

Technique Article

Using a Modified CPD Blood Bag to Store Blood from either ECMO or RRT Circuit Blood in Pediatric Patients

James R. Neal, CCP, FPP,* Tammy P. Friedrich, MSN, RN;† Gregory J. Schears, MD;‡
Carl H. Cramer II, MD§

*Department of Cardiac Surgery, †Department of Nursing, ‡Department of Anesthesiology and Critical Care Medicine, and §Division of Pediatric Nephrology, Mayo Clinic, Rochester, Minnesota

Presented at the 2018 AmSECT Pediatric Meeting, Miami, Florida, October 4–6, 2018.

Abstract: By adapting a citrate phosphate dextrose (CPD) whole blood storage bag, residual blood from a renal replacement therapy (RRT) circuit can be saved in pediatric patients, decreasing in donor exposure later. The techniques used for autologous preoperative blood storage are the basis of storing the RRT circuit blood. The CPD anticoagulant has a benefit of having a commonly used reversal agent for its anticoagulant properties, i.e., calcium. Also, unlike the traditional anticoagulants used in extracorporeal membrane oxygenation (ECMO), i.e., heparin, and direct thrombin inhibitors, i.e., bivalirudin, there is no increase in anticoagulation laboratory parameters after administration. The CPD volume in the bag is reduced but keeps the original ratio the same between CPD and blood. This is

accomplished by removing all CPD from the bag, adding back only the exact amount of CPD needed for the smaller amount of blood being transferred from the circuit. The RRT circuit managed at our institution uses 23 mL of CPD for 165 mL of circuit blood when stored with this technique. This calculation assumes a normal patient calcium level. This technique has been used successfully multiple times in more than 30 pediatric patients without incident for 7 years at our center. The CPD bag can also be used to store the residual blood from ECMO circuits after removal of ECMO to allow the blood to be given back to the patient at a later time by keeping the same citrate-to-blood ratio.
Keywords: ECMO, CRRT, blood conservation, CPD, storage. *J Extra Corpor Technol. 2020;52:146–50*

OVERVIEW

For pediatric and neonate patients on extracorporeal membrane oxygenation (ECMO) and continuous renal replacement therapy (CRRT), the volume of circulating blood contained within the circuit may be equal to or greater than the patient's native estimated blood volume. This can create a scenario where those patients may not tolerate the reinfusion of the blood from these circuits should the need arise where the renal replacement therapy (RRT) circuit is temporarily or permanently

disconnected from the extracorporeal membrane oxygenation (ECMO) circuit. In addition, it is well known that the transfusion of autologous red cells has been shown in multiple single- and multicenter studies to decrease survival to discharge at larger mL/kg amounts (1). Although ECMO patients, especially pediatric patients, do require blood transfusions, any attempt at reducing or delaying blood product exposure or preventing blood loss should be considered. This is especially true because many long-term pediatric ECMO patients may be on a transplant list (2).

As the modality of ECMO is increasing, CRRT in combination with ECMO is increasing in the pediatric population. The survival to discharge of pediatric patients needing both technologies is significantly worse (3,4). However, there may be specific patient situations where ECMO and CRRT used together may allow for best chance of survival. Most published articles in the area

Received for publication March 16, 2020; accepted May 14, 2020.
Address correspondence to: James R. Neal, CCP, FPP, Perfusionist, Department of Cardiac Surgery, Mayo Clinic, 1216 2nd St. SW, Rochester, MN 55902. E-mail: neal.james@mayo.edu

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.

of ECMO that include mechanical fluid management fall into either an internal pressure-driven fluid removal system using an adapted cardiopulmonary bypass hemoconcentrator, plus or minus a dialysate solution, or a pump-driven formal CRRT machine and disposable set (5,6). At our center, for the pediatric/neonatal population, we use the second method with the Prismaflex HF 1000 (Baxter, Deerfield, IL) with a prime amount of 165 mL. In addition, at our center, we occasionally use the first method by attaching a Hemocor JR (Minntech, Little Falls, NJ) with a circuit priming volume of 35 mL, without a dialysate solution. This technique may be used on patients who are strictly volume-overloaded without evidence of acute kidney injury. This Hemocor JR circuit will not be discussed in this article as its volume is able to be returned to any patient without needing to bag or store the product.

The dilemma regarding this amount of extra-patient volume had been an issue at our center, with the increased use of CRRT in pediatric/neonatal ECMO. Before this described storage method was developed, the RRT circuit blood was simply discarded should the patient need to be removed from CRRT because of necessary transportation within our hospital. If not transported for a period of time, then the RRT circuit would be changed electively usually every 72 hours based on manufacture recommendations, although this could be extended to 96 hours if transmembrane pressures are stable. This change would use a blood transfer from the old RRT circuit to the new RRT circuit and would not use the citrate phosphate dextrose (CPD) bag technique. The amount of anticoagulation running into the ECMO circuit is typically enough to keep the circulating blood within the CRRT circuit free of clot formation. However, should the blood be left stagnant or bagged without proper anticoagulant additives, then the risk thrombus would be high. At our center, bivalirudin and sometimes heparin are the anticoagulants used on ECMO with a goal activated partial thromboplastin time between 50 and 80 seconds. To reduce blood lost during transports to these patients, we considered the concept of adapting the techniques used in autologous preoperative blood storage. This concept was reviewed and found to be worthwhile to pursue because of the similarities of the product, the ease of reinfusion, and a long-term anticoagulant that was easy to reverse in a controlled setting.

DESCRIPTION

A CPD bag (Fenwal, Lake Zurich, IL) contains 63 mL of CPD and, assuming normal patient blood calcium levels, will fully anticoagulate 450 mL of whole blood. Because the combination of either the ECMO circuit or the RRT circuit

does not contain that amount of volume, less CPD was needed for proper ratio of blood to citrate. Our technique for this procedure includes modifying the CPD bag slightly as our process is different from that the manufacturer had originally designed the bag for. The bag's normal access line is clipped with metal compression fittings to prevent any of the CPD in that line from coming into the bag. Next, a spiked infusion line product number 4C2498H (Fenwal) was added to the bag with a stopcock, and all the CPD in the bag was removed via a 60-mL syringe (Figure 1). Then, only the amount of calculated CPD is added back into the bag for the amount of projected blood from the circuit (Table 1). The blood volume needs to be reached but should not be overestimated or the ratio will be incorrect, thus increasing the risk of forming thrombus in the bag. At our center, the blood volume can be easily captured by reviewing the blood volume transfused noted on the Prismaflex. If not using an RRT machine with this feature, it is suggested that a perfusionist or other provider can use a 60-mL syringe to measure blood amounts before adding into the CPD bag.

There are additional considerations made with RRT circuits that have citrate added into the RRT circuit during CRRT. Before the circuit is stopped, a sample from the distal sample port of the RRT circuit is obtained to check the actual free calcium level in the RRT circuit blood. With this data point, the CPD level is adjusted in comparison to the estimated normal free calcium value (Table 2).

Proper labeling as per the American Association of Blood Banking (AABB) was incorporated into our practice by adding a printed patient label with the name and medical record number of the patient, as well as an area for processing information. This information includes the amount of CPD added back into the bag, the amount of blood placed into the bag, the time of the processing time, initials of two professionals processing the product, and expiration date and time (Figure 2). The expiration time is 8 hours from the time of process collection as per the AABB guidelines for acute normovolemic hemodilution blood draws (7).

When the time comes to prime a new RRT circuit, the dialysis team primes the circuit with Plasma-Lyte A (Baxter Deerfield). Once the RRT circuit is fluid-primed, the priming bag is removed and the CPD blood bag is connected to the inflow line of the RRT circuit and the blood slowly displaces the clear priming fluid. Once the citrated blood is completely in the RRT circuit, the CPD bag is discarded and the RRT lines are handed to the ECMO specialist to hook directly into the ECMO circuit. Our current method of CRRT access into the ECMO circuit is via a double Luer-lock connector in the venous line with a wide bore 1/8" tubing off the connector and a stopcock between the 1/8" tubing and RRT machine. There is a process being considered that uses our drug manifold line as the access and return sites for CRRT, but this would not

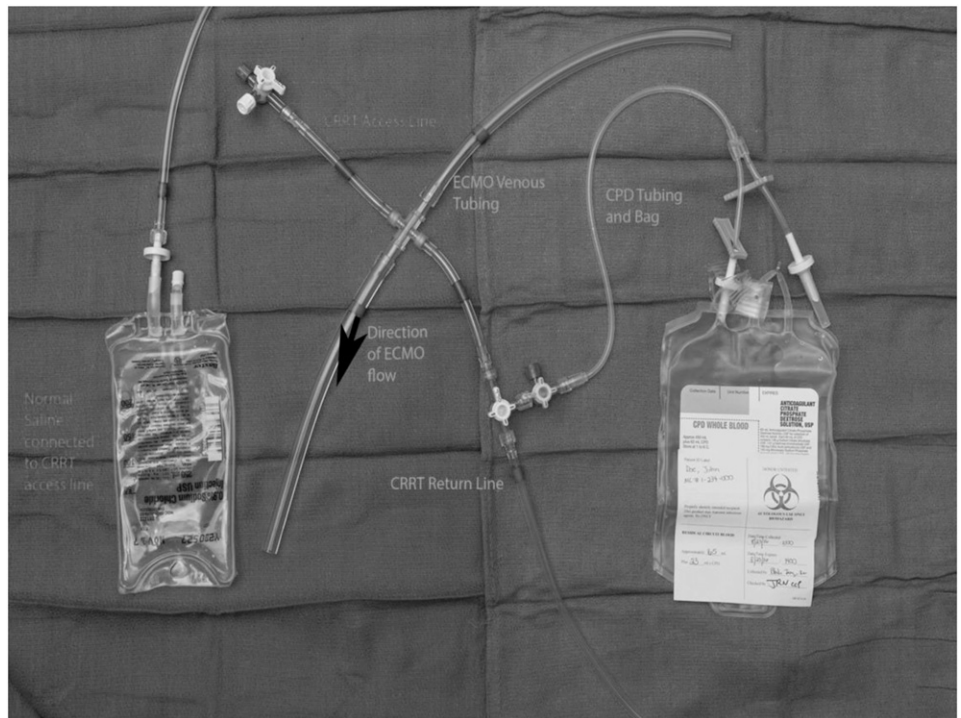


Figure 1. Setup of the RRT system just before flushing the Plasma-Lyte into the RRT system displacing the blood into the CPD bag.

affect the citrate bag process. The RRT circuit is started slowly around 30–40 mL/min for a target blood flow. Calcium chloride injections are available, if needed, to treat hypocalcemia upon starting CRRT again. Having access to point-of-care laboratory testing is advised during this reinstatement of therapy, as the need to give additional additives might be necessary.

DISCUSSION

Because the RRT machines attached to the ECMO circuits cannot be mobile because of limited battery life and highly sensitive weighing of fluids, this technique was

Table 1. Where X is the solved value of CPD to return to bag and for our circuit 165 mL is the whole blood volume in the circuit wishing to be saved.

No Citrate Infusing into CRRT circuit example:	$\frac{63\text{mL}}{450\text{mL}} \times \frac{x\text{mL}}{165\text{mL}} = 23\text{mL CPD returned to bag}$	Solve for x using a ratio
--	---	---------------------------

This value would be different based on each institution’s circuit primes.

developed. The described procedure has allowed pediatric/neonatal ECMO patients who are on CRRT to go to the operating room, image studies, catheterization laboratory, ambulation or rehabilitation, or interventional radiology for line placement and not need additional blood to prime a new RRT circuit. With the blood stored in a controlled way, the loss of significant amount of whole blood, including platelets and plasma, is prevented. This leads to a reduction in needed additional allogenic blood products.

The CPD anticoagulant has a benefit of having a commonly used reversal agent for its anticoagulant properties being calcium unlike traditional anticoagulants used in ECMO

Table 2. This calculation is based on a drawn laboratory value of 2.0 mg/dL of free calcium; this value would be different for any patient, as compared with a normal level of 5.0 mg/dL of free calcium.

Citrate Infusing into CRRT circuit example:	$\frac{2.0\text{mg/dL}^*}{5.0\text{mg/dL}^{**}} \times 23\text{mL} = 9.2\text{mL CPD returned to bag}$	<p>*CRRT Post-Filter Calcium Level **Assumed Normal Calcium Level</p>
---	--	---

This ratio is then multiplied with the amount of CPD calculated from Table 1’s calculation to give the provider the amount of CPD to use in a circuit that already has some level of CPD in it.


<p>Patient ID label</p> <p>Properly Identify Intended Recipient. This product may transmit infectious agents. Rx ONLY</p>	<p>DONOR UNTESTED</p>  <p>AUTOLOGOUS USE ONLY BIOHAZARD</p>
<p>RESIDUAL CIRCUIT BLOOD</p> <p>Approximately _____ mL Plus _____ mLs CPD</p>	<p>Date/Time Collected _____/_____/_____</p> <p>Date/Time Expires _____/_____/_____</p> <p>Collected by _____</p> <p>Checked by _____/_____/_____</p>

Figure 2. Label used to properly identify and label the collected product.

such as heparin and direct thrombin inhibitors, i.e., bivalirudin. By not using additional amounts heparin or bivalirudin to store the blood, the patient’s anticoagulation levels are not elevated when exposed to this blood after priming a new RRT circuit. This is also the case in transfusing the blood directly to the patient over hours if no new circuit is needed.

This practice has been performed on approximately 30 patients who had ECMO and CRRT running. In most patients, the procedure was performed multiple times. Since originally conceptualized in 2012, there have been no adverse events reported. This includes no sign of visible thrombus in any CPD bag before reinfusion. The design and refinement of this practice was developed in response to a critical need to lower the allogenic blood product needs of these patients. This process was then developed more formally, using a multidisciplinary team approach, with protocols being drafted and approved by the medical directors over both ECMO and pediatric nephrology. This protocol was very important to have available, as the ECMO practice numbers and staff have grown over the last 7 years. It was suggested this CPD bag technique be used once every 3 days at most, to avoid citrate toxicity in the patients. The development of this protocol allowed

for providers from multiple disciplines to have a better understanding of the process and to follow the process correctly. Having estimated written protocols for complex events that happen to ECMO patients has been shown to improve outcomes as well (8).

ACKNOWLEDGMENTS

We wish to thank the multidisciplinary team that cares for the pediatric ECMO patients at our center. We also thank Blake Frazier, BSN, RN, CCRN and Brittany Krom, BSN, RN, CCRN for their design of the calculation table layouts.

REFERENCES

1. Smith A, Hardison D, Bridges B, et al. Red blood cell transfusion volume and mortality. *Perfusion*. 2012;28:54–60.
2. Kochhar PK, Ghosh P, Kochhar RS. Effect of blood transfusion on subsequent organ transplantation. *Blood Transfus Clin Pract*. 2012;1: 245–54.
3. Gorga SM, Sahay RD, Askenazi DJ, et al. Fluid overload and fluid removal in pediatric patients on extracorporeal membrane oxygenation requiring continuous renal replacement therapy: A multicenter retrospective cohort study. *Pediatr Nephrol*. 2020;35:871–82.

4. Gupta P, Beam B, Schmitz ML. Outcomes associated with the used of renal replacement therapy in children receiving extracorporeal membrane oxygenation after heart surgery: A multi-institutional analysis. *Pediatr Nephrol.* 2015;30:1019–26.
5. Symons JM, McMahon MW, Karamlou T, et al. Continuous renal replacement therapy with an automated monitor is superior to a free-flow system during extracorporeal life support. *Pediatr Crit Care Med.* 2013;14:404–8.
6. Gander JW, Rhone ET, Wilson WG, et al. Veno-venous extracorporeal membrane oxygenation for continuous renal replacement in a neonate with propionic acidemia. *J Extra Corpor Technol.* 2017;49:64–6.
7. Maynard K. Administration of blood components. *AABB Technical Manual*, 18th ed. Bethesda, MD: AABB; 2014:545–59.
8. Kubicki R, Höhn R, Grohmann J, et al. Implementing and assessing a standardized protocol for weaning children successfully from extracorporeal life support. *Artif Organs.* 2018;42:394–400.