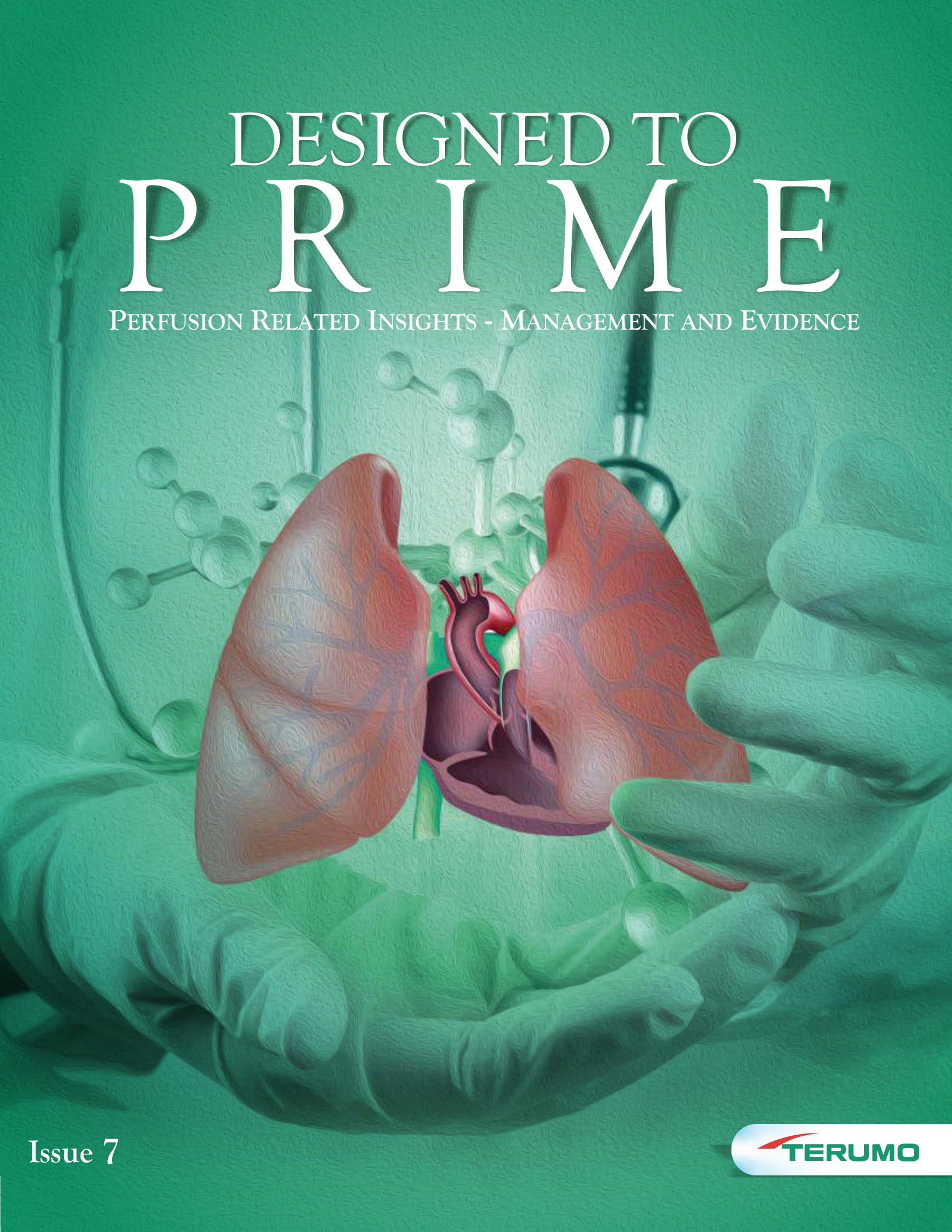
DESIGNED TO PRIME

Perfusion Related Insights - Management and Evidence



Issue 7

TERUMO

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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, 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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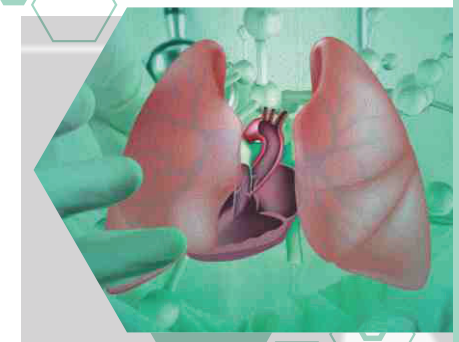
TERUMO

Editorial Letter

Dear Readers,

We are pleased to present the seventh issue of PRIME to you. PRIME – 'Perfusion Related Insights - Management and Evidence' – is a scientific newsletter published every quarter with the help of our editorial board members, and includes latest reviews, guidelines, and expert experiences in relation to perfusion strategies.

In this seventh issue, we are happy to present five articles under the section ''Review Articles''. The first article examines the safety of transesophageal echocardiography while using extracorporeal life support. The second article highlights the possibility that bubble transgression in membrane oxygenators may be caused by vacuum-assisted venous drainage vacuum. The third article assesses the management of massive hemoptysis while on extracorporeal membrane oxygenation. The fourth article elucidates the ammonia perfusion positron emission tomography in patients with hypertrophic cardiomyopathy. The fifth article assesses the efficacy of stress echocardiography versus myocardial perfusion imaging in patients presenting to the emergency department with low-risk chest pain.



The ''Expert Experiences'' section covers two interesting topics by the experts — criteria for size selection of membrane oxygenator for patients with cyanotic congenital heart disease and kinetic-assisted venous drainage on cardiopulmonary bypass for redo mitral valve replacement.

The ''Guidelines'' section focuses on ''Safety devices'' from the American Society of ExtraCorporeal Technology Standards and Guidelines for Perfusion Practice (2013). The ''Latest News'' section deals with the methodology to improve bypass surgery techniques and the best predictor of transfusion of packed cells: Preoperative hemoglobin level.

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

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Safety of Transesophageal Echocardiography while using Extracorporeal Life Support

Introduction

In critically ill patients, refractory to medical management, the use of extracorporeal life support (ECLS) has markedly increased. During extracorporeal therapy, transesophageal echocardiography (TEE) is commonly used to assess the position of the cannula and cardiac function. The purpose of this study was to determine whether TEE probe insertion and removal in systemically anticoagulated ECLS patients was safe as compared to the patients without ECLS and normal coagulation studies.

Methods

It involved an analysis of 87 separate TEE examinations in 53 adult ECLS patients. Routine coagulation testing was performed two hours prior to the TEE exams. Controls (N = 87) were age- and gender- matched patients undergoing perioperative TEE without ECLS and normal coagulation.

Results

In ECLS patients, overall TEE-associated morbidity was 2.3% and consisted of minor oropharyngeal bleeding (2/87 TEE exams) (Table 1). The patients suffering from oropharyngeal bleeding were administered heparin for anticoagulation and had two or more abnormal coagulation studies at the time of TEE. Among the ECLS patients, 79% received intravenous heparin infusions, 6.8% argatroban, and 3.4% epoprostenol. Due to pre-existing bleeding, bleeding complications, and/or deranged plasmatic coagulation profiles, 10.8% of the patients were not anticoagulated at the time of TEE.

> **The indications for TEE exams in ECLS patients should be carefully analyzed on a case-by-case basis.**

Table 1: Complications associated with TEE examinations

	ECLS (N = 87)	Control (N = 87)	*P*
Diffuse oral bleeding	2 (2.3%)	0	n.s.
Upper gastrointestinal hemorrhage	0	0	
Esophageal perforation	0	0	
Dental injury	0	0	
Endotracheal tube dislodgement	0	0	

Abbreviation: n.s., no significance.

CONCLUSION

Transesophageal echocardiography is safe in critically ill patients with ECLS — even though there was systemic anticoagulation — during probe insertion, manipulation, and removal.

Source: Nowak-Machen M, Schmid E, Schlensak C, Consferent C, Haeberle HA, Rosenberger P, *et al.* Safety of transesophageal echocardiography during extracorporeal life support. *Perfusion.* 2016 Apr 28.

Bubble Transgression in Membrane Oxygenators may be caused by Vacuum-Assisted Venous Drainage Vacuum

Introduction

Vacuum-assisted venous drainage (VAVD) is commonly used to enhance venous blood return from patients undergoing cardiopulmonary bypass. The vacuum can accidentally reach the oxygenator of the heart-lung machine and can draw gas bubbles into the blood. This is called as bubble transgression (BT) and may cause air emboli in the arterial blood line. In order to elude BT and reduce the risk of patient injury, knowledge of oxygenator tolerance to vacuum load is critical. The purpose of this study was to determine how much vacuum a membrane oxygenator can withstand before BT appears.

Methods

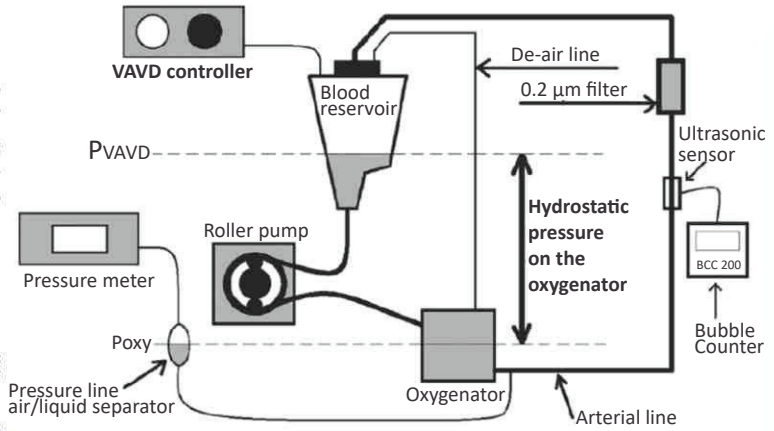
Four adult oxygenators; Quadrox-i, Affinity Fusion, Capiox RX25, and Inspire 6M were tested in an *in vitro* setup where VAVD vacuum was allowed to reach the oxygenator via a nonocclusive roller pump (Figure 1). Counting of the bubbles on the arterial line, when the arterial pump was restarted, was done using an ultrasonic clinical bubble counter, Gampt BCC 200.

Results

There was a significant increase in bubble count for two of the oxygenators, caused by -30 mmHg of VAVD in the blood reservoir (Affinity Fusion and Inspire 6M). Massive air ingress was observed in two of the oxygenators; caused by -30 mmHg of VAVD vacuum in the Capiox RX25 reservoir and -40 mmHg of VAVD vacuum in the Affinity Fusion reservoir.

> **Safety while using VAVD can be accomplished by using an alarm trigger on negative pressure in the oxygenator or a pressure relief valve.**

Figure 1: The schematic overview of the *in vitro* setup



CONCLUSION

Vacuum-assisted venous drainage vacuum may cause BT in an oxygenator and this is observed for all the oxygenators in this experiment.

Source: Nygaard K, Thiara AS, Tronstad C, Ringdal MA, Fiane AE. VAVD vacuum may cause bubble transgression in membrane oxygenators. *Perfusion.* 2016 May 25.

Management of Massive Hemoptysis while on Extracorporeal Membrane Oxygenation

Introduction

Veno-arterial extracorporeal membrane oxygenation (V-A ECMO) is an important procedure in patients with both respiratory and cardiac failure. Since patients must be maintained on anticoagulants, bleeding complications are common. A rare complication of ECMO is massive hemoptysis but can cause death if not managed meticulously.

Methods

In order to identify episodes of massive hemoptysis, a retrospective chart review of consecutive ECMO patients from 7/2010–8/2014 was made. Massive hemoptysis was defined as an inability to control bleeding (> 300 mL/day) from the endotracheal tube via conventional maneuvers, such as bronchoscopy with cold saline lavage, diluted epinephrine lavage, and selective lung isolation. Owing to all this, it was necessary to disconnect the ventilator tubing and clamping the endotracheal tube, causing full airway tamponade.

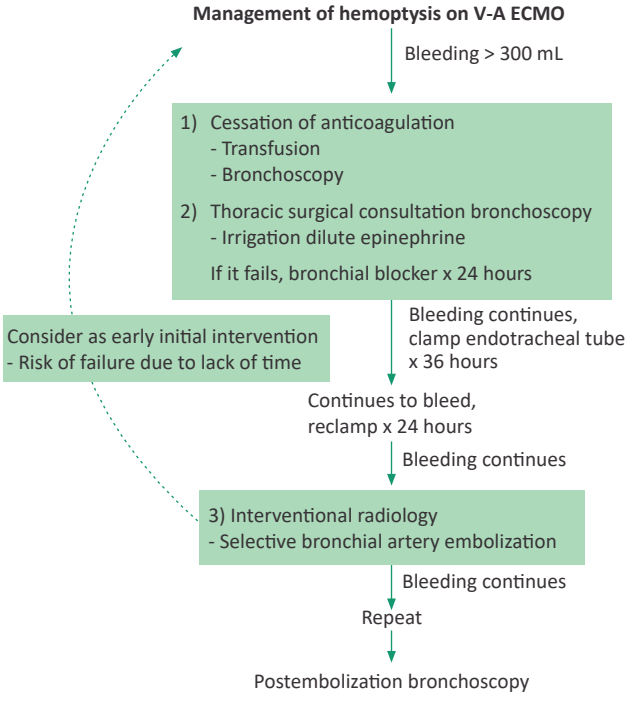
Results

One hundred and eighteen patients were on ECMO, and 3 patients had the complication of massive hemoptysis. One case was associated with pulmonary catheter migration and the other two were spontaneous bleeding events that were propagated by antiplatelet agents. Bronchial artery embolization in the interventional radiology suite was performed in all the 3 patients. Anticoagulation was done during the period of massive hemoptysis without any embolic complications. There was no recurrent bleed after suitable intervention. All the three patients were successfully separated from ECMO.

The algorithm for the management of massive hemoptysis, of the patient on ECMO, is demonstrated in Figure 1.

> **Early identification and rapid intervention are necessary in the management of pulmonary hemorrhage in ECMO patients.**

Figure 1: Algorithm for the management of massive hemoptysis of the patient on ECMO



CONCLUSION

Bleeding complication is a major issue in patients with ECMO. It is safe to disconnect the ventilator and clamp the endotracheal tube with full respiratory and cardiac support by V-A ECMO. Re-hemoptysis can be prevented by an early involvement of interventional radiology to embolize any potential source of the bleed.

Source: Pitcher HT, Harrison MA, Shaw C, Cowan SW, Hirose H, Cavarocchi N. Management considerations of massive hemoptysis while on extracorporeal membrane oxygenation. *Perfusion*. 2016 May 25.

Ammonia Perfusion Positron Emission Tomography in Patients with Hypertrophic Cardiomyopathy

Introduction

In patients with hypertrophic cardiomyopathy (HC), vasodilator-induced transient left ventricular (LV) cavity dilation by positron emission tomography (PET) is common. Since most patients with PET-LV cavity dilation do not have obstructive epicardial coronary artery disease, the researchers hypothesized that vasodilator-induced subendocardial hypoperfusion resulting from microvascular dysfunction underlies this result.

Methods

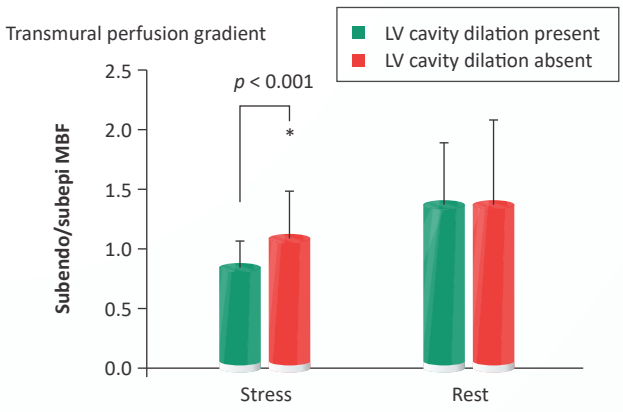
In order to study the hypothesis, myocardial blood flow (MBF) [subepicardial, subendocardial, and global MBF] and left ventricular ejection fraction (LVEF) in 104 patients with HC without significant coronary artery disease, using $^{13}NH_3$-PET was quantified. Based on the presence/absence of LV cavity dilation ($LVvolume_{stress}/LVvolume_{rest} > 1.13$) the patients were divided into 2 groups.

Results

In 52% of the patients with HC, transient PET-LV cavity dilation was evident. In patients with HC with LV cavity dilation; LV mass, stress left ventricular outflow tract gradient, mitral E/E', late gadolinium enhancement, and prevalence of ischemic ST-T changes after vasodilator were significantly higher. Between the two groups, baseline LVEF was similar. But LV cavity dilation$^+$ patients had lower stress-LVEF (43 ± 11 vs. 53 ± 10%; $p < 0.001$), lower stress-MBF in the subendocardial region (1.6 ± 0.7 vs. 2.3 ± 1.0 mL/min/g; $p < 0.001$), and greater regional perfusion abnormalities (summed difference score: 7.0 ± 6.1 vs. 3.9 ± 4.3; $p = 0.004$). An indicator of subendocardial perfusion i.e. transmural perfusion gradient was similar at rest in the 2 groups (Figure 1). Left ventricular cavity dilation$^+$ patients had lower stress-transmural perfusion gradients (0.85 ± 0.22, LV cavity dilation$^+$ vs. 1.09 ± 0.39, LV cavity dilation$^-$; $p < 0.001$), suggesting vasodilator-induced subendocardial hypoperfusion. The stress-transmural perfusion gradient, global myocardial flow reserve, and stress-LVEF were linked with LV cavity dilation.

> **In order to identify the patients with true cavity dilation versus imaging cavity dilation in HC, more studies combining PET and cardiac magnetic resonance imaging following vasodilator infusion are needed.**

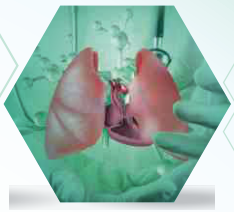
Figure 1: Comparison of MBF in HC patients with/without LV cavity dilation in the subendocardial region



CONCLUSION

Microvascular dysfunction causes diffuse subendocardial hypoperfusion and myocardial ischemia which contribute to the development of transient LV cavity dilation in HC.

Source: Yalçin H, Valenta I, Yalçin F, Corona-Villalobos C, Vasquez N, Ra J, *et al*. Effect of diffuse subendocardial hypoperfusion on left ventricular cavity size by 13N-Ammonia perfusion PET in patients with hypertrophic cardiomyopathy. *Am J Cardiol.* 2016 Dec 15;118(12):1908–15.



Efficacy of Stress Echocardiography versus Myocardial Perfusion Imaging in the Patients Presenting to the Emergency Department with Low-Risk Chest Pain

Introduction

Two frequently used modalities namely stress echocardiography (SE) and myocardial perfusion imaging (MPI) are assigned appropriate use scores across the continuum of symptomatic patients. The purpose of this study was to compare clinically relevant cardiovascular outcomes and downstream utilization linked with SE and MPI in the emergency department patients with low-risk chest pain.

Methods

In a retrospective study, health insurance claims data for a national sample of privately insured patients over the period of January 1 to December 31, 2011 were analyzed. The study consisted of patients who reported to the emergency department with primary or secondary diagnosis of chest pain and underwent either SE or MPI. The percentage of patients in each group who underwent downstream cardiac catheterization, revascularization, repeat noninvasive testing, return emergency department visit with chest pain, and hospitalization for myocardial infarction were the primary endpoints (Table 1). The mean length of follow-up in both groups was 190 days. The final analysis included 48,202 patients or 24,101 propensity-matched pairs.

Results

In comparison to SE, MPI was linked with markedly higher odds of subsequent cardiac catheterization (adjusted odds ratio [AOR], 2.15 [95% CI, 1.99–2.33]) and revascularization procedures (AOR, 1.58 [95% CI, 1.36–1.85]) as well as repeat emergency department visits (AOR, 1.14 [95% CI, 1.11–1.19]). The mean cost of downstream care was markedly higher in the MPI group ($2,193.80 vs. $1,631.10, $p < 0.0001$).

Table 1: Comparison of MPI with SE

Variable	MPI	SE	AOR*	*P*
Cardiac catheterization 3,384 (7%)	9.4%	4.7%	2.2	< .0001
Coronary revascularization procedure 775 (2%)	1.9%	1.3%	1.6	< .0001
Coronary revascularization procedure to cardiac catheterization ratio	20.2%	27.7%	----	.0008
Repeat emergency department visit 3,891 (8%)	8.1%	8.0%	1.1	.003
Repeat test 7,654 (16%)	16.6%	15.1%	1.0	0.84
Myocardial infarction 155 (0.3%)	0.34%	0.30%	1.2	0.20

*Adjusted odds ratio

CONCLUSION

The findings of this study indicate the need for assessing diagnostic tests based on how they affect hard endpoints since identification of disease may not provide any clinical advantage.

Source: Davies R, Liu G, Sciamanna C, Davidson WR Jr, Leslie DL, Foy AJ. Comparison of the effectiveness of stress echocardiography versus myocardial perfusion imaging in patients presenting to the emergency department with low-risk chest pain. *Am J Cardiol.* 2016 Dec 15;118(12):1786–91.

Which is the most Appropriate Criterion for Size Selection of Membrane Oxygenator for Patients with Cyanotic Congenital Heart Diseases: Body Weight or High Hematocrit?

Contributed by: Ritu Airan, Ujjwal K. Chowdhury, Poonam K. Malhotra, and Balram Airan

Aim

In cyanotic patients, polycythemia causes a decrease in microcirculatory blood flow, thereby causing tissue hypoperfusion and hypoxia. The aim of the study was to compare the intraoperative systemic arterial oxygen saturation (SaO2) in these patients and its association to different-sized membrane oxygenators.

Methods

This retrospective study consisted of 130 consecutive cyanotic patients between 18 months and 30 years of age (mean ± SD 102.2 ± 80.1) undergoing surgical correction (intracardiac repair of tetralogy of Fallot; n = 104; bi-directional Glenn: n = 20; total cavopulmonary connection: n = 6) using hypothermic cardiopulmonary bypass (CPB). Group I involved 70 patients who preoperatively had hematocrit < 60%, whereas Group II involved 60 patients who had hematocrit > 60%. In all the study patients, FiO_2/sweep gas was kept constant and hematocrit was maintained between 25–30%. The oxygenator was selected based on the body weight stated in Table 1.

Results

Group I patients had normal SaO2 during CPB. In group II, 32 patients weighing between 20–30 kg and > 30 kg with Terumo SX-10 and SX-18 oxygenators, respectively, had systemic arterial desaturation (91–98%) with intraoperative hematocrit ranging > 35% and intraoperative hematuria (n = 20). In order to achieve optimal intraoperative SaO2 > 99%, further hemodilution was performed in patients weighing > 30 kg and by the withdrawal of prime to promote additional hemodilution in patients weighing between 20–30 kg. With this background, in 15 of 20 (75%) patients weighing between 8–12 kg to achieve SaO2 between 99–100% patients, Terumo SX-10 was successfully used instead of Minimax.

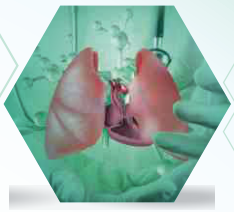
Table 1: Selection of the oxygenator based on body weight

Body weight (kg)	Oxygenators	Priming volume (mL)	Flow range (LPM)	Group I (n = 70)	Group II (n = 60)
8–12	Medtronic- Minimax	800	0.5–2.3	20	5 + 15*
12–30	Terumo SX-10	1,000	0.5–4.0	40	20 + 8
> 30	Terumo SX-18	1,800	0.5–7.0	10	12

*Used Terumo SX-10

CONCLUSION

The study demonstrated a higher risk of arterial desaturation in cyanotic patients with high hematocrit undergoing hypothermic CPB.



Kinetic-Assisted Venous Drainage on Cardiopulmonary Bypass for Redo Mitral Valve Replacement – A Case Report

Contributed by: K. Thanigainathan, P. Mathavan, Dr. B V Saichandiran

Kinetic-assisted venous drainage (KAVD) is a method of applying a controlled suction on the venous line with a kinetic pump to augment the venous drainage. It allows the use of smaller venous cannulae, shorter circuit tubing, and lower priming and blood transfusion volumes.

Methods

A 28-year-old male patient was taken up for redo mitral valve replacement for the stuck prosthetic mitral valve. The estimated perfusion flow rate for cardiac index 2.4 L/min/m^2 was 4.2 L/min. After exposing the femoral region for emergency cannulation, the patient was prepared for a redo sternotomy. Using standard aortic cannulation (22 Fr) and venous cannulation with femoral vein (20 Fr) and selective SVC cannula (22 Fr – metal tip), CPB was established. In order to accommodate components for KAVD, the CPB circuit was modified. Into the venous line between the venous cannulae and the venous reservoir, a Biomedicus pumphead (Bio-Pump BPX-50, Medtronic) driven by a Biomedicus 550 pump was incorporated. Ten centimeters before the inlet of the venous pump, a pressure monitoring line was connected to the venous line. Bypass started with the gravity drainage and was not adequate to drain the heart completely. Then KAVD was started by using the kinetic pump motor and increasing the speed to approximately 1,000–1,200 rpm. Due to increased venous siphon, the venous reservoir volume subsequently increased. The highest flow rate was noted and compared with initial gravity flow rate. The negative pressure during bypass did not exceed -50 mmHg. A limitation linked with KAVD is the trapping of air in the centrifugal pump-head. In order to overcome this, a provision was added for bypass line to restore the venous return till the centrifugal chamber was to be deaired.

Result and Conclusion

A unique technique to augment venous drainage in redo surgeries, especially when gravity siphonage fails, is KAVD. Benefits of KAVD are additional flow using a small venous catheter, easier insertion, a better surgical view, and a smaller incision and thereby decreasing priming volume. The optimal venous siphon is best regulated by determining the assist pump's inlet pressure.

The American Society of ExtraCorporeal Technology Standards and Guidelines in Individuals with Perfusion Practice (2013)

Standards and guidelines for safety devices

Pressure monitoring of the arterial line, cardioplegia delivery systems, and venous reservoir shall be utilized during cardiopulmonary bypass (CPB) procedure. The pressure monitor should consist of an audible and visual alarm. The pressure monitor should either be servo-regulated to control the arterial/cardioplegia pump or to allow interruption to the arterial cardioplegia flow.

During the CPB procedures, a bubble detector shall be utilized. In order to control the arterial pump or to allow interruption of the arterial blood flow, a gross/macro bubble detector shall be used. An audible and visual alarm may be present in the detector system and be positioned as per manufacturer's instruction for use, to enable timely identification and action.

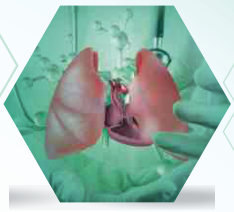
A level sensor shall be utilized during CPB procedures using a reservoir. The level sensor shall be either servo-regulated in order to control the arterial pump or to permit interruption of the arterial blood flow. An audible and visual alarm may be present on the level sensor and be positioned as per the manufacturer's instruction, to allow an appropriate reaction time and a safe operational volume.

During CPB procedures, temperature monitoring of the arterial outflow from the oxygenator shall be employed. In order to prevent high arterial outlet temperatures, the temperature sensor shall include an audible and visual alarm.

An arterial-line filter and a one-way valve in the vent line shall be utilized during CPB procedures. During CPB procedures, a method for retrograde flow shall be utilized for systems using centrifugal pumps for systemic circulation. Examples of retrograde avoidance systems are one-way flow valves, hard stop detent controls, electronically activated arterial line clamps, and a low speed visual and audible alarm.

An anesthetic gas scavenge line shall be utilized whenever inhalation agents are introduced into the circuit during CPB procedures. During CPB procedures, hand cranks and a back-up gas shall be available. A back-up battery supply for the CPB machine shall be available during CPB procedures.

Source: Baker RA, Bronson SL, Dickinson TA, Fitzgerald DC, Likosky DS, Mellas NB, *et al*; International Consortium for Evidence-Based Perfusion for the American Society of ExtraCorporeal Technology. Report from AmSECT's International Consortium for Evidence-Based Perfusion: American Society of Extracorporeal Technology Standards and Guidelines for Perfusion Practice: 2013. *J Extra Corpor Technol*. 2013 Sep;45(3):156–66.



Bypass Surgery Techniques can be Improved using Synthetic Heart Valves, Arteries, and Veins

An invention of the researchers from the University of British Columbia has made it possible for doctors to significantly improve their bypass surgery techniques without depending on animals. The invention was synthetic heart valves, arteries, and veins made of polyvinyl alcohol hydrogel. Due to polyvinyl tissue, the surgeons and medical residents could practise bypass surgery using the synthetic material as compared to the current practise of using arteries and veins of dead pigs or human cadavers.

The major limitation of using arteries from human or animal cadavers is that they break down easily if not treated with preservatives. On the other hand, synthetic material does not decompose and cannot be contaminated. The material can be manufactured safely and cheaply. The invention is now primarily used for teaching purpose but surgeons and medical residents at the Kelowna General Hospital in British Columbia's interior are already using it.

The design of the new synthetic material gives careful consideration to how the living human tissue feels like and resembles it. The arteries from the animals or human cadavers, used for practicing bypass surgery, feel different than the living human tissue. The synthetic heart valves, veins, and arteries presently used for practicing bypass surgery on actual hearts are harvested from pigs. The two researchers are presently working to develop a synthetic heart using the new material, which would circumvent the necessity to use animal or human cadaver tissue and organs while practicing heart surgery.

Source: Synthetic heart valves, arteries and veins could vastly improve bypass surgery techniques [Internet] [Updated Sep 1, 2016]. Available at: http://www.news-medical.net/news/20160901/Synthetic-heart-valves-arteries-and-veins-could-vastly-improve-bypass-surgery-techniques.aspx. Accessed on Dec 28, 2016.

The Best Predictor of Transfusion of Packed Red Cells: Preoperative Hemoglobin Level

Methods

The study consisted of 4,022 patients undergoing cardiothoracic surgery between 2008 and 2013. The patients were divided into three groups; no blood transfusion, transfusion of packed red cells only, and any other combination of blood transfusion. In all, around 16 variables were tested for their association with the administration of homologous blood. The variables linked with blood transfusion were included in a stepwise multinomial logistic regression analysis to find the variables with the strongest association.

Results

For the transfusion of packed red cells only and any other combinations of blood transfusion, the following predictors were noted, which included factors such as gender, age, weight, type of surgery, reoperation, unstable angina pectoris, endocarditis, recent myocardial infarction, preoperative creatinine level, preoperative hemoglobin level, and preoperative platelet count. Preoperative hemoglobin level (4.1 to 7.8 mmol/L) is the best predictor for the transfusion of packed cells (Table 1). In case of other blood products, the strongest association was found with type of surgery (aortic surgery, ventricular septal rupture, and intracardiac tumor).

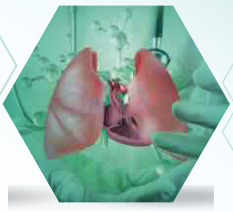
Table 1: Classification of continuous variables

Variable	Category 1	Category 2	Category 3	Category 4
Length	142–167 cm	167–172 cm	173–206 cm	–
Weight	42–71 kg	71–85 kg	85–157 kg	–
Preoperative creatinine level	36–72 µmol/L	72–102 µmol/L	103–972 µmol/L	–
Preoperative hemoglobin level	4.1–7.8 mmol/L	7.8–8.4 mmol/L	8.4–8.9 mmol/L	8.9–11.4 mmol/L
Preoperative platelet count	24–196 x 10^9/liter	196–312 x 10^9/liter	312–838 x 10^9/liter	–
Age	Age was used as a continuous variable since there was a linear relationship between the odd ratios of the different quintiles.			

CONCLUSION

For the transfusion of packed cells alone, any other blood products, or a combination with packed red cells, a group of predictors was identified. In the case of packed red blood cells, the best predictor was identified, and it was different from the predictor associated with other blood products.

Source: de Boer WJ, Visser C, Ganushchak YM. Preoperative hemoglobin level: The best predictor of transfusion of packed red cells. *Perfusion*. 2016 Jul 8.



SELF ASSESSMENT

SECTION 5

1. **An 18-year-old man is brought to the trauma center after sustaining a gunshot wound. On physical examination, a narrow pressure, jugular venous distention, muffled heart sounds, and pulsus paradoxus are reported. What is the most likely diagnosis?**
   a. Cardiac tamponade ☐
   b. Cardiogenic shock ☐
   c. Perforation of the left ventricle ☐
   d. Pneumothorax ☐
2. **A 60-year-old man, recovering in the hospital 15 days after undergoing repeat repair of an ascending aortic aneurysm, has had atrial fibrillation for the past five days. As per the laboratory test, the platelet count is 45,000/mm^3, and this confirms the diagnosis of heparin-induced thrombocytopenia. To prevent the complications associated with the condition, anticoagulation therapy is planned. Before warfarin therapy, the most appropriate anticoagulant therapy is the administration of which of the following medications?**
   a. Argatroban ☐
   b. Clopidogrel ☐
   c. Enoxaparin ☐
   d. Eptifibatide ☐
3. **Which of the following is not a primary responsibility of the perfusionist during CPB?**
   a. Ensure circuit tubing is free of air before going on CPB. ☐
   b. Ensure tubing is connected to pumps to avoid venous air-lock. ☐
   c. Ensure correlation between aortic and radial arterial pressure. ☐
   d. Maintain an adequate level of anesthesia with potent inhaled anesthetics. ☐
4. **How is the unexpected electrical activity of the heart dealt with during complete CPB?**
   a. Excess blood is squeezed out of the heart by hand. ☐
   b. The surgeon asks the anesthesiologist to administer additional muscle relaxant. ☐
   c. The surgeon asks the perfusionist to provide an additional cardioplegic solution. ☐
   d. The heart is shocked at 200 J. ☐
5. **During myocardial fibrillation, energy stores are used more quickly than if the heart was in sinus rhythm.**
   a. True ☐
   b. False ☐
6. **The primary objectives of CPB are to provide adequate ventilation as well as maintain circulation and perfusion, and temperature regulation.**
   a. True ☐
   b. False ☐
7. **What is the major concern for the anesthesiologist during CPB when cardioplegic solution is administered by the perfusionist?**
   a. It may cause critically elevated blood glucose. ☐
   b. It may cause fluid overloading which can manifest as pulmonary edema later. ☐
   c. It may cause ischemia and dysrhythmias because it's cold and has low O_2 content. ☐
   d. It may dilute coagulation factor concentrations to critically low levels. ☐

Answers: 1–A; 2–A; 3–C; 4–C; 5–A; 6–A; 7–C.

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Date of preparation: January 2017

TIPL-014-05-PRI

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