ECMO. Another technique to potentially lower the transfusion requirements for ECMO patients is a complete circuit blood transfer during an ECMO circuit exchange. While selective component changes are preferred if possible, occasionally a complete circuit change must be done. To minimize hemodilution or prevent priming with blood products, the original ECMO circuit's blood can be transferred to the new ECMO circuit before connecting to the patient. Both of these techniques, in our opinion, helped to reduce the number of transfusions that our ECMO patients have seen during these critical time periods. **Keywords:** extracorporeal membrane oxygenation, modified ultrafiltration, blood conservation, autologous priming. *JECT. 2016;48:23–26*

OVERVIEW

Although it is possible for some patients to avoid transfusion during extracorporeal membrane oxygenation (ECMO), most patients having this therapy will require allogeneic blood products (1). Allogeneic blood transfusions have been negatively collated to long-term patient outcomes (2). Through employment of known transfusion-sparing techniques, such as modified ultrafiltration (MUF) and autologous priming, clinicians are able to reduce transfusion rates during and after cardiopulmonary bypass (CPB) (3,4). Novel approaches to these techniques can be used on ECMO to minimize blood product exposure to this specific patient population.

MUF has been adopted as a primary method to reverse the dilution effects of CPB after separation from bypass

(5). This technique has been shown to reduce blood exposure and organ edema, while improving hemodynamics in pediatric and neonatal patients (3–6). The use of MUF has not been frequently applied to ECMO patients. A single publication exists that discusses the use of MUF post-ECMO (7). Deptula et al. describes a technique that uses MUF to reinfuse the residual ECMO circuit blood into the patient after separation from ECMO. In contrast, our group used MUF immediately after the transition from CPB to ECMO to reduce the residual CPB circuit blood sent to the Fresenius Continuous Autotransfusion System machine (Terumo CVS, Ann Arbor, MI). The blood sent to the cell saver device would be stripped of its plasma and platelets and only the red cells would be returned to the patient. This would potentially cause further dilution of clotting factors and platelets with its transfusion.

Another technique that may be used to reduce blood product exposure is used during a complete ECMO circuit change. The premise behind the technique is that although the patient's ECMO circuit needs to be replaced, for example due to diffuse clot in entire circuit, the blood in the circuit is still viable. Through temporary suspension of ECMO for about 2 minutes, the blood from the old circuit can be used to displace the Plasma-Lyte A (Baxter, Chicago, IL)

Received for publication November 20, 2015; accepted March 3, 2016.
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The senior author has stated that the authors have reported no material, financial, or other relationship with any healthcare-related business or other entity whose products or services are discussed in this paper.

prime volume in the new circuit prior to connecting the new circuit to the arterial and venous cannulas.

DESCRIPTION

MUF Immediately after Transfer from CPB to ECMO

After the patient has been transferred from CPB to ECMO, several adaptations must be made prior to performing MUF. First, the surgeon should ensure the CPB arterial line tubing has a straight cut. This is necessary if a scalpel is used to remove the bypass tubing from the arterial cannula. Then a $\frac{1}{4}$ " male swivel adapter (product number 60,030, Medtronic, Dublin, Ireland) can be inserted into the newly cut CPB arterial line. If the arterial cannula connector does not have a luer port present, then a $\frac{1}{4}$ " \times $\frac{1}{4}$ " connector with a luer must be added into the ECMO circuit's arterial line. This should be placed approximately 2 inches from the arterial cannula and de-aired. Next, the arterial CPB line can be connected to the arterial luer port by slowly advancing the arterial CPB pump during the connection to aide in de-airing. This becomes the blood access line for the MUF circuit. Finally, the MUF/cardioplegia line from the CPB circuit can be connected to the luer port on the venous cannula connector. This is now the blood return line for the MUF circuit. Both of the previously discussed connection steps require brief interruptions of ECMO (Figure 1).

In our MUF setup, one of our twin roller S5 Stockert pumps (Sorin, Milan, Italy) controls the draw from the MUF access/CPB arterial limb access line into a Dideco DHF 0.2 hemoconcentrator (Sorin). After passing through the hemoconcentrator, blood flows through a cardioplegia heat exchanger and is returned by the MUF return/

cardioplegia limb line back into the venous cannula connector. The residual blood from our CPB circuit including its venous line, venous reservoir, pump boot, oxygenator, and part of the arterial line can be all reinfused with MUF. The result is an increased hematocrit and decreased hemodilution. While performing MUF, the perfusionist responsible for the ECMO circuit communicates the reading from the ECMO venous pressure transducer periodically to the perfusionist performing MUF to ensure there is no venous cannula cavitation. Normally, this pressure value should stay above -25 mmHg from our experiences.

Blood Displacement during an ECMO Circuit Exchange

The blood displacement procedure is done with the assistance of an operating room team and two perfusionists. Our institution has found it helpful to have a multidisciplinary pause prior to the procedure to review the steps and ensure all supplies are readily available, and reduce the time the patient is off ECMO. Items needed to complete the transfer of blood are tubing clamps, two 1-L sterile basins, 1 L of .9% sodium chloride (Baxter), a $\frac{1}{4}$ " \times $\frac{1}{4}$ " connector, and a new primed ECMO circuit. The new ECMO tubing is handed up to the sterile field. Our circuits contain either a Pedimag or Centrimag centrifugal pump (Thoratec, Pleasanton, CA) for neonate and pediatric patients, respectively. The functioning ECMO circuit revolutions per minute (RPMs) should be reduced and the venous line can be clamped to separate from ECMO support. The arterial and venous lines from the old ECMO circuit are removed from the patient's cannulas with a scalpel. The bladed section of the arterial line is cut off and a $\frac{1}{4}$ " \times $\frac{1}{4}$ " connector is attached to this line. The new circuit's venous line is attached to the other end of the $\frac{1}{4}$ " \times $\frac{1}{4}$ " connector through utilization of a wet-to-wet de-airing technique. Next, the old venous line is placed into a 1-L basin of saline. It is important to ensure that all air is removed from the tubing as it is placed into the basin. The new circuit's arterial line is placed into the empty basin. The perfusionist controlling the old ECMO circuit leaves their centrifugal pump on in a low RPM setting to prevent excessive negative venous pressures. The perfusionist controlling the new ECMO circuit leaves their centrifugal pump off. If shunt lines are present in either circuit, these should be turned off to prevent unintended recirculation. After confirming all components are properly de-aired, the old circuit's blood can be pumped into the new circuit. Once the clear prime is displaced the new ECMO circuit's venous line can be clamped to stop the process. The new arterial and venous lines can be connected to the cannulas using a wet-to-wet technique and ECMO can be reinstated (Figure 2). The blood from the old circuit's shunt line can then be removed with a large syringe and used to displace the crystalloid prime of the

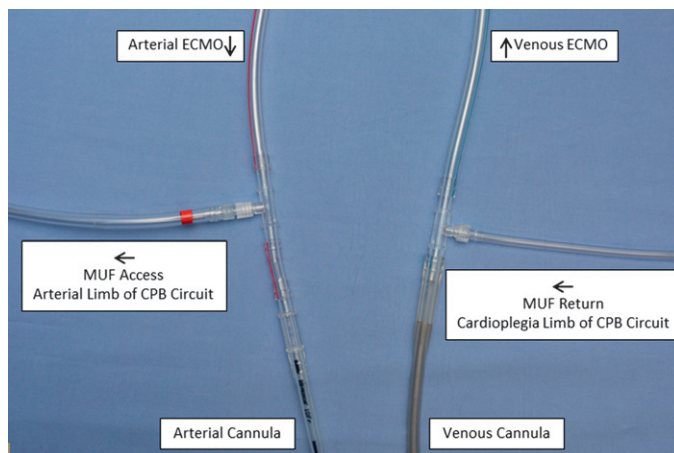


Figure 1. A mock setup of the completed adaptations in the sterile field between the CPB circuit and the ECMO circuit to allow for MUF of the residual CPB volume while the patient is supported on ECMO.

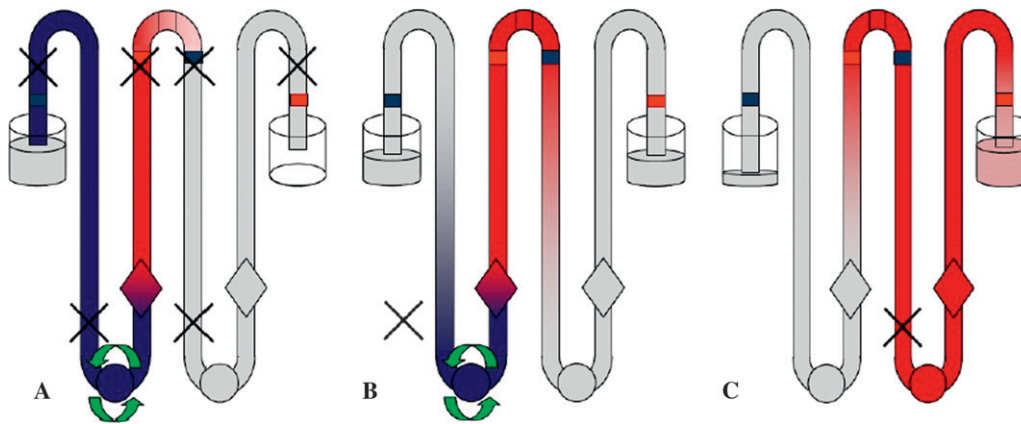


Figure 2. (A) The setup after the ECMO tubing from both circuits have been connected together and basins prepared for the blood transfer with all necessary tubing clamps applied. (B) The displacement initiation with the new circuit's crystalloid being displaced by the blood from the old circuit. Note that the old circuit pump is on and the new circuit pump is off. In addition, the perfusionist controlling the new circuit has a clamp available by the venous line to stop the process at completion or if air is entrained from the old circuit's basin. (C) The completion of the process with clamp reapplied. Note that some low red blood cell containing crystalloid is displaced into the new circuit's basin to ensure minimal crystalloid remains in the new ECMO circuit.

new circuit's shunt line, before it is opened to the patient, but after restarting ECMO support.

DISCUSSION

Through modification of currently available CPB techniques, we have the potential to improve patient care during two critical periods ECMO patients may encounter. The techniques described build on the use of MUF and autologous priming, by trying to reduce hemodilution, edema, and prevention of loss of coagulation factors and platelets. The ability to perform these two techniques requires multidisciplinary team involvement and communication to ensure safe and effective use. Normally, we use MUF post-CPB and consider ECMO after completing MUF if the patient is unstable. For patients that require ECMO immediately post-CPB, these patients can still receive the benefits of MUF through temporary connections between the CPB and ECMO circuits.

Once on ECMO, our institution's practice is to perform selective interventions if a specific component of the ECMO circuit needs attention (i.e., oxygenator change out or a selective change out of a venous or arterial line). It is our practice to perform a full circuit exchange only if multiple areas of the circuit are problematic. This would include scenarios like diffuse clot in many areas of the circuit's arterial and venous tubing and oxygenator. At our center before this new technique was developed neonatal and small pediatric patients requiring a full ECMO circuit change would normally be exposed additional packed red blood cells, and fresh frozen plasma to prime the new circuit. The hemodilution episode also would normally require administration of platelets once the circuit exchange was completed. The old circuit's blood was either processed via a cell salvage device, with the red cell product transfused

later, or the circuit blood was discarded. Through utilization of the prime displacement technique described, these additional blood exposures were prevented during the circuit exchanges. This technique is also applicable to adults and can potentially reduce the need for additional packed red blood cell and platelet exposure. This technique could also be applied at ECMO intuitions that have roller pumps as their propulsion device. This would require slight modifications given the nature of the positive displacement mechanism of roller pumps. As with any instance when a patient is removed temporarily from ECMO, discussion within the care team to assess the safety, risk, and benefit of any technique should be considered. This should be considered even with the techniques discussed in this paper as they have not been based on data as of yet or the risks quantified.

Finally, an additional benefit of performing prime displacement during a circuit exchange is the maintenance of the patient's pre-existing level of anticoagulation. Without this technique, the concentration of the medications in the patient's system would be diluted. This is especially important for ECMO patients who may be on a multi-drug anticoagulation regimen including, but not limited to, heparin, argatroban, bivalirudin, dipyridamole, acetylsalicylic acid, or clopidogrel. These regimens would be difficult to reproduce in a circuit primed with crystalloid and/or allogeneic blood products. By continuing to redefine standard techniques or create new methods to serve our patients we can improve patient care. This takes the ingenuity of a multidisciplinary team with the drive and will to evolve our practice.

ACKNOWLEDGMENTS

We wish to thank the operating room team personnel that have made these techniques safe and possible including the CCPs, CRNAs, CSTs, RNs, SAs, residents, and consultants.

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