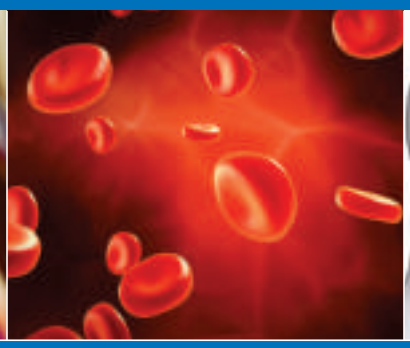
Issue 11

PRIME

Perfusion-Related Insights – Management and Evidence






Review Articles

Expert Experiences

Guidelines

Latest News

Self-Assessment

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PRIME Newsletter invites new authors for their contribution to the perfusion community. If you are interested in volunteering your time writing an article or a topic of your expertise and willing to share your knowledge with our readers, we certainly encourage you to do so. We invite everyone interested in joining our team, and you can contact us at the email given below. Any amount of time that you can volunteer in adding to our quality of publication will be greatly appreciated. Thank you for your interest in PRIME Newsletter. What are you waiting for?

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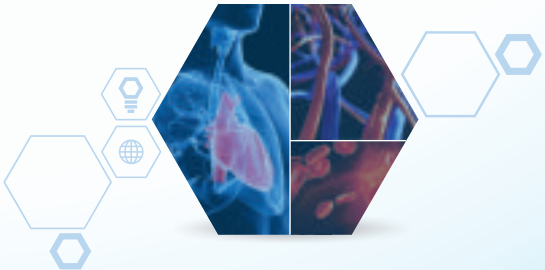

Editorial Letter

Dear Readers,

We are glad to present to you yet another engaging issue of the PRIME newsletter. The “Perfusion-Related Insights - Management and Evidence” or "PRIME" is a scientific newsletter, which is published every quarter with the help of our editorial board members. It includes latest reviews, guidelines, and expert experiences associated with perfusion strategies.

In this eleventh issue of PRIME, we have focused on five interesting articles under the section “Review Articles.” The first article examines the benefits of retrograde autologous priming in adult patients undergoing cardiac surgery. The second article compares the use of roller pumps with that of centrifugal pumps in pediatric patients undergoing cardiac surgery. The third article determines the effectiveness of blood conservation schema in coronary artery bypass graft surgery. The benefits of blood conservation during cardiac surgery are highlighted in the fourth article. The final study evaluates the usefulness of blood conservation techniques in pediatric cardiac surgery.

The section “Expert Experiences” presents a unique case experience of a pregnant woman with severe acute respiratory distress syndrome who was managed on venovenous extracorporeal membrane oxygenation, as shared by our expert.

The "Guidelines" section offers recommendations made by the Society of Thoracic Surgeons, the Society of Cardiovascular Anesthesiologists, and the American Society of ExtraCorporeal Technology regarding the management of temperature during cardiopulmonary bypass.

The section "Latest News" shares recent insights on the superior blood-saving effect in neonates and infants via the comprehensive blood-saving strategy.

The final section "Self-assessment" is a fun section, which will allow you to evaluate your knowledge in cardiology.

We hope that perfusionists will find these articles interesting and helpful. We look forward to receive your valuable feedback, comments, and suggestions to help us work better on the future issues.

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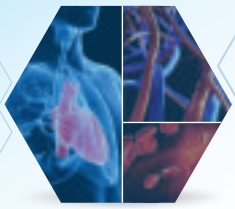

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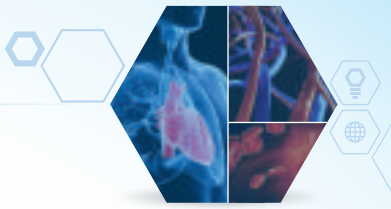


REVIEW ARTICLES

SECTION 1

Benefits of Retrograde Autologous Priming in Adult Patients Undergoing Cardiac Surgery

Introduction

The setup of a cardiopulmonary bypass (CPB) circuit requires a priming volume of around 1,500 mL of crystalloid solution, which results in relevant hemodilution. Hemodilution lowers hematocrit (HCT) levels during CPB and is responsible for impaired hemostasis and detrimental effects on the end-organ function as well as the cognitive outcome. Cardiopulmonary bypass increases the risk of blood transfusion, resulting in several serious complications, like transfusion-related acute lung injury, modulation of the immune system, and an increased postoperative infection risk. Hofmann B *et al*. carried out a randomized prospective study to assess the effects of retrograde autologous priming (RAP) with a specifically designed RAP bag (Terumo) on hemodilution, blood transfusion, and patient outcome.

> **"Retrograde autologous priming reduces the rate of intraoperative and postoperative blood transfusions without increasing perioperative or postoperative complications. This results in favorable outcomes."**

Methods

The study included 118 adult patients undergoing first-time elective coronary artery bypass grafting (CABG) or elective aortic valve replacement. These patients were randomly assigned into two groups—the RAP group (n = 54) in which the patients were subjected to RAP and the non-RAP group (n = 64) in which the same setting was used without the possibility to save the priming volume.

Results

The rate of intraoperative blood transfusion was significantly reduced in the RAP groups versus the non-RAP group (p = 0.04) [Figure 1]. In terms of intraoperative red blood cell (RBC) transfusion, patients managed with RAP showed an absolute risk reduction of 13.5%, whereas those who were managed with a non-RAP approach showed an increased relative risk of 4.6% (p = 0.039) [Figure 2]. In addition, the postoperative mean arterial pressure was 79.8 ± 9.7 mmHg in the RAP group versus 81.2 ± 9.2 mmHg in the non-RAP group.

Figure 1: Effect of RAP on intraoperative transfusions

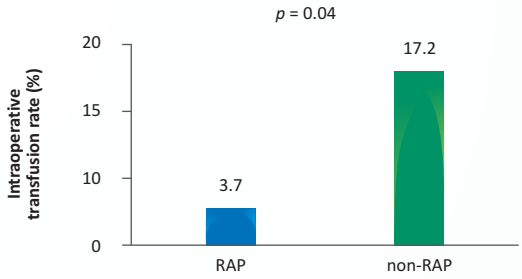
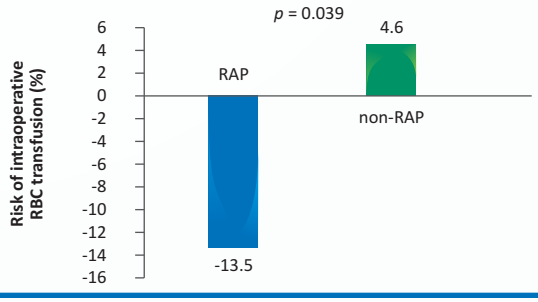


Figure 2: Risk associated with intraoperative transfusions



CONCLUSION

Retrograde autologous priming appears to be a safe, simple-to-use, and effective procedure to reduce blood transfusions in an elective adult cardiac surgery.

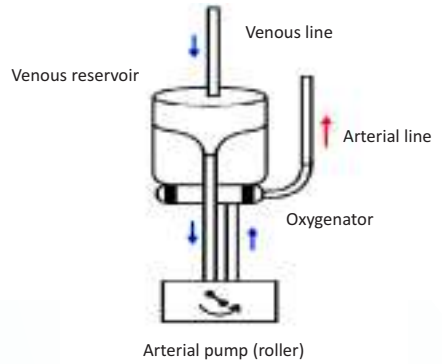
Reference: Hofmann B , Kaufmann C, Stiller M, Neitzel T, Wienke A, Silber R, *et al*. Positive impact of retrograde autologous priming in adult patients undergoing cardiac surgery: A randomized clinical trial. *J Cardiothorac Surg.* 2018 May 21;13(1):50.

Positive Impact of a Roller Pump on Homologous Blood Transfusion in Pediatric Cardiac Surgery

Introduction

Clinical perfusionist who is in charge of neonates and infants undergoing CPB faces a major challenge of reducing priming volumes and decreasing blood transfusions. Large prime volumes associated with centrifugal pumps render these pumps unsuitable in the heart lung machine (HLM) circuitry for children. The Heart Center at Arnold Palmer Hospital, Florida, transitioned a centrifugal pump into a roller arterial pump (Figure 1) to reduce blood product utilization.

Figure 1: Schematic representation of CPB circuits in roller pumps



Methods

The present retrospective study evaluated 140 patients placed on CPB. The patients were divided in the control group (n = 40), consisting of the patients placed on CPB with a centrifugal pump and kinetic assist venous drainage, and the study group (n = 100), consisting of those placed on CPB with a roller arterial pump and gravity venous drainage.

Results

The study showed a significantly lower CPB prime volume in the study (roller pump) group than in the control (centrifugal pump) group ($p < 0.001$) [Figure 2]. Consequently, the prime HCT levels increased significantly in the study group ($p < 0.0001$) [Figure 3]. The mortality at discharge was 5% in the control group versus no mortality in the study group.

> **"Reducing the residual volume allows a shift to whole blood re-transfusion, thereby salvaging the patient's native platelets and clotting factors."**

Figure 2: Effect of a roller pump on CPB prime volumes

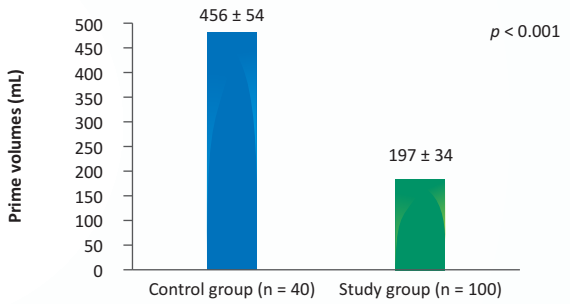
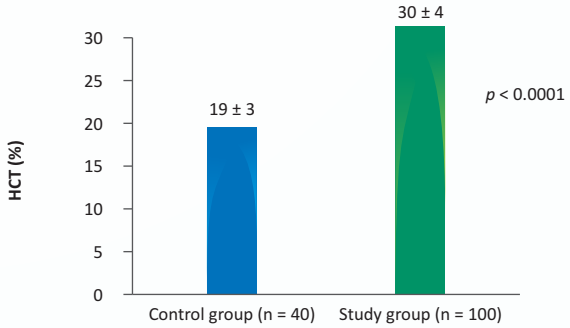


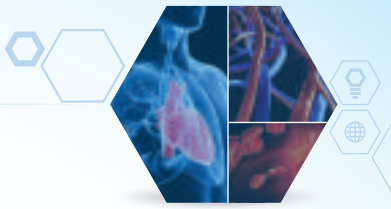
Figure 3: Effect of a roller pump on HCT levels



CONCLUSION

The study demonstrated that transitioning to roller pumps in the arterial position of the HLM considerably reduces the priming volume and provides a basis for a comprehensive blood conservation program. Thus, by maintaining higher HCTs on CPB, intraoperative homologous blood transfusions can be reduced.

Reference: Datt B, Nguyen MB, Plancher G, Ruzmetov M, O'Brien M, Kube A, *et al*. The impact of roller pump vs. centrifugal pump on homologous blood transfusion in pediatric cardiac surgery. *J Extra Corpor Technol*. 2017 Mar;49(1):36–43.



An Improved Hemodynamic Status in Coronary Artery Bypass Graft Surgery through Blood Conservation Schema

Introduction

The off-pump period in a CABG surgery presents as a high-risk period for transfusion, as it culminates in intraoperative hemodilution. During this period, the cannulas are removed, the chest tubes are placed, and the pericardium and median sternotomy procedures are closed. A study conducted by Tran MH *et al*. implemented blood conservation measures to reduce RBC transfusions during the off-pump period of the surgery.

Methods

The measures implemented to reduce intraoperative hemodilution included:

- A reduction in the intravenous fluid (IVF) volume by minimizing the pre-pump IVF administration
- A reduction in the circuit size to minimize the CPB circuit prime by shortening of the length and bore of CPB tubing
- Accommodation of autologous priming and return of the reservoir volume before decannulation (whenever possible)

In addition to the above-mentioned measures, the other previously enacted measures were as follows:

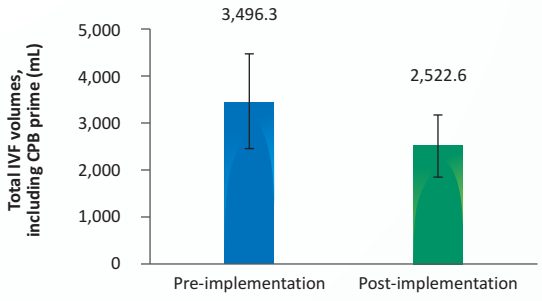
- Continuous intraoperative antifibrinolytic infusion
- Intraoperative cell salvage
- Use of individualized heparin management
- Biocompatible circuits
- Endovascular vein harvesting
- Restrictive transfusion trigger

The study included 136 patients undergoing CABG, with 72 of them in the pre-implementation group and 64 in the post-implementation group.

Results

In comparison to the patients in the pre-implementation group, those in the post-implementations group showed significant improvements in intraoperative fluid volumes, mean HCT results, and off-pump RBC transfusions. The intraoperative hemodilution volume showed an overall reduction of 973.7 mL in the post-implementation group ($p < 0.001$) [Figure 1]. The mean values for the lowest on-pump and last on-pump HCT measurements showed an improvement of 2.4% ($p = 0.004$) and 2.1% ($p = 0.002$), respectively. The number of patients receiving any RBC transfusions during the off-pump period reduced by 20.6% ($p = 0.014$).

Figure 1: Mean total IVF volumes administered



CONCLUSION

The implemented blood conservation schema reduced the mean intraoperative hemodilution volume by around 1 L, improved on-pump HCT levels by more than 2%, and resulted in a 20% reduction in RBC transfusions during the subsequent off-pump period.

Reference: Tran MH, Lin DM, Wilcox T, Schiro D, Cannesson M, Milliken J. Effects of a multimodality blood conservation schema toward improvement of intraoperative hemoglobin levels and off-pump transfusions in coronary artery bypass graft surgery. *Transfusion*. 2014 Oct;54(10 Pt 2):2769–74.

Benefits of Blood Conservation during Cardiac Surgery

Introduction

During the perioperative period of a cardiac surgery, up to 60% of the patients require blood transfusions. These transfusions have been associated with an unfavorable morbidity, mortality, and long-term outcome. The need for blood transfusions can be reduced by implementing various blood conservation strategies. A retrospective study by Avgerinos DV *et al*. examined the effects of an aggressive program for intraoperative blood conservation in patients undergoing cardiac surgery.

> **"The Society of Thoracic Surgery (STS)/the Society of Cardiovascular Anesthesiologists (SCA) guidelines recommend adopting effective blood conservation techniques to reduce the need for blood transfusions during and after cardiac operations."**

Methods

The study included two groups of patients evaluated in different time periods. Group 1 consisted of 1,126 patients who were studied for a 12-month period after the implementation of the new strategy. Group 2 consisted of 3,758 patients who were studied during the previous 36-month period.

The new strategy included:

- More aggressive intraoperative autologous donation (IAD) based on a newly constructed nomogram
- A shorter length circuit of CPB, which decreased the fluid volume of the prime

Further, RAP was maintained constant in both groups.

Results

The study showed a significant reduction in the intraoperative HCT levels ($P = 0.01$, Figure 1), an increase in the mean IAD volume ($P = 0.02$, Figure 2), and a decrease in the CPB priming volume ($P = 0.03$, Figure 3). Patients in group I required significantly fewer blood transfusions in the perioperative period, as compared to group II (29% vs. 49%, $P = 0.02$), and showed significantly reduced postoperative rates of respiratory failure (3% vs. 7%, $P = 0.03$), pneumonia (1% vs. 3.1%, $P = 0.01$), chest tube output (350 mL vs. 730 mL, $P = 0.01$), reoperation for bleeding (1.2% vs. 2.5%, $P = 0.04$), and length of stay (6.1 days vs. 8.2 days, $P = 0.05$).

Figure 1: Effect of blood conservation strategy on HCT levels

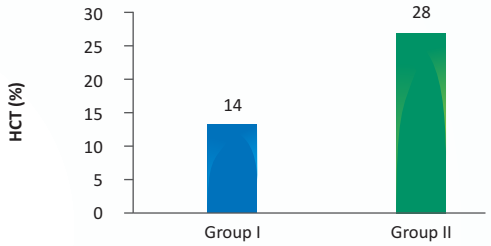


Figure 2: Effect of blood conservation strategy on IAD volume

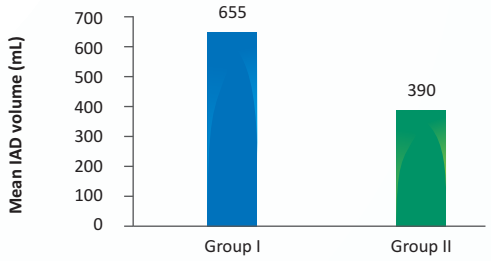
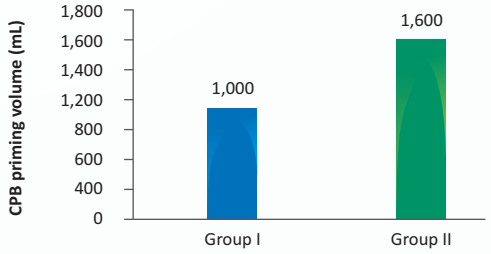


Figure 3: Effect of blood conservation strategy on CPB priming volume



CONCLUSION

Implementation of the blood conservation strategy through aggressive IAD use, low CPB prime, and effective RAP resulted in a significant decrease in blood transfusion. The strategy presented as an effective measure in cardiac surgery.

Reference: Avgerinos DV, DeBois W, Salemi A. Blood conservation strategies in cardiac surgery: More is better. *Eur J Cardiothorac Surg*. 2014 Nov;46(5):865–70.

A Paradigm Shift of Blood Use in Pediatric Cardiac Patients through Blood Conservation

Introduction

Conservation of blood is very important during a surgical procedure because of the shortage of donor blood and the risks associated with the use of allogeneic blood products. Also, transfusions make patients vulnerable to a variety of potential cellular as well as humoral antigens, and disease transmissions. It is believed that in cardiac operations, decreased exposure of children to RBCs may lower the associated complications and improve postoperative outcomes.

Methods

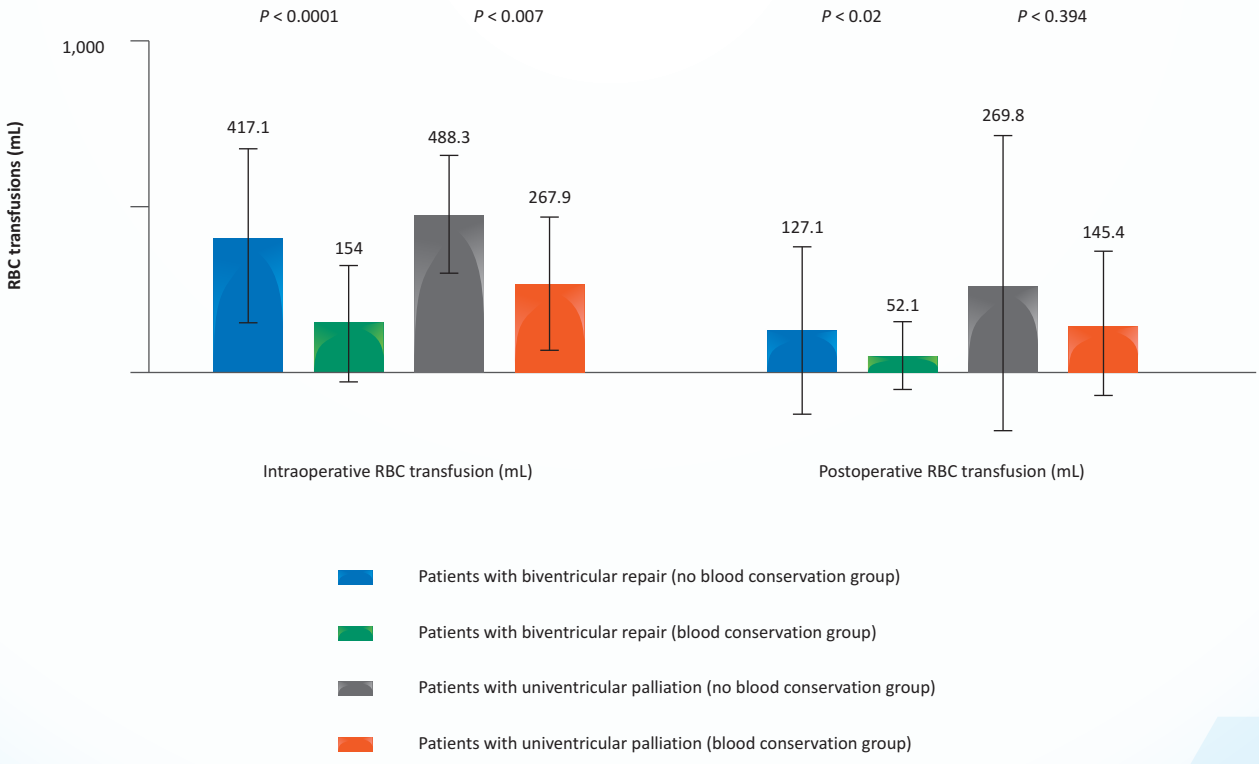
A retrospective analysis was carried out by Karimi K *et al*. in 168 pediatric patients undergoing open cardiac operations to compare the outcomes of blood conservation strategies with the traditional ones. The two groups of patients are compared in Table 1.

The patients were further subgrouped into the no blood conservation group (n = 86 [biventricular = 74 and univentricular = 12]) and the blood conservation group (n = 82 [biventricular = 68 and univentricular = 14]).

Results

The patients in the blood conservation group had significantly fewer intraoperative and postoperative RBC transfusions in biventricular repair and univentricular palliation, as compared to the no blood conservation group (Figure 1). Also, those in the blood conservation group had lower inotropic scores, reduced ventilator days, and shortened length of hospital stay versus the no blood conservation group.

Figure 1: Effect of blood conservation on RBC transfusions



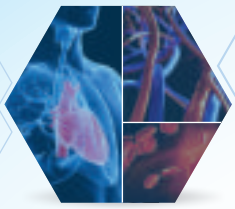


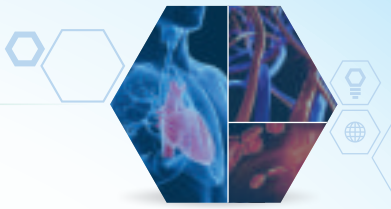
Table 1: Comparison of blood conservation strategies with the traditional techniques

Perfusion techniques	2006–08 (no blood conservation)	2008–10 (blood conservation)
Circuit prime volume (mL)	600	300
Integrated arterial filter with oxygenator	Absent	Present
Cerebral and somatic saturation	Absent	Present
Retrograde arterial priming	Absent	Present
Biventricular HCT during CPB	> 30%	> 21%
Univentricular HCT during CPB	> 40%	> 25%
Biventricular HCT after CPB	> 30%	> 21%
Univentricular HCT after CPB	> 40%	> 35%

CONCLUSION

The study concluded that implementation of blood conservation techniques in pediatric cardiac operations helps lower the need for blood transfusions, and is associated with decreased postoperative inotropic needs, reduced ventilator days, and shortened hospital stay.

Reference: Karimi M, Florentino-Pineda I, Weatherred T, Qadeer A, Rosenberg CA, Hudacko A, *et al*. Blood conservation operations in pediatric cardiac patients: A paradigm shift of blood use. *Ann Thorac Surg*. 2013 Mar;95(3):962–7.



EXPERT EXPERIENCES

SECTION 2

Survival of a Patient with Severe Acute Respiratory Distress Syndrome and Intrauterine Bleeding Managed on Venovenous Extracorporeal Membrane Oxygenation - A Unique Case Experience

Contributed by: Prakash PVS, Mani K, Immanuel S, Selvakumar R, Maria A, Dr. Shetty R, Dr. Shetty V

Introduction

In patients with severe acute respiratory distress syndrome (ARDS), extracorporeal membrane oxygenation (ECMO) can be a lifesaving therapy and should be considered when conventional therapy fails to maintain adequate oxygenation. Extracorporeal membrane oxygenation helps stabilize gas exchange and hemodynamic compromise, thereby preventing further hypoxic organ damage.

Case

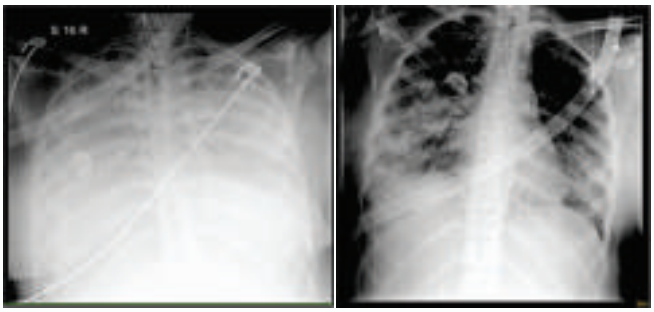
A 31-year-old pregnant woman presented with severe breathlessness in her second trimester and was immediately put on a ventilator. When the conventional methods failed, she was put on venovenous ECMO, which was initiated with a Rotaflow Centrifugal Pump and Maquet PLS Quadrox Oxygenator. Even though the initial plan was to save both the mother and the child, the fetal heart rate was found to be absent on the second day of ECMO and an abdominal ultrasound scan confirmed fetal death. The fetus was evacuated using pharmacologically induced uterine contractions. Heparin was stopped, and the circuit was run heparin-free for the next 2 days to reduce bleeding. However, intrauterine bleeding persisted and was managed with massive transfusions of blood products and intrauterine packs. Dilutional coagulopathy resulting from the pregnant state led to severe bleeding, which required thromboelastographic monitoring. Also, the interventional radiologist embolized some uterine arteries to reduce bleeding.

Discussion

The use of ECMO for severe ARDS in pregnant and postpartum women has shown a survival rate of 66%, with bleeding being the most common cause of death. In the present case, the perfusionist faced a major challenge in managing the patient without heparin and running at low activated clotting time. The patient was anuric and required dialysis due to multiple transfusions. The presence of bronchiolitis obliterans organizing pneumonia was suspected, and the condition was treated aggressively using steroids. Thromboelastographic monitoring was used extensively to administer blood products and control bleeding. The appropriate management and multidisciplinary team approach helped salvage the patient.

The patient was weaned off ECMO successfully after 19 days and was discharged from the hospital after 40 days.

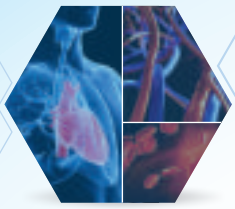
Figure 1: Chest X-rays of the patient on administration and at the end of the ECMO course



Day 1 Day 18

CONCLUSION

The present case demonstrated the usefulness of ECMO as a lifesaving therapy by offering support during the recovery of lungs from infection.



GUIDELINES

SECTION 3

The Society of Thoracic Surgeons, the Society of Cardiovascular Anesthesiologists, and the American Society of ExtraCorporeal Technology Recommendations on the Management of Temperature during Cardiopulmonary Bypass

Optimal site for managing temperature

- The oxygenator arterial outlet blood temperature should be used as a surrogate for measuring the cerebral temperature during CPB.
- To accurately monitor the cerebral perfusate temperature at the time of warming, assume that the oxygenator arterial outlet blood temperature underestimates the cerebral perfusate temperature.
- The use of a pulmonary artery catheter or the way of recording the nasopharyngeal temperature should be considered reasonable for immediate post-bypass temperature measurement.

Avoiding hyperthermia

- To avoid the stage of cerebral hyperthermia, the surgical team should limit the arterial outlet blood temperature to < 37 °C.

Understanding the peak cooling temperature gradient and cooling rate

- Ensure that the temperature gradients from the arterial outlet and venous inflow on the oxygenator during CPB cooling do not exceed 10 ^{0}C in order to avoid gaseous emboli.

Understanding the peak warming temperature gradient and rewarming rate

- Ensure that the temperature gradients from the arterial outlet and venous inflow on the oxygenator during CPB rewarming do not exceed 10 °C in order to avoid outgassing while the warm blood is returned to the patient.

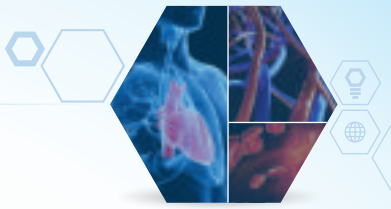
Understanding rewarming when arterial blood outlet temperature ≥ 30 °C

- To achieve the required temperature for separation from CPB:
  - Maintain a temperature gradient of ≤ 4 °C between the arterial outlet temperature and the venous inflow.
  - Maintain a rewarming rate of ≤ 0.5 °C/min.

Understanding rewarming when arterial blood outlet temperature is < 30 °C

- To achieve the required temperature for separation from CPB, maintain a maximal temperature gradient of 10 °C between the arterial outlet temperature and venous inflow.

Reference: Engelman R, Baker RA, Likosky DS, Grigore A, Dickinson TA, Shore-Lesserson L, *et al*; Society of Thoracic Surgeons; Society of Cardiovascular Anesthesiologists; American Society of ExtraCorporeal Technology. The Society of Thoracic Surgeons, the Society of Cardiovascular Anesthesiologists, and the American Society of ExtraCorporeal Technology: Clinical practice guidelines for cardiopulmonary bypass—Temperature management during cardiopulmonary bypass. *Ann Thorac Surg*. 2015 Aug;100(2):748–57.



LATEST NEWS

SECTION 4

Association of comprehensive blood-saving strategy with Superior Blood-Saving Effect and Postoperative Recovery in Infants Undergoing Open Heart Surgery

Introduction

The small body surface area and the low body weight of neonates and infants undergoing an open heart surgery develop unique challenges in the management of CPB. This population becomes susceptible to excessive hemodilution, leading to severe complications, like edema, hypoxia, and hemorrhage. Transfusion of allogeneic blood reduces excessive hemodilution but is associated with high fever, allergic reactions, postoperative infections, and longer ventilation time and intensive care unit (ICU) stay owing to immature organs and inadequate immune functions in this population. In a recent study, Wu T *et al*. analyzed the effect of a comprehensive blood-saving strategy on the postoperative recovery of low-weight infants undergoing open heart surgery.

Methods

The present prospective study included 84 consecutive neonates and infants with acyanotic congenital heart disease. They were randomized into a comprehensive strategy group (n = 42) and a control group (n = 42) [Table 1].

Results

In comparison to the patients in the control group, those in the comprehensive group showed a significantly lowered total priming volume as well as lower requirement of banked RBCs (Figure 1). The patients in the comprehensive group demonstrated a recovery of around 40 mL of RBCs, whereas those in the control group underwent a net use of around 190 mL of RBCs. Further, the comprehensive group showed a significant decrease in the inotrope score (P = 0.032), ventilation time (P = 0.028), ICU stay (P = 0.039), and hospital stay (P = 0.033) after surgery.

Figure 1: Effect of comprehensive strategy

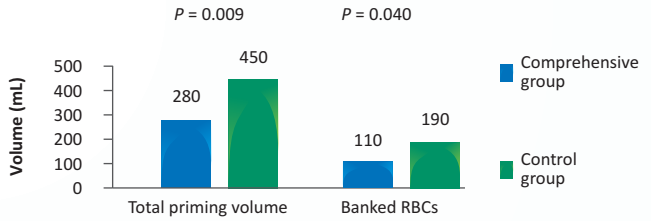


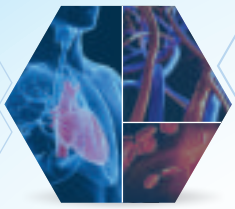
Table 1: Comparison between the techniques used in the two study groups

Techniques	Comprehensive strategy group	Control group
Pump position	Two mast, three fixed pumps	Five fixed pumps
Oxygenator with arterial filter	Yes (Terumo FX05)	No (Terumo RX05)
Elevation of the oxygenator, vacuum assisted venous drainage, and customized circuit	Yes	No
Miniaturized circuit	Yes (4 mm)	No (6 mm)
Ultrafiltration connecting circuit	2.5–3 mm	4 mm
Use of cell saver	Yes	No
Priming with plasma	No	Yes

CONCLUSION

The study concluded that the use of comprehensive blood-saving strategy during CPB was associated with a reduced blood use and favorable postoperative recovery in low-weight infants with congenital heart disease undergoing open heart surgery.

Reference: Wu T, Liu J, Wang Q, Li P, Shi G. Superior blood-saving effect and postoperative recovery of comprehensive blood-saving strategy in infants undergoing open heart surgery under cardiopulmonary bypass. *Medicine* (*Baltimore*). 2018 Jul;97(27):e11248.



Updates on Perfusion and Cardiopulmonary Bypass Techniques Used for Neonatal and Infant Cardiac Surgery

Recent innovations in perfusion techniques and CPB technologies have positively impacted the survival of neonates even after complex cardiac surgeries. The problem of transfusion can be addressed by minimizing the blood prime and improving its quality. Techniques, like acute normovolemic hemodilution, RAP, venous autologous priming, and zero-balance ultrafiltration or dilution ultrafiltration, decrease the requirement of RBC transfusion.

Oxygenators

An ideal oxygenator is the one which can achieve the balance of oxygen and carbon dioxide exchange with a minimal blood damage. High permeability of gas exchange is necessary at the alveolar–capillary interface. Oxygenator fiber bundles, wrapped with an arterial line filter, have been proven to be safe and are routinely used. The commercially available oxygenators that are used currently have prime volumes approaching 10 mL.

> **"Neonatal and infant cardiac surgery has been catapulted into the mainstream standard of care through the development of CPB and perfusion techniques."**

Pumps

An ideal blood pump has the below-mentioned characteristics:

- Low priming volume
- Durable/no mechanical failures
- Easy to set up and operate
- No hemolysis or damage to the elements of the blood
- Antithrombogenic property
- No need for anticoagulation
- Electrical control
- Reproducible stroke volume
- Backup of battery available

In pediatric CPB, the use of occlusive roller pumps is preferred.

Perfusion techniques

Cerebral blood flow with selective antegrade cerebral perfusion (SACP) helps lower the neurologic risks associated with isolated deep hypothermic circulatory arrest (DHCA). The SACP adjunct to standard perfusion enables to improve the cerebral blood flow and minimize the cerebral injury during DHCA.

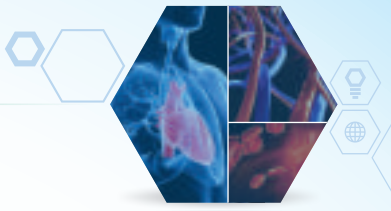
Myocardial protection

The use of cardioplegic solutions in a pediatric cardiac surgery helps arrest the heart in a relaxed diastolic phase and provides maximum myocardial protection.

CONCLUSION

The continued development of CPB technologies, perfusion techniques, and patient management skills will allow the reduction of RBC utilization and postoperative recovery time and will bring out improvement in the long-term clinical outcomes.

Reference: Sturmer D, Beaty C, Clingan S, Jenkins E, Peters W, Si MS. Recent innovations in perfusion and cardiopulmonary bypass for neonatal and infant cardiac surgery. *Transl Pediatr.* 2018 Apr;7(2):139–50.



SELF-ASSESSMENT

SECTION 5

1. The contraction of the ventricles during systole causes _____.

a. All four heart valves to close ☐
b. All four heart valves to open ☐
c. The atrioventricular valves to close and the semilunar valves to open ☐
d. The atrioventricular valves to open and the semilunar valves to close ☐

2. What is the pressure generated by the ventricle to overcome the higher pressure in the aorta known as?

a. Stroke volume ☐
b. Contractility ☐
c. Preload ☐
d. Afterload ☐

3. A 1+ grade in arterial pulses indicates _____.

a. Bounding pulse ☐
b. Weak pulse ☐
c. Increased pulse ☐
d. Absent pulse ☐

4. In order to monitor oral anticoagulant therapy, which test provides the best means for standardizing measurement of prothrombin time?

a. Plasma thrombin time ☐
b. International normalized ratio ☐
c. Partial thromboplastin time ☐
d. Activated bleeding time ☐

5. Why are serial serum cardiac markers monitored in a patient with chest pain?

a. Cardiac markers help determine whether the cardiac damage is occurring. ☐
b. Cardiac markers help identify the area of myocardial damage. ☐
c. Decreasing cardiac marker levels help clinicians estimate the recovery time in a patient with myocardial damage. ☐
d. Cardiac marker results reveal whether a patient is truly having chest pain. ☐

6. Which of the following is a noninvasive method used to evaluate the blood flow?

a. Doppler ultrasonography ☐
b. Venography ☐
c. Angiography ☐
d. Cardiac catheterization ☐

Reference: Self-test: Cardiac quiz. *Nursing*. 2007 Aug;37(8):62–5.