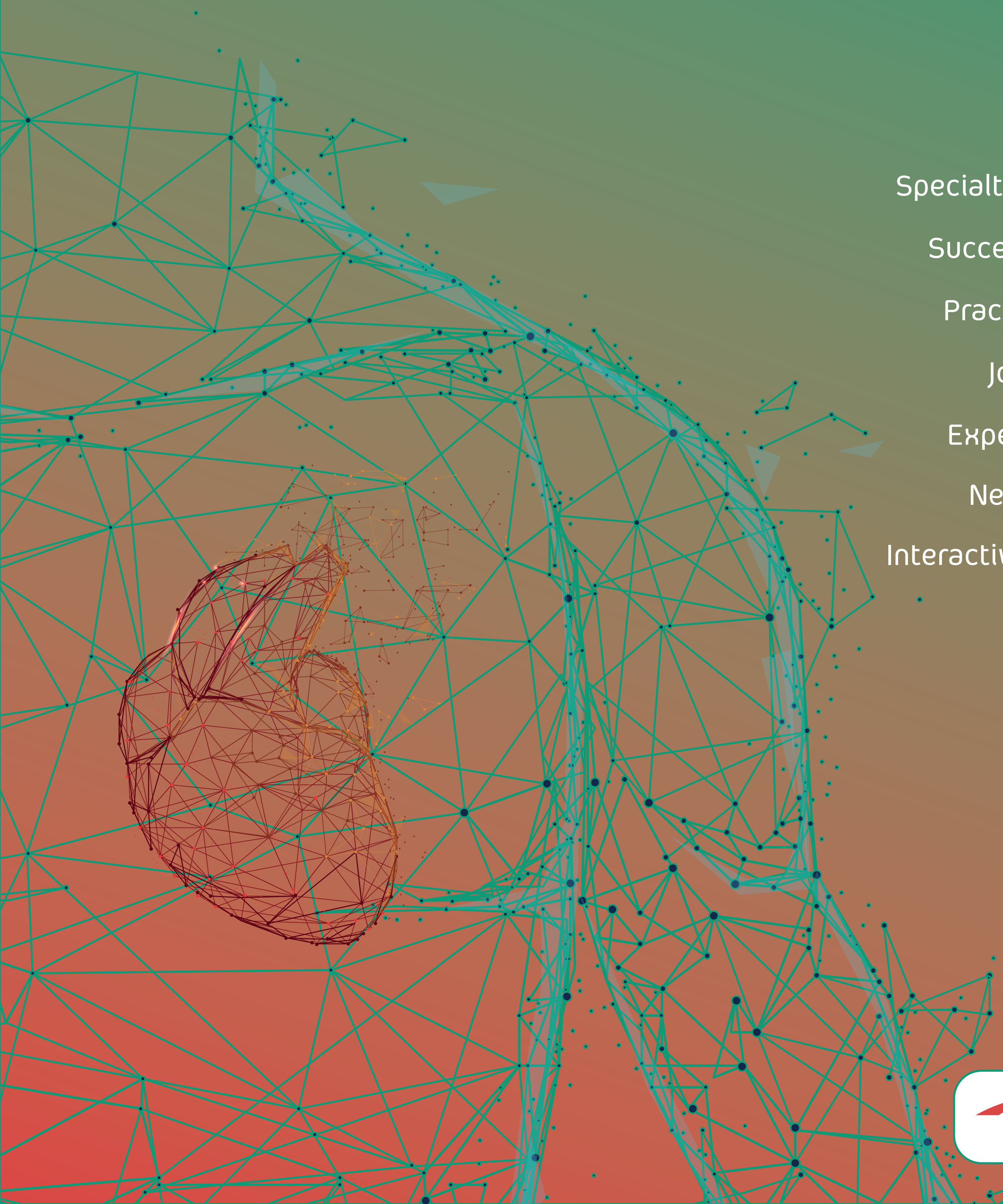
ISSUE 19

PRIME

Perfusion-Related Insights – Management and Evidence



TERUMO

Editorial Letter

It is with immense pleasure that we present 19^{th} issue of PRIME Newsletter — "Perfusion-Related Insights– Management and Evidence" — a quarterly scientific newsletter that includes review article, recently published recommendation, guideline, expert opinion and practice pearls on cardiopulmonary bypass (CPB) and perfusion strategies.

The current issue brings to you an interesting article and guidance recommendations, starting with the first section 'Speciality Insights', which highlights the role of CytoSorb® device in clearance of oral anticoagulant apixaban in a patient underwent CPB.

The first article of second section 'Success Stories' sheds light on importance of miniaturized CPB circuits to reduce the use of ultrafiltration in pediatric patients during congenital heart surgery. The second article describes significance of blood conservation protocol in pediatric bloodless surgery using the standard available CPB unit components.

The third section 'Practice Pearls' reviewed various blood conservation approaches to enable transfusion-free heart surgery in pediatric patients. The first article of next section 'Journal Talk' exhibits management of anticoagulation in patients undergoing pulmonary endarterectomy with CPB and deep hypothermic circulatory arrest. The second article evaluates the relation between biochemical indication of sarcopenia and postoperative pulmonary complications and other morbidities/mortality outcomes in elderly patients undergoing off-pump coronary artery bypass surgery.

The fifth section 'Expert Opinion' is comprised of two articles. The first one presents beneficial role of extubation during extracorporeal membrane oxygenation (ECMO) in adults. The second one summarizes the European guidelines for the practice of CPB and to improve the surgery outcome in patients undergoing cardiac surgery.

Under the sixth and last section 'News Corner', three recent cases on air in ECMO circuit and its consequences are discussed.

We hope this newsletter enriches your knowledge with the current practices and research updates in the field of CPB and perfusion.

Kindly let us know your comments and suggestions to help us improvise based on your feedback.

Dr. Amit Garg
Director Medical, Clinical Affairs
and Strategy Planning
Terumo India Pvt. Ltd.

Rahul Sharma
Sr. Manager Medical Affairs
Terumo India Pvt. Ltd.
rahul_sharma@terumo.co.jp

Scientific Committee

Name	Designation
Dr. Kamla Rana	HOD – Perfusion Department at Medanta - The Medicity, Gurgaon
Mr. P. V. S. Prakash	Consultant Chief Perfusionist at Narayana Hrudayalaya, Bengaluru
Mr. Bhaskaran Vishwanathan	Chief Perfusionist at Madras Medical Mission Hospital, Chennai
Mr. Manoj M. C.	Perfusionist at Kokilaben Dhirubhai Ambani Hospital, Mumbai
Mr. Atul Solanki	Chief Perfusionist at U. N. Mehta Hospital, Ahmedabad
Mr. R. Nair	Consultant Chief Perfusionist at Sir Ganga Ram Hospital, Delhi

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 willingness 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?

rahul_sharma@terumo.co.jp

Table of Contents

INTRAOPERATIVE CLEARANCE OF APIXABAN USING CYTOSORB® DEVICE IN A PATIENT UNDERGOING CARDIOPULMONARY BYPASS

Introduction

The new direct oral anticoagulant apixaban has gained popularity in prevention of stroke and venous thrombosis. But it has a short-life, hence requires daily double dosing, and also associated with multiple transfusions and other blood-related complications. A hemoadsorption device, the CytoSorb® which is developed by CytoSorbents Corportaion, USA, is used in retrieval of pro-inflammatory mediators and drugs from the circulation after inserting into the cardiopulmonary bypass (CPB) circuit. This study evaluated the efficiency of CytoSorb® device used as an adjunct to CPB in an elderly patient undergoing emergent reoperation for active endocarditis and used apixaban for anticoagulation.

Case Study

An 83 year old lady (47 kg body weight) was admitted to the hospital due to decompensated heart failure and hyperthermia. 2 years prior to admission she had chronic heart failure, bioprosthetic mitral valve replacement, chronic atrial fibrillation and a recent lower limb deep vein thrombosis for which she was treated with 2.5 mg of apixaban twice daily. Owing to her severe mitral valve prosthesis stenosis and vegetation on the bioprosthetic leaflets, she was scheduled for emergent surgery to replace the mitral valve. She had administered with apixaban 7 hours before the surgery. The CPB circuit included a centrifugal pump, a membrane oxygenator, a hard-shell reservoir, a hemoconcentrator and a cardioplegia device. CytoSorb® cartridge was inserted between this oxygenator and the venous reservoir, and hemoadsorption was continued for the whole CPB duration. Apixaban-specific anti-factor Xa activity (AFXaA) and heparin reversal with protamine were measured peri-operatively.

Results

- The pre-operative conditions of the patient are presented in the Table 1.
- Activated clotting time (ACT) reached 409 seconds after administration of 27,000 IU of non-fractioned heparin.
- 1,376 ml of cold cristalloïd cardioplegia was used to replace the infected bioprosthesis with a porcine stented bioprosthesis.
- Total CPB duration was 100 minutes.
- After CPB initiation, the level of AFXaA was increased to 114 ng/ml.
- After CPB weaning and protamine administration (15,000 IU) AFXaA level was dropped to 32 ng/ml that remained stable for the next 7 hours.
- AFXaA level remained >20 ng/ml for the next 24 hours (Figure 1).
- As no bleeding complications were observed, the patient had left the ICU on day 2 after the surgery.
- The patient was discharged on day 26.

Condition	Blood parameter	Value
Anemia	Hemoglobin	9.1 g/dl
	Hematocrit	28%
Thrombocytopenia	Platelets	146 g/l
Stage II acute kidney injury	Serum creatinine	106 µmol/l
Inflammation	C-reactive protein	126 mg/l
Blood coagulation	ACT	104 seconds
	Thromboplastin time	26 seconds
Prophylaxis of thrombosis	AFXaA	72 ng/ml

Table 1: Pre-operative conditions of the patient

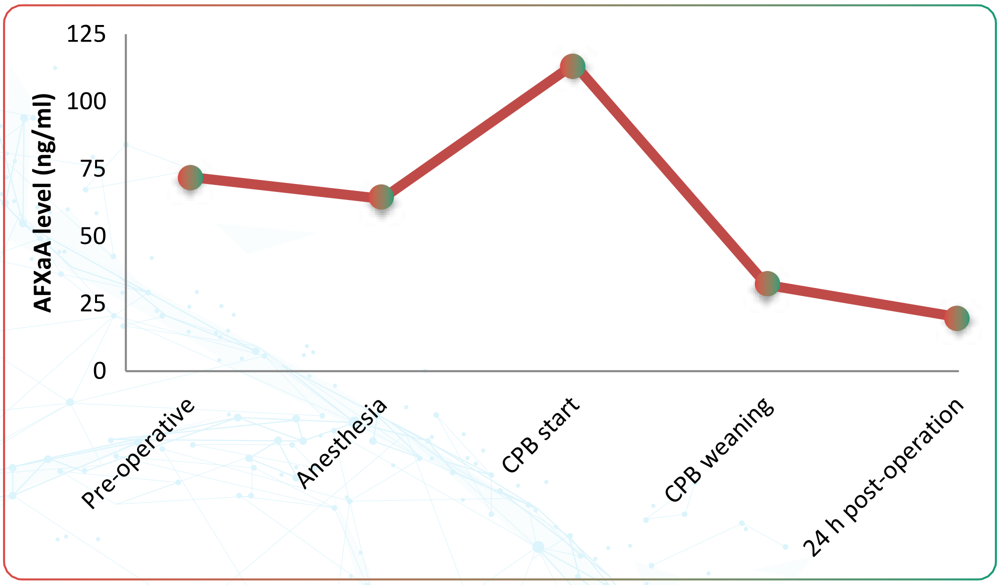


Figure 1: Change in AFXaA levels on different time points before and after the surgery

Conclusion

- CytoSorb® device is safe and easy to insert into the CPB circuit for the clearance of inflammatory cytokines and drugs in patients undergoing surgery.
- A 50% reduction in AFXaA levels was noted between CPB initiations and weaning using CytoSorb® device.
- This study first time reported the intraoperative clearance of apixaban using CytoSorb® device and showed better peri-operative hemostatic management.
- Furthermore, this study also standardized the concentration of apixaban depending on its reported half-life.

Reference

Mendes V, Colombier S, Verdy F, Bechtold X, Schlaepfer P, Scala E, Schneider A, Kirsch M. Cytosorb® hemoadsorption of apixaban during emergent cardio-pulmonary bypass: a case report. Perfusion. 2020 Oct 26:0267659120967827.

MINIATURIZED CARDIOPULMONARY BYPASS CIRCUITS REDUCES USE OF ULTRAFILTRATION IN PEDIATRIC PATIENTS DURING CONGENITAL HEART SURGERY

Introduction

Cardiopulmonary bypass (CPB) in children undergoing cardiac surgery leads to side effects like systemic inflammatory response and hemodilution that further are associated with decreased O_2 carrying capacity, multiple organ dysfunction and subsequent morbidity and mortality. Use of ultrafiltration (UF) tool during and after CPB is suggested, as it removes excess body water and increases hematocrit, osmotic pressure, and concentrations of coagulation factor, thereby decreasing the post-operative bleeding and the systemic inflammatory response. Pediatric CPB includes two types of UF: conventional ultrafiltration (CUF) and modified ultrafiltration (MUF). The latter is believed to improve post-surgery hemodynamic and respiratory functions and reduces the length of ICU/hospital stay, but is also costly and associated with potential disadvantages. Hence, a conventional CPB circuit system using miniaturized CPB circuits with the selective use of UF was taken into consideration. Therefore, this study investigated the clinical significance of the miniaturized CPB system during congenital heart surgery with CPB and assessed whether it can reduce the use of UF.

Methodology

- A retrospective analysis of children undergoing congenital cardiac surgical procedures was done during May 2015-September 2019.
- Subjects (n=2145) were classified into four groups: i) UF with conventional CPB group, ii) non-UF with conventional CPB group, iii) UF with miniaturized CPB group, and iv) non-UF with miniaturized CPB group.
- Mast-mounted roller pump, oxygenator and 30-50 mmHg of perfusion pressure were used in open CPB circuit system.
- In conventional CPB, lactated Ringer solution, fresh frozen plasma or human albumin along with priming drugs were used.
- In miniaturized CPB, Baxter multiple electrolyte solution and priming drugs were used.

Results

- Distributions of 2145 pediatric patients who were classified in the conventional and miniaturized CPB groups, either requiring UF or not are shown in the Figure 2.
- Due to lower age (1.5 months) and pre-operative weight (3.9 kg), patients in UF with miniaturized CPB group were not compared to other groups.
- The miniaturized CPB group (12.5%) showed significantly lower ($p < 0.001$) use of UF, compared to conventional CPB group (76.8%).
- A significantly shorter post-operative mechanical ventilation time ($p < 0.05$) and a shorter ICU/hospital stay ($p < 0.001$) were found in the non-UF with miniaturized CPB group.

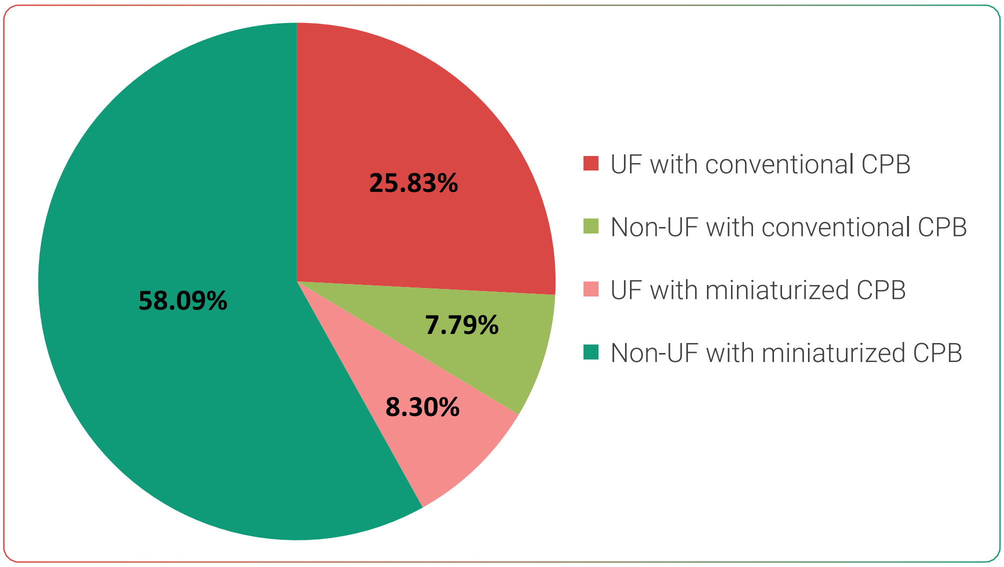


Figure 2: Distributions of patients undergoing congenital cardiac surgery

- Patients of non-UF with miniaturized CPB group demonstrated a significantly higher ($p < 0.001$) urine volumes during operation and bloodless priming rate in comparison to patients of other groups.
- Baseline characteristics and post-operative outcomes of the patients in three groups are summarized in Table 2.

	UF with conventional CPB	Non-UF with conventional CPB	Non-UF with miniaturized CPB
Pre- and intra-operative characteristics			
Age (months)	8.7	7.8	8.5
Weight (kg)	7.3	7.0	7.4
Pneumonia (n)	133	15	150
Mechanical ventilation (n)	26	4	25
CPB duration (mins)	74.6 ± 35.5	68.3 ± 24.7	72.2 ± 31.3
Aortic cross-clamp duration (mins)	38.6 ± 23.2	37.1 ± 19.6	37.5 ± 20.0
Operation time (minutes)	160.4 ± 80.7	141.2 ± 38.9	144.7 ± 85.9
Surgery outcomes			
Hematocrit (%)	36.5 ± 5.0	34.5 ± 4.8	35.5 ± 9.4
Mechanical ventilation time (h)	22.8	18.8	5.2
ICU stay (days)	2.8	1.9	1.0
Hospital stay (days)	8	7	6

Table 2: Subgroup analysis of pediatric patients requiring congenital cardiac surgery

Conclusion

- Different sizes of miniaturized CPB circuit systems depending on patient's body weights and perfusion needs allowed perfusionists to use priming volume as low as 65 mL for a newborn and ~100 mL for other children. This in turn reduced the water and sodium retention and increased the bloodless priming rate in these patients.
- Improved rate of bloodless priming, reduced blood product application, grater urine volume and lower length of ICU/hospital stay suggested the advantage of miniaturized CPB system.

- These satisfactory results in children of non-UF with miniaturized CPB group suggested that miniaturized CPB system can be used to decreases the need of UF utilization.

Reference

Wu K, Meng B, Wang Y, Zhou X, Zhang S, Ding Y. Impact of miniaturized cardiopulmonary bypass circuits on ultrafiltration during congenital heart surgery. Perfusion. 2020 Nov 3:0267659120967206.

SIGNIFICANCE OF BLOOD CONSERVATION IN BLOODLESS PEDIATRIC SURGERY USING CARDIOPULMONARY BYPASS COMPONENTS

Introduction

Fluid management and blood conservation is necessary in pediatric patients, who are using cardiopulmonary bypass (CPB), as it is associated with hemodilution and an acute systemic inflammatory response syndrome. The latter leads to capillary fluid leakage and increases total body water those results in hypovolemia. This condition requires need for blood product transfusion, increasing the risks of infection, post-injury multiorgan failure, and further increasing the length and cost of ICU/hospital stay. Instead of using blood components, use of bloodless surgeries in pediatric cardiac surgical centers has gained popularity. To prevent the CPB hemodilution and conserve patient's blood through blood conservation protocol, a multifunction circuit consist of cardioplegia delivery, conventional ultrafiltration and modified ultrafiltration is generally used. This study explored the role of blood conservation protocol on fluid management and blood components conservation.

Methodology

- This retrospective study included 600 pediatric patients who have undergone corrective congenital heart surgery to repair different congenital heart defects using CPB procedure during January 2010-September 2016.
- Six groups were assigned according to patient's body weights: Control and studied groups (IC and IS, ≥30 kg), control and studied groups (IIC and IIS, ≥20 kg), and control and studied groups (IIIC and IIIS, ≥10 kg).
- Control groups received routine CPB procedures, whereas, studied groups obeyed the blood conservation protocol.
- Fluid management, blood components conservation and pediatrics clinical outcome characteristics were assessed.

Results

- All patients achieved the zero crystalloids balance, while most of the patients achieved zero colloids balance. This in turn decreased the blood components transfusion and improved the hemodynamics, coagulation and morbidity.
- As 44 patients in IIIS group had body weight of 10-6 kg, they have experienced nonhemic prime, hence divided into further two groups: control and studied groups (IIICA and IIISA, ≥6 kg; IIICB and IIISB, ≥3 kg).
- All patients (≥6 kg) achieved zero fluid balance and bloodless surgery with significant ($p<0.02$) autotransfusion of red blood cells, plasma and total proteins.
- Patients weighed <6 kg received a significantly ($p<0.05$) lower amount of homologous packed red blood cells, fresh frozen plasma, platelets and protein products in comparison to control group.

- Pateint's characteristics before and during the procedure is presented in Figure 3.
- Clinical outcome findings showed that patients of IS, IIS and IIIS groups had significantly reduced ($p<0.05$) blood loss, intubation duration and ICU stay.

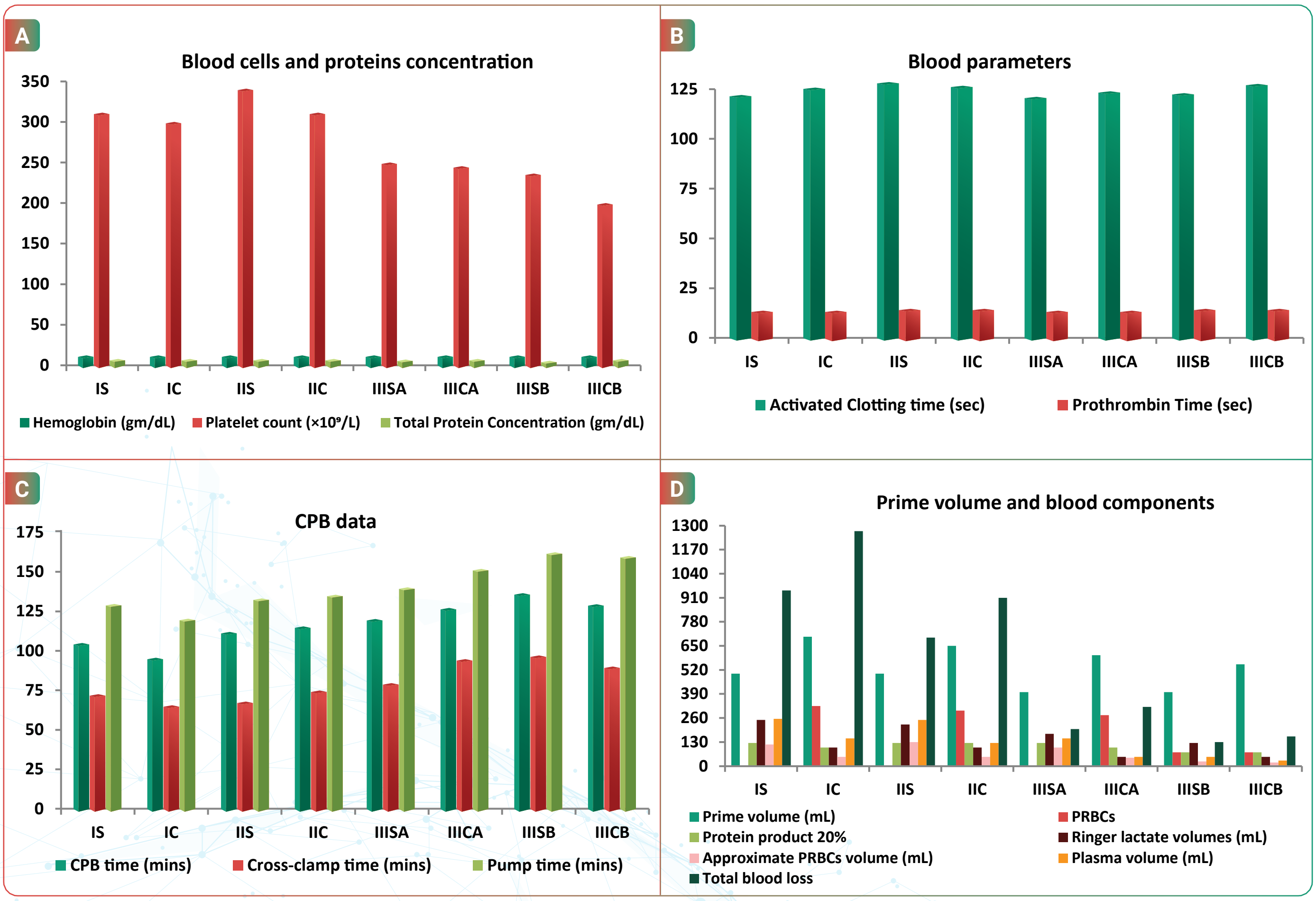


Figure 3: Pre-operative (A) and peri-operative (B-D) characteristics of studied patients. PRBCs: Packed red blood cells

Conclusion

- Autotransfusion process facilitated the reversal of hemodilution and inhibited the dilutional coagulopathy in pediatric patients who underwent bloodless CPB procedures.
- The process eliminated the need of transfusion and diminished the hospital stay, cost as well as morbidity.
- In pediatric patients (6-30 kg), blood conservation protocol seemed to be a successful method for bloodless surgery using the standard available CPB unit components.

Reference

Saleh M. Blood conservation protocol based on modified ultrafiltration towards bloodless pediatric surgery. Archives of Clinical Hypertension. 2020 Feb 25;6(1):001-12.

STRATEGY FOR TRANSFUSION-FREE CONGENITAL HEART SURGERY USING CARDIOPULMONARY BYPASS IN PEDIATRIC PATIENTS

Introduction

Traditional use of donor blood in neonates and infants during cardiopulmonary bypass (CPB) is accountable for many complications, such as infection, allergic reactions and isoimmunization. A number of cardiac surgical units promoted blood-saving strategies in adults, though pediatric patients are still overlooked. This study reviewed various blood conservation approaches, possible CPB techniques to enable transfusion-free heart surgery and different procedures of perfusion in children.

Prerequisites for bloodless open-heart surgery using CPB in pediatric patients

- As blood management is still not established in pediatric cardiac surgery hence, in anemic patients, blood transfusions are needed. Therefore, open-heart surgery requires patients with normal volume of red blood cells (RBCs) to prevent hemodilution.
- In addition, the patients must have a functional coagulation state before the surgery, as hemodilution affects the platelet and humoral factor-dependent coagulation process.
- Patient needs to remain hydrated to maintain normal fluid balance.
- Routine medical blood sampling before the operation should be avoided.
- The surgical team should set the lowest tolerable levels of hemoglobin (Hb) and hematocrit (Hct) and also minimize blood loss in patients during surgery.

Cardiopulmonary Bypass

Dynamic Priming Volume

- Hypovolemia due to aortic and venous cannulation and de-airing of the cannulas is managed by substitution of external volume or pharmacological vasoconstriction. Onset of bloodless CPB must be commenced slowly by holding back some preload and let the left ventricle eject to maintain the coronary blood circulation until the asanguineous priming has mixed with the patient's blood.
- Cardiotomy suction affects the dynamic priming volume usually by increasing in relation to the tubing length. In general, a 4 m suction line holds 8 ml of blood, therefore smaller line (2 m) must be used to facilitate a transfusion-free CPB.

Decannulation

- With weaning and coming off CPB, venous decannulation should be performed.
- With hemodynamic stability, arterial decannulation should be performed.

- Patients with body weight up to 11 kg needs to be retransfused as soon as possible to achieve normovolemia and elevate the Hct level.
- The ~60 mL blood that is left in the patient's (body weight up to 10 kg) circuit after weaning from CPB is given back to boost the preload.
- Ultrafilters, especially modified ultrafiltration (MUF) elevates cytokine and inflammatory processes and are not ideal for the blood-saving strategy.

Anticoagulation/Coagulation Management

- Poor anticoagulation during CPB subsequently leads to disorders of hemostasis, thrombosis and inflammation in the post-CPB period.
- In children, 6 IU/mL of heparin is recommended to achieve an activated clotting time (ACT) above 750 seconds and to suppress the inflammation and coagulation activation.
- Besides heparin ACT values are affected by hypothermia and hemodilution.

Cardioplegia

Blood cardioplegia adds 31-52 mL of volume, but crystalloid cardioplegic solution has disadvantage of temporary hemodilution that can mix with the primary circulation. Therefore, it needs to be removed in patients, but in case it is impossible then the extra volume needs to be removed by means of conventional ultrafiltration.

Ultrafiltration

- An extension of the extracorporeal circuit, leading to further hemodilution is used as ultrafiltration circuit that exposes the patients' blood to a large surface area. During ultrafiltration, the filter is temporarily filled with patient's blood that is emptied into the cardiotomy reservoir following each surgery.
- To minimize dynamic priming volume, a hemoconcentrator with a low priming volume short tubing connections is required.

Surgical Aspects

- With standard sterility draping approach, circuit miniaturization is safe and user-friendly.
- Dry-in and dry-out technique reduces blood loss pre- and post-CPB.
- Normothermia or mild hypothermia is more effective than hypothermia.

Perioperative Blood Transfusion

- Stored packed RBCs (PRBCs) lacks 2,3-bisphosphoglycerate and promotes the formation of inflammatory cytokines, hence needs to be avoided or postponed toward the end of CPB.
- Use of one unit of PRBCs during CPB, one during anesthesia, and one during ICU shows potential effect to minimize the total amount of blood used.

Results

- Rate of complete transfusion-free operation was 29% and bloodless CPB was performed in 61% while maintaining Hb level (> 8 g/dL).

- Patients (2.2-7 kg body weight) with no transfusion during CPB had 9.8±1.8 g/dL of Hb concentration before CPB discontinuation.
- In corrective surgery, transfusion-free CPB is possible even in neonates.
- Asanguineous priming helps to avoid blood transfusions during CPB and also reduces transfusion requirements during the hospital stay.

Conclusion

- Low mortality, higher hemoglobin level and shorter CPB duration support transfusion-free CPB procedure.
- A reduction in post-operative morbidity and mortality upon performance of CPB without blood transfusion in low-weight patients is reported.
- Bloodless CPB circuit priming can be used even in neonates and infants during open-heart surgery.

Reference

Boettcher W, Dehmel F, Redlin M, Sinzobahamvya N, Photiadis J. Cardiopulmonary bypass strategy to facilitate transfusion-free congenital heart surgery in neonates and infants. The Thoracic and cardiovascular surgeon. 2020 Jan;68(01):002-14.

MANAGEMENT OF ANTICOAGULATION IN PATIENTS UNDERGOING PULMONARY ENDARTERECTOMY WITH CARDIOPULMONARY BYPASS AND DEEP HYPOTHERMIC CIRCULATORY ARREST

Introduction

Chronic thromboembolic pulmonary hypertension (CTEPH), characterized by increased pulmonary vascular resistance, pulmonary hypertension and right heart failure is basically caused by incomplete resolution of pulmonary embolism. CTEPH is surgically treated with pulmonary endarterectomy (PEA) that requires cardiopulmonary bypass (CPB) and deep hypothermic circulatory arrest (DHCA). During surgery, the blood is continuously exposed to non-biological surfaces of the CPB circuit that leads to thrombin generation hence, unfractionated heparin is used. Although activated clotting time (ACT) is influenced by hemodilution and hypothermia that lowers the anticoagulation levels, it is still majorly used to monitor the anticoagulant effect of heparin. The present study investigated ACT-based anticoagulation management in CTEPH patients during PEA with CPB, and the effect of hypothermia on their hemostatic activation.

Methodology

- Oral anticoagulation was stopped in patients (n=18, 18-85 years old) a week before the PEA and were given low-molecular-weight heparin subcutaneously.
- Heparin dose–response (HDR) test was used to identify patients with low heparin sensitivity.
- Anticoagulation was monitored by ACT and heparin concentration.
- Thromboelastometry (TEM), platelet aggregation and several plasma coagulation markers were measured to determine the perioperative hemostasis of the patients.

Results

- Heparin sensitivity of all the patients was ranged from 50 to 120 seconds/IU/mL.
- Patient's baseline hemostatic test parameters and characteristics before and during the procedure are presented in Table 3 and 4 respectively.
- Cooling was found to increase the tube-based ACT from 719 seconds to 1,273 seconds ($p < 0.01$) and cartridge-based ACT from 693 seconds to 883 seconds ($p < 0.01$).
- Rewarming decreased the tube-based ACT from 1,042 to 710 ($p < 0.01$) and the cartridge-based ACT from 842 to 588 ($p < 0.01$).
- During cooling, platelet count was decreased from 162 to 78 that recovered at the end of CPB, and platelet aggregation was decreased and again increased during rewarming.
- During cooling, an 8 fold increase was noted in thrombin–antithrombin.
- During CPB, the heparin concentration showed a decreasing pattern.

Hemostatic test	Value
Platelet count	262 10^9/L
Hematocrit	47%
Activated partial thromboplastin time	37 seconds
International normalized ratio	1.06
Antithrombin	144 µg/mL

Table 3: Baseline hemostatic test parameters of the patients (n=18)

Characteristics	Number (n)	Percentage (%)
Males	12	67
Recurrent pulmonary embolism	13	72
Deep vein thrombosis	4	22
Splenectomy	1	16
Circulatory arrests	3	16.67

Table 4: Pre-operative and intraoperative characteristics of the patients (n=18)

Conclusion

- A wide variation in heparin sensitivity in the study participants undergoing PEA with DHCA was observed.
- All patients undergoing PEA did not show low heparin sensitivity, but patients with reduced heparin sensitivity showed frequent cases of thrombocytosis.
- In PEA patients, ACT-based anticoagulation management resulted in heparin concentrations below the required calculated heparin concentration.
- Tube-based and cartridge-based ACT device differs only in terms of clot detection and sample volume, values of which suggested a high level of anticoagulation; though low heparin concentration in majority of patients during CPB hindered the anticoagulation status.
- This status may result in hemostatic activation, therefore increasing the risk for thrombotic and/or bleeding complications, especially during the rewarming.

Reference

Veerhoek D, van Barneveld LJ, Haumann RG, Kamminga SK, Vonk AB, Boer C, Symersky P. Anticoagulation management during pulmonary endarterectomy with cardiopulmonary bypass and deep hypothermic circulatory arrest. Perfusion. 2021 Jan;36(1):87-96.

BIOCHEMICAL INDICATION OF SARCOPENIA AND POSTOPERATIVE PULMONARY COMPLICATIONS IN OLDER PATIENTS UNDERGOING OFF-PUMP CORONARY ARTERY BYPASS SURGERY

Introduction

25–60% of elderly patients undergoing major surgeries reported to suffer from sarcopenia, characterized by poor muscle quality and low muscle strength due to low muscle quantity. Recently creatinine/cystatin C (CysC) ratio is introduced as a biochemical indicator of sarcopenia, as serum creatinine originates from muscle catabolism and CysC is produced by nucleated cells and low creatinine/CysC ratio is accountable for low muscle mass. After cardiac surgery, sarcopenia often leads to post-operative pulmonary complications (PPCs). Another factor closely related to sarcopenia is CONtrolling NUTritional status (CONUT) score that is also associated to PPCs. This scoring system includes parameters like total lymphocyte count, cholesterol and albumin concentration. This retrospective, single-centre study aimed to evaluate the relation between creatinine/CysC ratio and CONUT score and PPCs (primary outcomes) and other morbidities/mortality outcomes (secondary outcomes) in elderly patients undergoing off-pump coronary artery bypass surgery (OPCAB).

Methodology

- 605 elderly patients (≥ 65 years) who underwent OPCAB from January 2010 to December 2019 were enrolled in this study.
- Baseline demographic data and medical history along with serum creatinine, CysC, albumin, cholesterol, C-reactive protein, haemoglobin levels and total lymphocyte count were recorded.
- Normal or light undernutrition with CONUT score of < 5 was categorized as low CONUT grade; whereas moderate-to-severe undernutrition with CONUT score of ≥ 5 was indicated as high CONUT grade.
- ***Primary endpoint:*** Association of the creatinine/CysC ratio and CONUT score with PPCs, characterized by pneumonia, ventilation for more than one day and required reintubation.
- ***Secondary endpoint:*** Association of the indices with one of the following conditions:
  - Renal failure
  - Delirium
  - Reoperation due to bleeding or tamponade
  - Permanent stroke
  - Mortality

Results

- PPCs were recorded in 80 patients with a statistically significant lower ($p = 0.001$) creatinine/CysC ratio compared to non-PPC group. Baseline characteristics of the patients are presented in Figure 4.
- Patients with PPC were frequently diagnosed with anaemia, lower serum albumin concentration and congestive heart failure in comparison to non-PPC group.

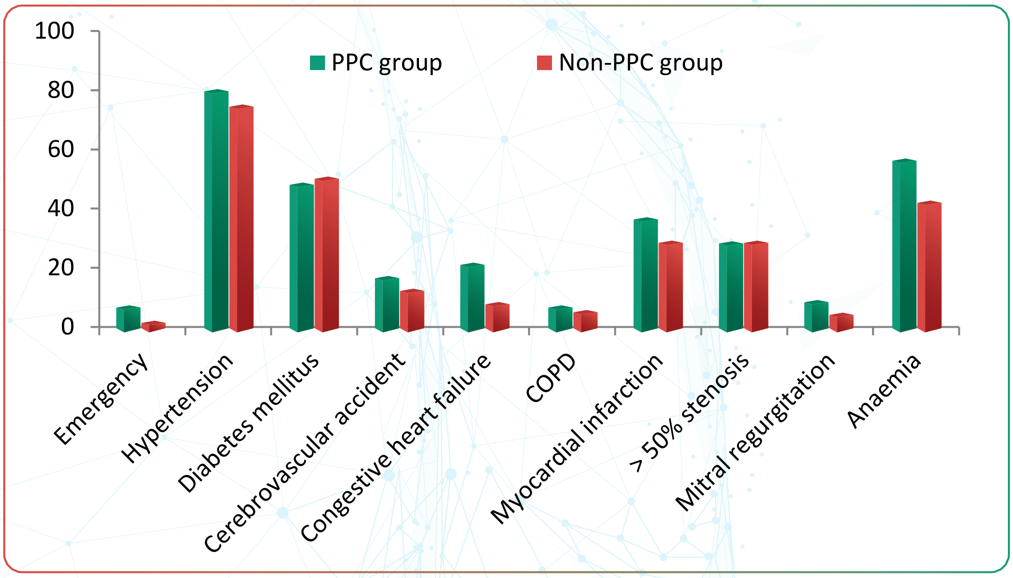


Figure 4: Comparative data of baseline characteristics (%) of patients in PPC and non-PPC groups. COPD: Chronic inflammatory lung disease

- Adjusted odds ratio showed that a 10-unit increase of creatinine/CysC ratio reduced the risk of PPC occurrence, pneumonia, reintubation, permanent stroke and ICU/hospital stay.
- Older, especially female patients showed a lower creatinine/CysC ratio along with a greater incidence of emergent operation.
- Low levels of haemoglobin, lower albumin and higher C-reactive protein levels were observed in these patients.

- Low creatinine/CysC ratio was also associated with renal failure and mortality.
- High CONUT grade seemed to be associated with lower creatinine/CysC ratio, higher C-reactive protein, anaemia, higher incidence of PPC along with cerebrovascular accident, and myocardial infarction.
- Patient's pre-, intra- and post-operative characteristics are presented in Table 5.

Variables	PPC group (n = 80)	Non-PPC group (n = 525)
Baseline		
Age (years) (mean ± SD)	73.4 ± 4.3	71.5 ± 4.4
BMI (kg/m²) (mean)	23.5	24.0
CONUT (mean)	2	2
Creatinine/ CysC ratio (mean ± SD)	80.6 ± 16.5	87.5 ± 18.2
Intraoperative		
Graft number (mean)	3	3
Duration of anaesthesia (mins) (mean)	298	300
Duration of operation (mins) (mean)	225	228
Total fluid input (mL) (mean ± SD)	2443 ± 753	2318 ± 845
Urine output (mL) (mean)	240	280
Blood loss (mL) (mean)	530	610
Number of patients who had pRBC transfused n(%)	23 (28.7)	112 (21.3)
Number of patients who had blood transfused n(%)	24 (30.0)	129 (24.6)
Postoperative		
Total fluid input (mL) (mean)	3730	3736
Urine output (mL) (mean)	2550	2670
Number of patients who had pRBC transfused n(%)	26 (32.5)	144 (27.4)
Number of patients who had blood transfused n(%)	35 (43.8)	204 (38.9)

Table 5: Characteristics of the patients in PPC and non-PPC groups

Conclusion

- This study demonstrated that low creatinine/CysC ratio is associated with higher risk of PPCs occurrence in elderly patients undergoing OPCAB.
- Low creatinine/CysC ratio is also related to greater risk of permanent stroke, renal failure, mortality and prolonged ICU or hospital stay.
- The current results also displayed that a low creatinine/CysC ratio is more appropriate than CONUT score for identifying patients vulnerable to PPCs.
- As the patient's effort is not required, the creatinine/CysC ratio is an easy screening option for patients with neurocognitive impairment or unstable vital signs or patients who are in need of emergent operation and critical care unit.

Reference

Kim HJ, Kim HB, Kim HY, Shim JK, Lee C, Kwak YL. Associations of creatinine/cystatin C ratio and postoperative pulmonary complications in elderly patients undergoing off-pump coronary artery bypass surgery: a retrospective study. Scientific reports. 2021 Aug 19;11(1):1-9.

Expert Opinion

EXPERT'S OPINIONS ON EXTUBATION DURING EXTRACORPOREAL MEMBRANE OXYGENATION IN ADULTS

Introduction

Although the use of extracorporeal membrane oxygenation (ECMO) in adults has increased over the last decades, but still lacks the liberation from invasive mechanical ventilation (IMV) during the process. IMV causes pneumonia, barotrauma, hemodynamic alterations, peripheral vasodilation, loss of ventilatory hypoxic drive, increased aspiration risk, general muscle weakness and increased mortality. For severe acute respiratory failure and cardiovascular collapse, a conventional approach is intubation and initiation of IMV prior to start of ECMO. Studies on extubation during ECMO is not well eastablished, hence expert opinions are required to prioritize research in this field. This study presented expert perceptions on the beneficial role of extubation during ECMO in adults and the usefulness of extubation clinical practice guideline or ECPG.

Methodology

In-person focus group discussions and in-depth interviews between appropriately trained persons in ECMO were conducted during an annual Extracorporeal Life Support Organization (ELSO) conference. Participants who were attending or presenting at the annual ELSO conference were recruited according to homogeneous purposive sampling.

Results

- Distribution of participants depending on different educational levels and ECMO centers (worldwide) from where they belong are presented in Figure 5.
- With duration of 11-46 mins, two interviews and four focus groups were regulated.
- The selected themes were:

1. Paucity of evidence
2. Mindsets towards using an ECPG
3. Barriers
4. Criteria of extubation
5. Benefits of extubation
6. Culture towards extubation
7. Vision of the future

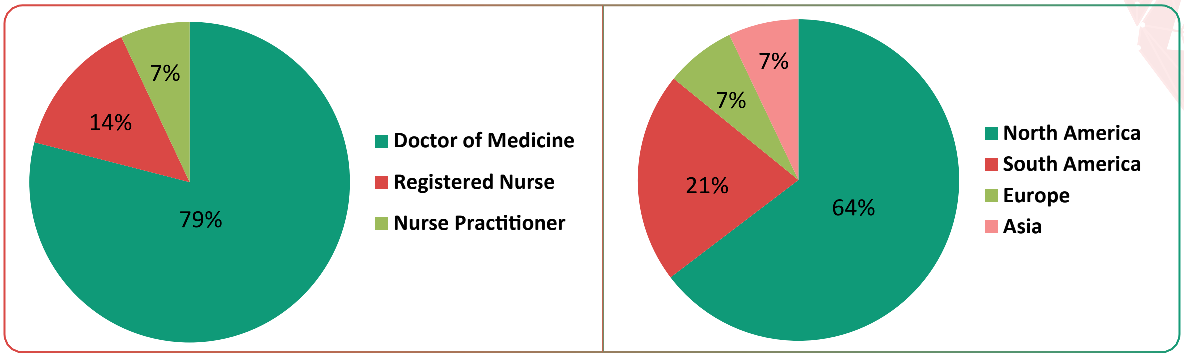


Figure 5: Percentage distribution of participants as per their educational levels (left) and their associated ECMO centers worldwide (right)

- In the 'First theme' the participants agreed to become less reluctant to extubate in case of accepted ECPG directed IMV weaning or decrease in mortality.
- Results of 'Scond theme' showed that the participants' mindsets were clear about using an ECPG during the ECMO. However, experts also emphasized that ECPGs are not required in case of interdisciplinary team-agreement.
- 'Criteria for extubation' is applicable to all critically ill, ECMO therapy, normal hematocrit level, no ECMO-related hemodynamic instability, neurological deficit or complications.
- 'Barriers extubation' were categorized as patient or ECMO device-related (comorbidities including obesity, advanced age, chronic lung disease) and non-clinical or culture-related (involved no staff consensus, a non-supportive unit environment and ECPGs on extubation during ECMO).
- Neurological, neuromuscular, and epidemiological factors were discussed as 'Benefits of extubation'.
- As part of 'Culture towards extubation' the participants referred to culture in the domains of communication silos and the extubation process.
- Election of extubation according to the patient and use of standardized extubation approach according to ECPG is recommended by the participants in 'Vision of the future' theme.

Conclusion

- Expert clinician's opinions about the process of extubation in adult-ECMO are provided in this study.
- Through this study ECPG has created a relevant foundation for future research.
- A standard extubation process in ECMO can be achieved based on team agreement, available institutional infrastructure and ECPG suggested protocolized approach.
- An ECPG is recommended according to etiology, the current clinical condition and the upcoming procedures for the IMV weaning in ECMO.
- This study gives an insight of various approaches of extubation during ECMO; more future studies on which is needed to enrich the knowledge of clinicians.

Reference

Tukacs M, Cato KD. Extubation during extracorporeal membrane oxygenation in adults: An international qualitative study on experts' opinions. Heart & Lung: The Journal of Cardiopulmonary and Acute Care. 2021 Mar 1;50(2):299-306.

GUIDELINES ON CARDIOPULMONARY BYPASS IN ADULT CARDIAC SURGERY BY EACTS/EACTA/EBCP

Introduction

European Association for Cardio-Thoracic Surgery (EACTS) Council, the Board of Directors of the European Association of Cardiothoracic Anaesthesiology (EACTA) and the Quality and Outcomes Committee of the European Board of Cardiovascular Perfusion (EBCP) have jointly developed evidence-based guidelines for the practice of cardiopulmonary bypass (CPB) and to improve the outcome of adult patients undergoing heart surgery. The task force members set the scope of the guidelines and review of the literature was done. The CPB guidelines are the first ever designed by EACTS/EACTA/EBCP and are summarized in this study (Table 6).

Methodology

- The systematic literature search was done for the years 2000-2019 and in some instances, also before the year 2000. Literature only in English and focused on contemporary evidence of adult-acquired cardiac surgery were included.
- Following the methodology manual by EACTS clinical guidelines, and after assessment of randomized control trials (RCTs), meta-analyses and observational studies, synthesis of best available scientific evidence and medical knowledge guideline were developed.
- Obeying the rules of the EACTS, the scientific and medical knowledge and the data available at the time of writing were carefully considered and subsequently the specific recommendation was developed.
- Data was derived from three levels: Level of evidence A (multiple RCTs or meta-analyses), Level of evidence B (single RCTs or large non-randomized studies) and Level of evidence C (consensus of expert opinion and/or small studies, retrospective studies, registries).
- Classes of recommendations are:
  - Class I (evidence and/or general agreement stating beneficial, useful and effective role of a treatment or procedure).
  - Class II (conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a treatment or procedure).
  - Class IIa (weight of evidence/opinion is in favour of usefulness/ efficacy).
  - Class IIb (usefulness/efficacy is less well established by evidence/opinion).
  - Class III (evidence/general agreement that a treatment/procedure is not useful/effective and may sometimes be harmful).

Recommendations	Class of recommendation	Level of evidence
For training, education and service delivery		
It is recommended that perfusionists complete a formal period of training in an approved educational training programme	I	C
It is recommended that perfusionists achieve certification by successfully completing an examination of skills and knowledge. The certification shall be maintained by the demonstration of an appropriate level of continued professional development, minimum caseload and professional standards	I	C
Simulation in perfusion should be considered to improve quality of care and patient safety	IIa	C
It is recommended that perfusion departments be structured around a quality management framework approved by the institution	I	C
It is recommended that each perfusion department have written standard operating procedures for the conduct of CPB	I	C
It is recommended that the perfusion department is adequately staffed, equipped and resourced	I	C
It is recommended that verbal communication between team members in the operating room is standardized and always acknowledged	I	C
Recording and submitting activity and outcomes to a regional database or registry should be considered, and these data should be used for quality assurance and improvement	IIa	B

Recommendations	Class of recommendation	Level of evidence
For training, education and service delivery		
Reporting and systematically analyzing errors or untoward events, including outcomes dissemination for shared learning, is recommended	I	C
For use of heart–lung machine hardware		
It is recommended that pressure monitoring devices are used on the arterial line and cardioplegia delivery systems during CPB	I	C
A bubble detector is recommended during CPB procedures on all inflow lines	I	C
It is recommended to use a level sensor during CPB procedures utilizing a (hard-shell) reservoir	I	C
It is recommended to have backups for vital systems of the heart–lung machines available at all times	I	C
It is recommended to have a maintenance plan for CPB equipment	I	C
For standards of monitoring during CPB		
It should be considered that pump flow is confirmed by ultrasonic measurement on the arterial line	IIa	C
Continuous arterial line pressure monitoring (pre-oxygenator and post-oxygenator) in the CPB circuit is recommended	I	C
Continuous oxygenator arterial outlet temperature monitoring is recommended	I	C
It is recommended to continuously monitor mixed venous oxygen saturation and haematocrit (HCT) levels during CPB	I	B
Monitoring of blood gas analyses through regular intervals or continuous observation is recommended during CPB	I	C
For the safety of CPB programmes		
It is recommended to objectively report, adequately record and properly analyse all adverse events related to CPB practice in an efficient and timely manner	I	C
For security and control of gas supply		
It is recommended that continuous piped supplies of oxygen, air and carbon dioxide (CO_2) are delivered and controlled during CPB with backup cylinder supplies available	I	C
Monitoring of all incoming and outgoing gases may be considered	IIb	C
When a supply system for volatile anaesthetics is used, a scavenging system at the outlet of the oxygenator is recommended	I	C
For disinfection and storage of heater-cooler unit (HCU)		
Validated decontamination and maintenance procedures for HCUs are recommended	I	C
It is recommended that HCUs be placed outside operating rooms to prevent the contaminated air from entering the operative field	I	C
For data collection and quality improvement		
Electronic automated data recording of perfusion parameters should be considered in a perfusion programme	IIa	B
It is recommended that the perfusionist collects data concerning the conduct of perfusion via a clinical registry or database and uses such data to actively participate in institutional and departmental quality assurance and improvement programmes	I	B

Recommendations	Class of recommendation	Level of evidence
For configuration and cannulation strategies		
It is recommended that there is a preoperative agreement between the perfusionist and surgeon on the choice of the size and type of venous and arterial cannulas in order to provide an adequate and safe venous return and an appropriate arterial flow tailored to the needs of the patient and the procedure	I	C
Epiaortic ultrasonography may be considered to detect the plaque of the ascending aorta before aortic cannulation to reduce the incidence of stroke	IIb	B
For use of venting and suction devices		
To limit trauma to blood elements, limited use of cardiotomy suction and avoidance of air entrainment into the cardiotomy and venting lines should be considered	IIa	B
For selection and use of reservoirs		
The use of a separated cardiotomy reservoir should be considered to decrease the deleterious effect of shed mediastinal blood	IIa	B
The use of a closed venous reservoir may be considered to attenuate the inflammatory response and improve biocompatibility when used together with other elements	IIb	B
For selection of an oxygenator		
Microporous membrane oxygenators are recommended as the first choice for use in CPB	I	B
Polymethylpentene membrane oxygenators are not recommended when volatile anaesthetics are used during the procedure	III	B
For selection of a blood pump		
The use of centrifugal pumps should be considered for expected longer CPB times	IIa	C
For use of blood filters		
Arterial line filters may be considered in order to reduce the number of microemboli	IIb	C
The routine use of leucodepletion filters, when combined with membrane oxygenators, is not recommended	III	B
For coating material of CPB circuits		
The use of any biocompatible coating to reduce postoperative complications should be considered	IIa	B
For use of pre-CPB safety checklists		
It is recommended to use an institution-approved pre-CPB checklist during the set-up of and prior to initiating CPB	I	C
It is recommended that completion of the perfusion checklist is acknowledged during the surgical safety checklist 'time out' procedure	I	C
For preoperative patient assessment		
A preoperative assessment of the patient is recommended in preparation for CPB	I	C
For the CPB circuit		
Minimally invasive extracorporeal circulation (MiECC) should be considered over standard conventional CPB systems to reduce blood loss and the need for transfusion	IIa	B

Recommendations	Class of recommendation	Level of evidence
MiECC should be considered over standard conventional CPB systems to increase the biocompatibility of extracorporeal circulation	IIa	B
A combination of MiECC features such as coating, the centrifugal pump, the separation of cardiotomy suction blood and the use of closed systems—should be considered to improve conventional CPB	IIa	C
For use of a CO_2 flush		
It is recommended that CO_2 flush of the CPB circuit before priming be established as the standard of care to reduce gaseous microemboli	I	B
CO_2 flooding of the operative field may be considered to reduce gaseous microemboli	IIb	B
For priming volume in the CPB circuit		
The use of modern low-molecular- weight starches in priming and non-priming solutions to reduce bleeding and transfusions is not recommended	III	C
Retrograde and antegrade autologous primings are recommended as part of a blood conservation strategy to reduce transfusions	I	A
For periprocedural anticoagulation management		
Heparin management		
Activated clotting time (ACT) above 480 sec during CPB should be considered in CPB with uncoated equipment and cardiotomy suction. The required target ACT is dependent on the type of equipment used	IIa	C
Individualized heparin and protamine management should be considered to reduce postoperative coagulation abnormalities and bleeding complications in cardiac surgery with CPB	IIa	B
In the absence of individual heparin dosing tools, it is recommended that ACT tests be performed at regular intervals based on institutional protocols, and heparin doses have to be given accordingly	I	C
Protamine management		
Protamine overdosing should be avoided in order to reduce postoperative coagulation abnormalities and bleeding complications in cardiac surgery with CPB	IIa	B
Alternative anticoagulation		
In patients with contraindications to heparin and/or protamine usage and in need of an operation requiring CPB, anticoagulation with bivalirudin should be considered	IIa	B
In patients with contraindications to heparin and/or protamine usage, in need of an operation requiring CPB and significant renal dysfunction, anticoagulation with argatroban may be considered	IIb	C
For acid-base balance and electrolyte management		
Alpha-stat acid-base management should be applied in adult cardiac surgery with moderate to mild hypothermia because neurological and neurocognitive outcomes are improved	IIa	B
Maintenance of a normal pH (7.35–7.45) and avoidance of hyperchloraemic acidosis should be considered in order to reduce the risk of postoperative complications	IIa	B

Recommendations	Class of recommendation	Level of evidence
Magnesium sulphate may be considered perioperatively for prophylaxis of postoperative arrhythmias	IIb	B
For control of mean arterial blood pressure (MAP) during CPB		
It is recommended to adjust the MAP during CPB with the use of arterial vasodilators (if MAP >80mmHg) or vasoconstrictors (if MAP <50 mmHg), after checking and adjusting the depth of anaesthesia and assuming sufficiently targeted pump flow	I	A
The use of vasopressors to force the MAP during CPB at values higher than 80 mmHg is not recommended	III	B
It is recommended that vasoplegic syndrome during CPB be treated with a1 adrenergic agonist vasopressors	I	C
In patients with vasoplegic syndrome refractory to a1-adrenergic agonist vasopressors, alternative drugs (vasopressin, terlipressin or methylene blue) should be used, alone or in combination with a1-agonists	IIa	B
Hydroxocobalamin may be used to treat vasoplegic syndrome during CPB	IIb	C
For pump flow management during CPB		
It is recommended that the pump flow rate be determined before initiation of CPB based on the BSA and the planned temperature	I	C
The adequacy of the pump flow rate during CPB should be checked based on oxygenation and metabolic parameters (mixed venous oxygen saturation, oxygen extraction ratio, near-infrared spectroscopy, carbon dioxide production and lactates)	IIa	B
The pump flow rate should be adjusted according to the arterial oxygen content in order to maintain a minimal threshold of oxygen Delivery under moderate hypothermia	IIa	B
Pump flow rates may be settled based on lean mass in obese patients	IIb	B
For the type of CPB pump flow		
Pulsatile perfusion may reduce postoperative pulmonary and renal complications and should be considered in patients at high risk for adverse lung and renal outcomes	IIa	B
For perioperative haemodynamic management		
Goal-directed haemodynamic therapyis recommended to reduce the rate of postoperative complications and length of hospital stay	I	A
For use of assisted venous drainage		
It is recommended that an approved venous reservoir be used for assisted venous drainage	I	C
It is recommended that the venous line pressure be monitored when using assisted venous drainage	I	C
Excessive negative venous pressures are not recommended due to the deleterious haemolytic effects	III	B
For transfusion management during CPB		
Packed red blood cells (PRBCs) transfusion		
It is recommended that PRBCs be transfused during CPB if the haemoglobin (Hb) value is <6.0 g/dl	I	C

Recommendations	Class of recommendation	Level of evidence
For HCT values between 18% and 24%, PRBCs may be transfused based on an assessment of the adequacy of tissue oxygenation	IIb	B
PRBCs should not be transfused during CPB if the HCT is >24%	III	C
Fresh frozen plasma (FFP) transfusion		
It is recommended that antithrombin concentrate be used instead of FFP to treat antithrombin deficiency to improve heparin sensitivity	I	B
If antithrombin concentrate is unavailable, FFP should be considered to treat antithrombin deficiency to improve heparin sensitivity	IIa	C
FFP should not be used prophylactically during CPB to reduce perioperative blood loss	III	B
For anaesthesia and pharmacological management		
Volatile anaesthetics should be considered during CPB	IIa	B
The oxygenator exhaust concentration of volatile anaesthetic agents during CPB should be at least the same as that before CPB (if used as the sole anaesthetic agent), except during rewarming, when it should be increased	IIa	C
Oxygenator exhaust concentrations of volatile agents should be monitored during CPB	IIa	B
Doses of intravenous anaesthetics and opioids, except remifentanil, during maintenance of CPB should be at least the same as before CPB (if used as the sole anaesthetic agent)	IIa	B
After the initiation of CPB, the remifentanil dose may be reduced after 20–30 min by 30% at 32° C. Hypothermia below 27° C requires immediate reduction by 60%.	IIb	B
Short-acting neuromuscular blocking agents should be considered in cardiac anaesthesia	IIa	B
Routine use of prophylactic intravenous corticosteroids is not recommended during cardiac surgery	III	A
Tight glycaemic control may be considered during CPB	IIb	B
For control of ischaemic cardiac arrest		
It is recommended that patient-centred myocardial protective strategies be used based on clinical condition and procedural complexity rather than on the use of a fixed institutional cardioplegic solution	I	C
Blood cardioplegia should be considered in selected patientsd to reduce haemodilution, bleeding complications and transfusion requirements	IIa	B
For lung protection during CPB		
Biocompatible modifications of circuits should be considered in order to protect the lungs from inflammatory responses and provide less oxidative stress	IIa	B
Modified ultrafiltration and selective pulmonary artery perfusion may be considered for improving postoperative respiratory function	IIb	B
Leucocyte filtration and hyperoxia are not recommended for protecting the lungs during CPB	III	A
PEEP during CPB should be considered in order to protect the lungs	IIa	B
Ventilation during CPB may be considered for lung protection	IIb	B
High-dose dexamethasone may be considered in order to protect the lungs in selected patients	IIb	B

Recommendations	Class of recommendation	Level of evidence
For use of non-invasive cerebral monitoring		
Routine use of processed electroencephalography monitoring to reduce the incidence of intraoperative awareness may be considered	IIb	B
The use of near-infrared spectroscopy-guided algorithms to improve clinical outcomes may be considered	IIb	B
For management of shed blood		
Discarding shed blood should be considered	IIa	B
Processing and secondary filtration of red blood cells should be considered to decrease the deleterious effects of reinfused shed blood	IIa	B
For minimally invasive surgery		
Perfusionists should be adequately trained and educated in the different aspects of minimally invasive cardiac surgery techniques	IIa	C
Minimally invasive heart valve surgery may be considered to reduce blood loss and the need for transfusion	IIb	B
Minimally invasive heart valve surgery may be considered in experienced units with respect to the patient's preference	IIb	B
For emergent institution and reinstitution of CPB		
It is recommended that a set-up CPB circuit be available at all times for emergent procedures	I	C
After the patient is weaned from CPB, it is recommended that the CPB circuit be kept functional until the patient's chest has been closed	I	C
For use of weaning checklist		
The use of a checklist before the weaning process is recommended to enhance team performance and augment patient safety	I	C
For haemodynamic monitoring		
A pulmonary artery catheter may be indicated in selected cases	IIb	B
Cardiac output with pulse contour analysis may be indicated in selected cases	IIb	B
Transoesophageal echocardiography should be considered in open-heart and thoracic aortic procedures unless there are contraindications	IIa	B
For use of positive inotropes		
Positive inotropic and/or vasopressor agents are recommended as a first-line treatment to reduce mortality rates in patients with haemodynamic instability	I	A
The use of phosphodiesterase inhibitors should be considered to increase weaning success	IIa	B
The prophylactic infusion of levosimendan to reduce adverse events and mortality is not recommended	III	A
Levosimendan as a therapeutic strategy in selected difficult-to wean patients having CPB may be considered	IIb	C
In patients requiring haemodynamic support after cardiac surgery, adding levosimendan to other positive inotropes or vasopressors is not recommended	III	B
For residual blood management		
Retransfusion of the residual volume of the CPB circuit at the end of the procedure is recommended as a part of a blood management programme to minimize allogeneic blood transfusions	I	C
Retransfusion of the processed residual volume of the CPB circuit at the end of the procedure should be considered for minimizing the risks of allogeneic blood transfusions	IIa	B

Table 6: Recommendations for CPB according to class and level of evidence

Conclusion

- This is the first guidelines designed by EACTS/EACTA/EBCP to conduct the CPB during cardiac surgery in adults.
- As lack of published data on essential practice was covered by consensus recommendations of the experts, hence more thorough, well-thoughtout and well-conducted scientific research in many aspects of CPB is still required.
- This European guideline contributed towards CPB technique optimization and standardization that further needs to be implicated into clinical practice.

Reference

Wahba A, Milojevic M, Boer C, De Somer FM, Gudbjartsson T, van den Goor J, Jones TJ, Lomivorotov V, Merkle F, Ranucci M, Kunst G. 2019 EACTS/EACTA/EBCP guidelines on cardiopulmonary bypass in adult cardiac surgery. European Journal of Cardio-Thoracic Surgery. 2020 Feb 1;57(2):210-51.

AIR IN EXTRACORPOREAL MEMBRANE OXYGENATION CIRCUIT

Introduction

Pump tripping and air embolism is often caused by air in the extracorporeal membrane oxygenation (ECMO) circuit. Use of venoarterial ECMO along with more complex interventions increases risk. Three recent cases on air in ECMO circuit and their consequences are discussed in this study.

Case I

- A 79-year-old man with complaint of acute anterior-inferior-wall infarction, post-infarction ventricular septal defects and cardiogenic shock was admitted to the hospital.
- Witnessing patient's condition, percutaneous septal closure and coronary angioplasty on ECMO was considered.
- ECMO was cannulated at right femoral vein and left femoral artery, and after achieving full flow (3,500 mL/min) percutaneous septal repair was started via these cannulations only.
- Arterial line was clamped and the pump was stopped as soon as return of massive air into venous line and oxygenator was observed. Oxygenator was used twice to remove the air.
- Due to negative pressure the air was introduced from right jugular venous sheath.
- A static pressure of below 2000 r/min was maintained until the septal repair was completed.
- Hemodynamic parameters and ECMO circuit were constantly monitored.
- During the entire process, no bubbles were visible in the arterial line, hence coronary stenting was done through right brachial artery.
- The patient was suffering from progressive conscious disturbance, irreversible brain injury and died.

Case II

- A 17-year-old underwent heart transplantation due to hypertrophic cardiomyopathy.
- As he was suffering from primary graft failure, the femoral venoarterial ECMO (3,300 L/min, 2900 r/min) was implanted after the surgery.
- On day 3, air bubbles were noted in the venous line, therefore, arterial line was clamped and the air was removed. The air came from stopcock on pulmonary artery catheter, which was not properly closed.
- After closing the stopcock, the circuit resumed work normally. The patient was discharged after 6 days with no neurological dysfunction.

Case III

- The patient was a 55-year-old woman, who was suffering from primary graft dysfunction after heart transplantation and thus placed on femoral venoarterial ECMO from cardiopulmonary bypass (CPB).

- Due to hemorrhage during chest closure, she was hypovolemic.
- ECMO speed and flow was tried to maintain as 3,000 r/min and 1.0-2.5 L/min respectively.
- Air was noticed in the venous line and oxygenator, hence removed and the pump was restarted.
- Either due to negative pressure, right atrial wall was fused to side holes of femoral venous cannula, hence led to presence of air in the line or cavitation caused by severe hypovolemia was the another reason.
- Volume resuscitation and sewing holes on atrial wall prevented entering of air.
- After 1 month the patient was discharged from hospital and her neurologic outcome was good.

Conclusion

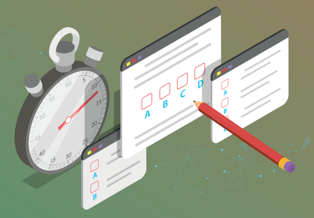
- In the first case, cerebral air embolism through ventricular septal was caused by brain injury, though brain imaging was not performed to confirm this reason.
- The working principle of ECMO is such that massive air is automatically pulled; hence the assistants regulating the surgery should ready to prevent the situation as much as possible (Table 7).
- In extreme cases when this situation cannot be avoided more attention should be given to the patient.

Management	Treatment
Use air detector	Clamp arterial line
Check Venous access at intervals	Turn off the pump
Do not increase ECMO speed	Remove air as soon as possible
	Check all venous access to find the air inlet and repair it

Table 7: Prevention and care for air in ECMO circuit

Reference

Yan S, Lou S, Zhao Y, Liu G, Ji B. Air in extracorporeal membrane oxygenation: can never be overemphasized. Perfusion. 2021 Jan;36(1):97-9.



Perfusion Quiz (Multiple Choice Questions)

1. According to EACTS/EACTA/EBCP guidelines the perioperative anticoagulation management requires:

a) Activated clotting time below 480 sec
b) Individualized heparin and protamine management
c) Overdosing of protamine
d) Besides heparin no other anticoagulants can be used

2. Which of the following factors is not responsible for air in the extracorporeal membrane oxygenation (ECMO) circuit:

a) Negative pressure
b) Improper closure of stopcock
c) Hypovolemia caused cavitation
d) Moisture in venous line

3. CytoSorb® device is useful for, except:

a) Hemodesorption
b) Removal of inflammatory cytokines
c) Clearance of drugs
d) Hemostatic management

4. Ultrafiltration tool during and after cardiopalmonary bypass (CPB):

a) Decreases osmotic pressure
b) Increases hematocrit
c) Reduces concentrations of coagulation factor
d) Increases systemic inflammatory response

5. Which of the following is false for modified ultrafiltration:

a) Improves post-surgery hemodynamics
b) Better post-operative respiratory functions
c) Reduces length of ICU/hospital stay
d) Low cost

6. During CPB donor blood in neonates and infants causes, except:

a) Infection
b) Allergic reactions
c) Hypovolemia
d) Isoimmunization

7. Class II recommendation for CPB by EACTS/EACTA/EBCP is:

a) Evidence/general agreement that a treatment/procedure is not useful/effective and may sometimes be harmful.

b) Evidence and/or general agreement stating beneficial, useful and effective role of a treatment or procedure.

c) Conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a treatment or procedure.

d) Evidence about the usefulness/efficacy of a treatment or procedure.

Individualized heparin and protamine management.	Moisture in venous line	Hemodesorption	Increases hematocrit	Low cost	Hypovolemia	Conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a treatment or procedure.

Designed and developed by

WorkSure

NEOCREST

The author **WorkSure India** & **NeoCrest Life Sciences** and the reviewer have, as far as it is possible taken care to ensure that the information given in this PRIME Newsletter Issue 19 is accurate and up to date.

Disclaimer: This material is provided by Terumo as a professional service to the medical community. Information related to any product(s) may not be consistent with the instruction for use (IFU). Please read the full instruction for use (IFU) for approved information on any products discussed in this publication and before patient usage.