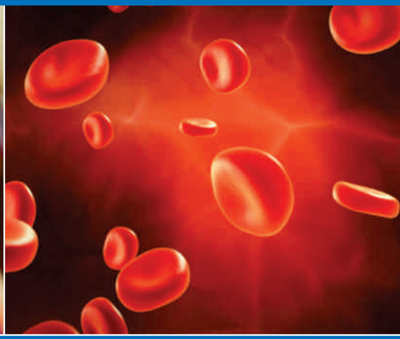
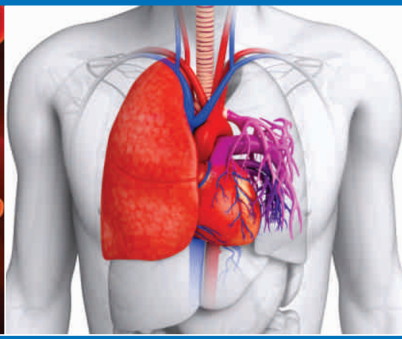
Issue 10

PRIME

Perfusion-Related Insights – Management and Evidence



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Scientific Committee

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

E-mail: rahul_sharma@terumo.co.jp

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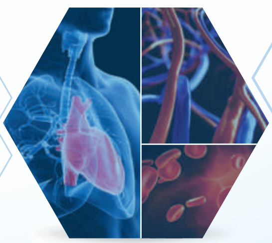

Editorial Letter

Dear Readers,

It is our pleasure to present before you the 10th issue of PRIME—"Perfusion-Related Insights - Management and Evidence"—a quarterly scientific newsletter that offers current reviews, guidelines, and specialist experiences with regard to perfusion strategies.

The current issue brings to you five interesting articles under the section "Review Articles." Does the ultrafiltration technology help in conserving blood during cardiac surgery? How can you detect myocardial perfusion impairments in patients with uncomplicated type 2 diabetes mellitus at an early stage? What are the complications associated with continuous-flow left ventricular assist device? How can red blood cell transfusions in cardiac operations be reduced? How can the risk of developing neurological complications post cardiac surgery be identified? Get answers to these questions and a lot of insightful information through our articles under Section I.

Section II will provide you a thoughtful take of our experts with examples of two case studies. Guidelines for maintaining the institution-specific protocols and perfusion records, along with blood management are covered in Section III. Section IV contains latest updates with regards to association of kidney injury with cardiac surgery. Finally, we have Section V to keep you engaged with an interesting quiz.

We hope that you will enjoy reading our informative newsletter. We look forward to receive your valuable feedback, comments, and suggestions to help us work better on the future issues.

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REVIEW ARTICLES

SECTION 1

Use of Ultrafiltration as a Blood Management Technique in Cardiopulmonary Bypass

Introduction

In cardiac surgery, ultrafiltration presents as a standard technique to filter out the excess water. Ultrafiltration applies hydrostatic forces to remove the plasma water directly across a semipermeable membrane, and thereby reverses the process of hemodilution. It helps in the eradication of small molecules, such as water and electrolytes, whereas large molecules, like blood cells and proteins, remain preserved and concentrated.

The benefits of ultrafiltration include:

- Minimizing the adverse effects of hemodilution, such as tissue edema and blood transfusion
- Concentrating the blood and enabling blood management
- Decreasing the extravascular lung water
- Reducing the circulatory inflammatory mediators
- Improving the neurologic outcome
- Raising the hematocrit/hemoglobin
- Improving hemostasis

Conventional ultrafiltration works by successfully removing the fluid, and returning much of it in the form of crystalloids, thereby maintaining the circulating volume during cardiopulmonary bypass (CPB). Maningding JC *et al*. conducted a comparative study in 20 patients to analyze the effect of conventional ultrafiltration during CPB.

Methods

The patients were randomly assigned into two groups: group A consisted of 10 patients who underwent cardiac surgery with CPB and conventional ultrafiltration, and group B consisted of 10 patients who underwent cardiac surgery with conventional CPB.

Results

The study results showed an increase in the hemoglobin (Hb) value postoperatively in group A, as compared to group B (Figure 1). Also, the crystalloids (nonblood liquid) added during CPB were significantly higher in group A versus group B (Figure 2).

Figure 1: Effect of ultrafiltration on Hb values

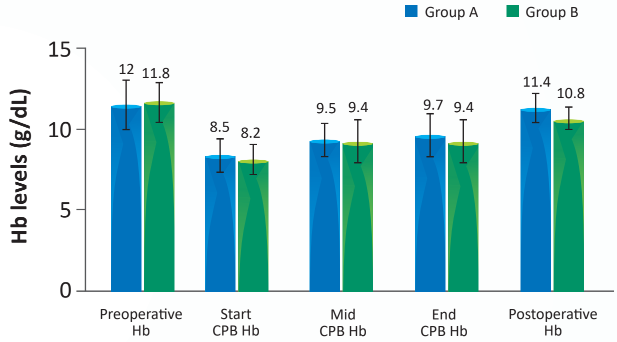
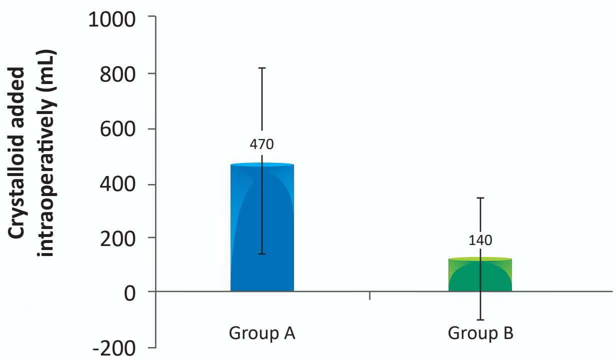


Figure 2: Effect of ultrafiltration on crystalloids



CONCLUSION

Ultrafiltration helps to increase the Hb values in patients during a CPB procedure.

Reference: Maningding JC. Will the use of ultrafiltration during bypass reduce blood transfusion compared to conventional bypass? [Internet] Available at: http://schoolofperfusion.au.dk/fileadmin/Perfusionistskolen/John_Carlo_Maningding.pdf. Accessed on May 11, 2018.

Use of Computed Tomography Myocardial Perfusion Imaging for Early Detection of Myocardial Perfusion Impairments in Patients with Uncomplicated Type 2 Diabetes Mellitus

Introduction

Silent myocardial ischemia is commonly present in patients with diabetes without coronary artery disease (CAD). Early detection of myocardial ischemia is very important in this population to reduce mortality. Multidetector computed tomography (MDCT), with a combination of coronary computed tomography angiography (CCTA) and computed tomography myocardial perfusion imaging (CTP), helps to simultaneously investigate coronary anatomy, cardiac function, and myocardial perfusion. Cai X *et al*. conducted a prospective study to evaluate, for the very first time, myocardial perfusion at rest in patients with uncomplicated type 2 diabetes mellitus (T2DM) by using a 320-MDCT.

Methods

The study included a total of 34 subjects with 544 myocardial segments; 17 of which had uncomplicated T2DM with no significant coronary artery stenosis on and 17 were healthy controls. The transmural perfusion ratio (TPR) was used to analyze myocardial perfusion.

> **"Resting myocardial perfusion changes can be detected prior to the development of cardiac morphology and functional abnormalities in patients with T2DM without CAD by using a 320-MDCT."**

Results

The TPR of 16 myocardial segments was observed decreased in the T2DM group, as compared to the c group, with significant reductions ($p < 0.05$) found the TPR of segments 5, 7, 9, and 10 to 14 (Figure 1).

The overall mean TPR was found to be 1.14 ± 0.01 control group and 1.07 ± 0.01 in the T2DM gr $p < 0.001$ (Figure 2).

Figure 1: Comparison of TPR distribution of 16 segments between the study groups

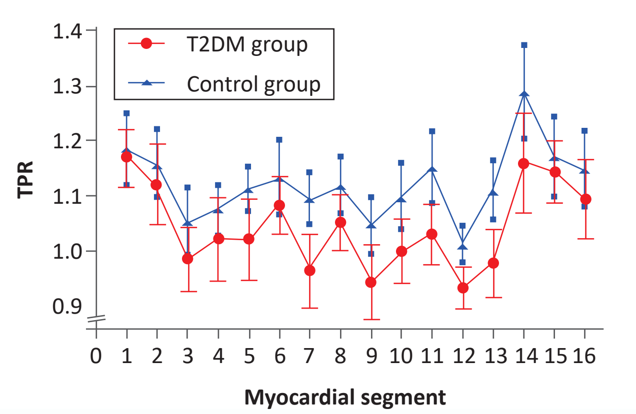
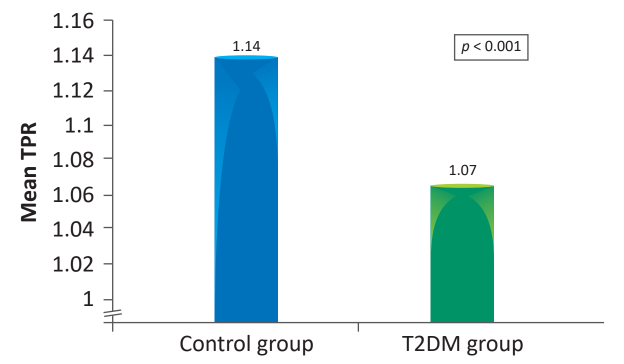


Figure 2: Comparison of the mean TPR between the study grou



CONCLUSION

A 320-MDCT, using a combination of CCTA and CTP, presents as a comprehensive screening tool patients with T2DM for early identification of cardiovascular complication and provides long-term prognostic information for patients with T2DM.

Reference: Cai X, Zhang S, Deng D, Li H, Guan X, Fang J, *et al*. Myocardial perfusion at rest in uncomplicated type 2 diabetes patients without coronary disease evaluated by 320-multidetector computed tomography. *Medicine*. 2018;97:5(e9762).

Heart Transplantation Associated On-Cardiopulmonary Bypass Vasoplegia

Introduction

For patients with end-stage heart failure, heart transplantation (HT) is the only reliable therapy. However, due to less organ availability, there are low annual transplants and long waitlist periods. A continuous-flow left ventricular assist device (CF-LVAD) poses as a "bridge-to-transplant" (BTT), improving both quantity and quality of life in patients awaiting transplantation.

One of the complications associated with the CF-LVAD transplant is vasoplegia. Vasoplegia is marked by arterial hypotension and a low systemic vascular resistance (SVR). It leads to problems in up to 15% of cardiopulmonary bypass (CPB) cases. It is known to cause delayed extubation, increased bleeding issues, prolonged intensive care unit stay, and multisystem organ dysfunction, ultimately resulting in increased mortality. This study was conducted to identify the prevalence of on-CPB vasoplegia and its impact on post-transplant morbidity and mortality.

Methods

A retrospective review of 138 HTs in patients aged 18 years and above was conducted, with the primary post-transplant outcome of interest as 30-day survival. A total of 85 patients underwent transplantation using a CF-LVAD, with an increasing proportion each year.

Results

Around 16% of the patients developed on-bypass vasoplegia. The mean SVR during each bypass run was 695 dynes s/cm^5 in vasoplegic patients, as compared to 983 dynes s/cm^5 in nonvasoplegic patients (Figure 1). Also, the on-bypass hypotension with a median mean arterial pressure (MAP) was found to be 58.4 mmHg in vasoplegic patients, whereas it was 64.4 mmHg in nonvasoplegic patients ($p < 0.001$) [Figure 2]. A 30-day survival was observed to be 86.4% in vasoplegic patients and 99.1% in nonvasoplegic patients ($p = 0.001$) [Figure 3].

Figure 1: Comparison of the mean SVR during CpB

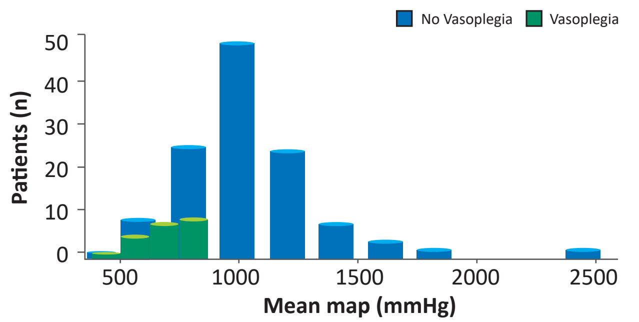


Figure 2: Comparison of MAP during CPB

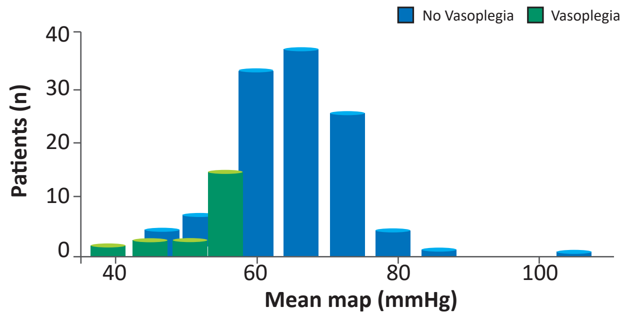
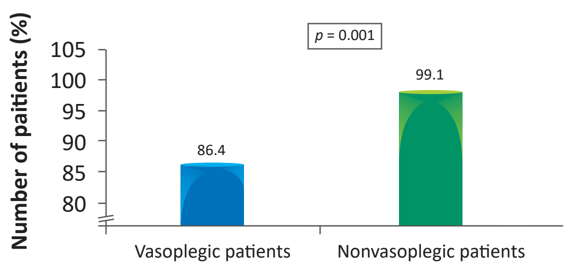


Figure 3: Comparison of a 30-day survival between the study groups



CONCLUSION

This study concluded that BTT with CF-LVAD is a significant risk factor for the development of vasoplegia. Vasoplegia was seen in around 16% of the HT recipients during the CPB run, and resulted in significant post-transplant mortality.

Reference: Truby LK, Takeda K, Farr M, Beck J, Yuzefpolskaya M, Colombo PC, *et al*. Incidence and impact of on-cardiopulmonary bypass vasoplegia during heart transplantation. *ASAIO J*. 2018 Jan/Feb;64(1):43–51.

Blood Management in Adult Cardiac Operations

Introduction

Bleeding and allogeneic transfusion are the major problems associated with open-heart surgical procedures. The risks carried by blood products include immunologic sensitization, anaphylactic reaction, and disease transmission. The use of practical, evidence-based strategies is important to optimize blood transfusion. Patient blood management programs employing multiple combined strategies help to minimize unnecessary exposure to blood transfusions. This retrospective study analyzed the use of a structured blood management program in reducing transfusions and transfusion-related complications during adult cardiac surgery.

Methods

Over a period of 12 months, the study evaluated 243 patients who underwent cardiac surgery with cardiopulmonary bypass (CPB), along with an implementation of a new blood management program (Group 1: Blood conservation) and 275 patients with no blood conservation (Group 2: Control). In the blood management program, the bypass circuit was aseptically assembled using a low-prime integrated oxygenator and reservoir, along with a Terumo System 1 pump console.

On the contrary, the control group consisted of a conventional oxygenator and reservoir. The static prime volume for the circuit was approximately 250 mL for Group 1 and 450 mL for Group 2.

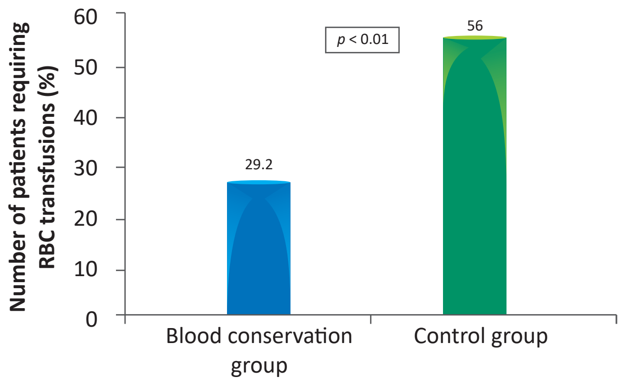
> **"A well-structured blood conservation program helps to reduce the RBC transfusions, without compromising on patient safety."**

Results

The study showed that around 56% patients in the control group were transfused with red blood cells (RBCs), as compared to 29.2% in the blood conservation group ($p < 0.01$) [Figure 1].

Similarly, the blood transfusion rate (1.7 ± 1 vs. 3.05 ± 1 units), postoperative hemorrhage (545 ± 50 vs. 775 ± 55 mL), respiratory support duration (12.4 ± 7 vs. 16.8 ± 8 h), and ICU stay (2.2 ± 1.1 vs. 3.5 ± 1.2 days) were found to be significantly better in the blood conservation group, as opposed to the control group.

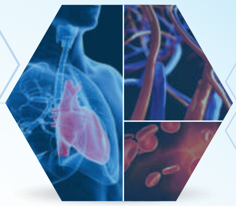
Figure 1: Prevalence of blood transfusions



CONCLUSION

Blood management programs implementing multiple strategies help to prevent the undesirable clinical outcome associated with transfusion of RBCs during CPB in the adult population.

Reference: Budak AB, McCusker K, Gunaydin S. A cardiopulmonary bypass based blood management strategy in adult cardiac surgery. *Heart Surg Forum*. 2017 Oct 24;20(5):E195–8.



Monitoring of Cerebral Perfusion in Adult Patients Undergoing Cardiac Surgery

Introduction

Strokes associated with adult cardiac surgery cause dangerous neurocognitive complications, which often remain undetected in the perioperative period. The traditional strategies to monitor perioperative alterations may not be able to uncover the acute changes in the cerebral perfusion, and thus makes it difficult to attain an optimal cerebral perfusion. Noninvasive cerebral oximetry monitoring may help clinicians to detect and respond to changes in perfusion. Slater T *et al*. conducted a feasibility check of noninvasive cerebral oximetry monitoring into the postoperative care environment.

Methods

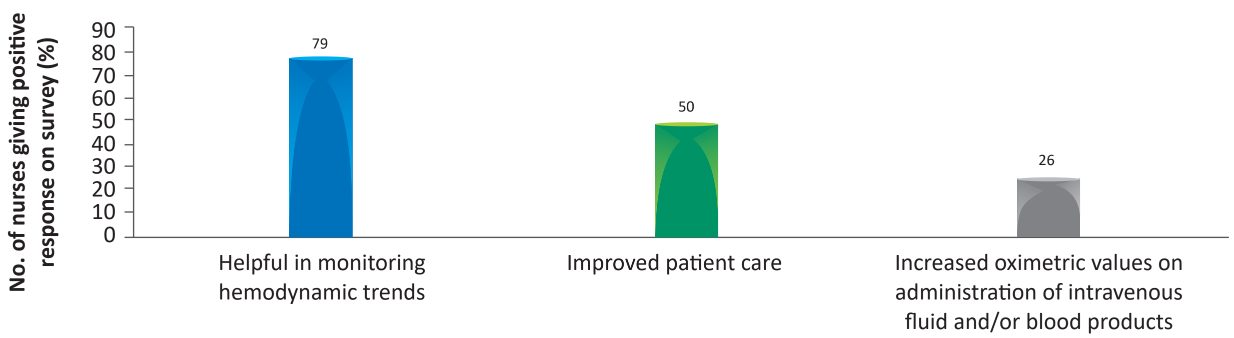
A total of 37 adult patients above 18 years of age and undergoing aortic valve surgery (with or without other cardiac surgeries) were subjected to noninvasive cerebral oximetry monitoring over the 4-month project period.

"Cerebral oximetry monitoring assists in identifying adult patients who are at a risk of developing any neurological complications post cardiac surgery."

Results

Around 94% of the patients underwent postoperative cerebral oximetry monitoring. Nurses completed the evaluation of 97% of the patients using cerebral oximetry monitoring. All the nurses who used the monitoring system to evaluate patients agreed that it was easy to use (Figure 1).

Figure 1: Responses of nurses on cerebral oximetry monitoring



CONCLUSION

This study concluded that a standardized procedure like noninvasive cerebral oximetry monitoring can help the clinicians to early detect and lessen the risks of developing the neurocognitive decline in the postoperative period following cardiac surgery. It, thus, helps in improving the quality of care for such patients.

Reference: Slater T, Stanik-Hutt J, Davidson P. Cerebral perfusion monitoring in adult patients following cardiac surgery: An observational study. *Contemp Nurse*. 2017 Dec;53(6):669–80.

Extracorporeal Membrane Oxygenation - A Unique Case Experience

Contributed by: Mr. Elayaraja, Manipal Hospital, Bangalore

Introduction

Patients requiring extracorporeal membrane oxygenation (ECMO) are often transferred from one center to another. The ECMO to ECMO transfer can be done via roadways or airways. Interhospital transports on ECMO can be performed safely; however, in case of critically ill patients on multi-modal organ support, such transport is risky and requires strict adherence to protocol format.

Case

A 23-year-old man was presented with the complaints of dyspnea, fever, chest discomfort, diarrhea, and extreme weakness. The patient developed these symptoms 3 weeks ago during his visit to India. He had a history of scleroderma and Raynaud's disease for 3 years. The patient's examination revealed tachycardia, systolic blood pressure of 80 mmHg, and ST-segment elevation in leads V2–V5 on electrocardiogram. The echocardiography imaging showed global left ventricular (LV) hypokinesia, severe LV dysfunction (EF = 15%), severe right ventricular dysfunction, and restrictive filling pattern. The patient was admitted to cardiac intensive care unit (ICU) and was given inotropic support and oxygen therapy. His laboratory investigations of cardiac biomarkers were abnormal. The patient's coronary angiogram revealed mild coronary artery disease. In view of hypotension, intra-aortic balloon pump was inserted through the left femoral artery, and the patient was kept on inotropic support. However, the patient's condition deteriorated with persistent hypotension. Therefore, the cardiac team decided to provide the ECMO support; and ECMO transport via road was initiated.

Methods

Important factors, such as logistic, geographical factors, transport vehicle, personnel, and equipment, were considered in the planning of ECMO transport. The ECMO procedure was initiated under local anesthesia. The patient was sedated and given an anticoagulant. The 17 Fr Medtronic femoral arterial cannula and 21 Fr Medtronic femoral venous cannula were placed in the femoral artery and femoral vein, respectively. For the distal limb perfusion, a 10 Fr DLP cannula was introduced into the superficial femoral artery. Primed MAQUET EXTRA CORPOREAL MEMBRANE OXYGENATOR - the ECMO machine was connected to the cannula. After hemostasis was confirmed, cannulas were secured to the skin at multiple sites and groin incision was closed. The patient was then shifted to the original center. At this center, the patient was admitted to the cardiac ICU, and inotropic support was readjusted. Meanwhile, the patient was diagnosed with myocarditis and given intravenous IgG therapy for 7 days. On the 6th day, the ventricular function gradually recovered to normal. Magnetic resonance imaging showed maintained LV systolic function, mild LV hypertrophy, and no LV outflow tract obstruction; while cardiac magnetic resonance showed no evidence of infarction, inflammation, or infiltrative cardiomyopathy. At the time of discharge, the patient was hemodynamically stable. There were no complications occurred during device implantation as well as during patient transport.

CONCLUSION

Transporting a patient with ECMO support to the tertiary level ICU is safe and has a positive impact on the patient's outcome.

Simultaneous Controlled Upper and Lower Body Perfusion

Contributed by: S. Azarudeen, V. Baskaran, Ananthu V, Dr. Sylvester and Dr. E. Sheriff

Modification of routine cardiopulmonary bypass circuits has been shown to improve simultaneous upper body and lower body perfusion and reduces the circulatory arrest, deep hypothermia, and perfusion-related risk in the complex aortic debranching procedure.

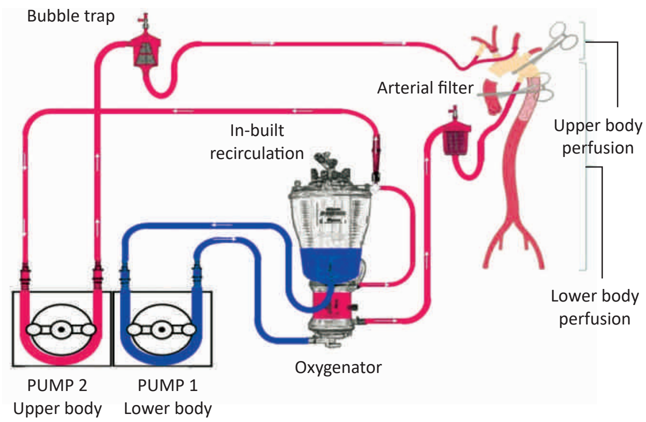
Case

A 22-year-old female presented with a clinical history of Takayasu's aortoarteritis and aortic aneurysm. The involvement of aorta, severe aortic regurgitation, annuloaortic ectasia, left carotid and subclavian artery stenosis were also observed. The Bentalls procedure, arch debranching, and arch replacement (Elephant Trunk Fashion) were recommended to the patient.

Method and perfusion technique used

For upper body circulation, Dedico d905 oxygenator with an extra-arterial pump was used for circuit setup; whereas for lower body perfusion, a 22 Fr Medtronic cannula was used (Figure 1). While for bilateral cerebral perfusion, 14-mm and 7-mm grafts were used. For upper body circulation, blood flow and perfusion pressure were maintained at 0.8–1.0 lit/min/m^2 and 40–50 mmHg, respectively. For lower body circulation, blood flow and perfusion pressure were 1.6–2.0 lit/min/m^2 and 60–80 mmHg, respectively. A hypothermic blood coronary ostial with St. Thomas solution was used for myocardial protection. Arch reconstruction was done in the Elephant trunk fashion using a 28-mm Dacron graft. Branch grafts of 14 mm and 7 mm were used for innominate and left common carotid arteries, respectively. On the 3rd day after operation, the patient was shifted from the intensive care unit to the general ward, and on the 11th day, the patient was discharged.

Figure 1: Aortic arch debranching and replacement circuit diagram



CONCLUSION

Simultaneous individually controlled upper and lower body perfusion helped in avoiding spinal, visceral, renal, and lower limb ischemia. It also reduced lactic acidosis and the depth of hypothermia. The technique provided clear surgical field for the anastomosis.

The American Society of ExtraCorporeal Technology Standards and Guidelines for Perfusion Practice (2013)

Institution-specific protocols

- An operating procedure shall be developed and implemented by an institution or a service provider.
- The protocol needs to be:
  - Approved by the Cardiac Surgery Chairman (or designee), Perfusion Director (or equivalent), and other relevant clinical governance committees
  - Reviewed and revised on an annual basis, or as and when needed

Perfusion record

- The perfusion record for every cardiopulmonary bypass (CPB) procedure will be included in the patient's permanent medical record and shall be maintained as well as stored as per the institution policy.
- The perfusion record will contain:
  - Patient demographics and preoperative risk factors
  - Information related to the procedure, personnel, and equipment
  - Patient physiological parameters as according to the institutional protocol
  - Monitoring results for blood gas and anticoagulation
  - Signature of the perfusionist who performs the procedure

Blood management

- The perfusionist needs to:
  - Minimize hemodilution and avoid unnecessary blood transfusions
  - Minimize the CPB circuit size and decrease the prime volume
  - Calculate and communicate the patient's predicted postdilutional hemoglobin or hematocrit to the surgical team before initiating CPB

Reference: 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. *J Extra Corpor Technol*. 2013 Sep;45(3):156–66.

Acute Kidney Injury in Children Undergoing Cardiac Surgery with Cardiopulmonary Bypass

Introduction

Acute kidney injury (AKI) is prevalent in up to 50% of the children undergoing cardiac surgery with cardiopulmonary bypass (CPB). Also, AKI increases the risk of in-hospital death among these children and is known to be a consequence of tubular injury. Urine neutrophil gelatinase-associated lipocalin (uNGAL), a siderophore which is seen in the proximal tubule during a tubular epithelial injury, forms a reliable biomarker to detect AKI associated with cardiac surgery in infants. Bojan M *et al*. conducted an observational study to find out the most predictable bypass variables, their threshold values, and the most predictive time below the threshold which is associated with the occurrence of renal injury (significant uNGAL < 1 h).

Methods

This observational study linked the electronically recorded bypass perfusion pressure and the oxygen delivery rate with intra-operative uNGAL excretion (measured within 1 h of bypass) in 72 infants. The main outcome evaluated was renal injury, which was identified by a high creatinine normalized uNGAL concentration (> 21.2 µg/mmol).

> "During a cardiac surgery, more than 40% drop in the CPB perfusion pressure among infants was associated with an intraoperative renal injury."

Results

The uNGAL < 1 h in patients with deep hypothermic circulatory arrest (DHCA) was higher than that seen in patients without DHCA (Figure 1).

At the end of bypass, 43.7% of the patients showed a high uNGAL < 1 h excretion (exceeding 21.2 µg/mmol).

The temperature during aortic cross-clamping was lower, as compared to that seen before cross-clamping and after unclamping (Figure 2).

There was a mean arterial pressure (MAP) drop > 40% in 71 patients and MAP drop > 50% in 61 patients.

The median duration of > 40% MAP drop was 2.54 min, and that for > 50% MAP drop was 1.52 min.

Smaller weight and longer CPB durations in infants were found to be associated with a higher risk of kidney injury.

Figure 1: uNGAL < 1 h measurements in patients with and without DHCA

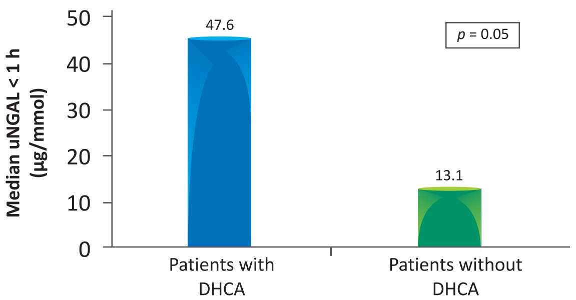
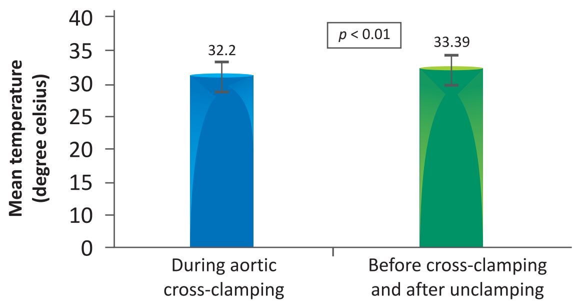


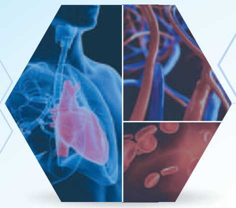
Figure 2: Temperature variations during clamping process



CONCLUSION

An effective renal protection can be achieved by maintaining the CPB perfusion pressure > 60% of the normal age-standardized MAP.

Reference: Bojan M, Basto Duarte MC, Lopez V, Tourneur L, Vicca S, Froissart M. Low perfusion pressure is associated with renal tubular injury in infants undergoing cardiac surgery with cardiopulmonary bypass. A secondary analysis of an observational study. *Eur J Anaesthesiol*. 2018;35:1–7.



Association of Postoperative Acute Kidney Injury with Intraoperative Blood Product Transfusions in a Cardiac Surgery

Introduction

Cardiac surgery-associated acute kidney injury (CSA-AKI) is estimated to be prevalent in up to 30% of the adults and results in increased mortality, morbidity, intensive care unit stay, infections, readmission, and hospital costs. Intraoperative packed red blood cell (RBC) transfusion forms a major modifiable risk factor that has been known to be associated with CSA-AKI. This study was conducted to understand the association between intraoperative transfusions of RBC, fresh frozen plasma (FFP), cryoprecipitate or platelet and acute kidney injury (AKI).

Kindzelski BA *et al*. studied the relationship between:

- Preoperative characteristics of patients and AKI
- Intraoperative transfusions and AKI
- Acute kidney injury and re-hospitalization or 30-day mortality

Methods

A retrospective analysis of 1,175 patients undergoing cardiac surgery was carried out.

Results

A total of 24.5% patients developed different stages of AKI (Figure 1). Higher use of RBC, FFP, and platelets was related to higher odds of AKI. The spline curve transformations were used to demonstrate the unadjusted probability of developing [3] Stage 2 AKI in relation to the number of units of RBC (Figure 2) and platelets (Figure 3).

Figure 1: Prevalence of AKI

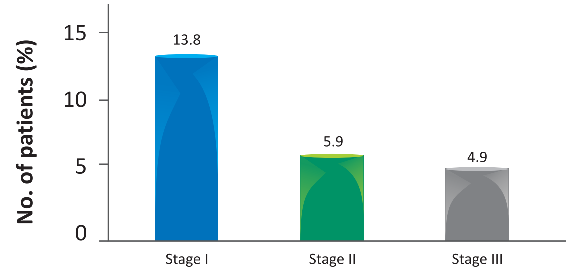


Figure 2: Probability of developing [3] Stage 2 AKI in relation to RBC

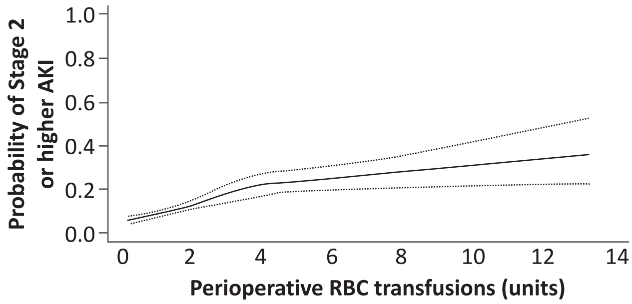
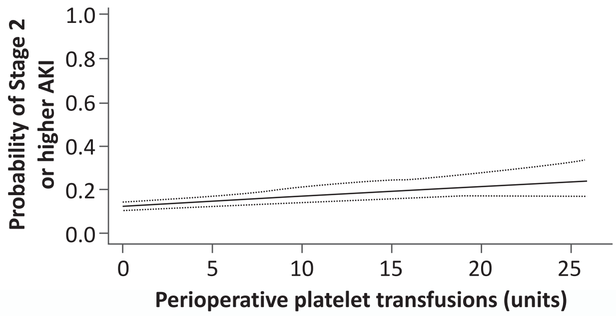


Figure 3: Probability of developing [3] Stage 2 AKI in relation to platelets



CONCLUSION

The study concluded that higher use of intraoperative transfusions of RBC, FFP, and platelets was independently associated with CSA-AKI.

Reference: Kindzelski BA, Corcoran P, Siegenthaler MP, Horvath KA. Postoperative acute kidney injury following intraoperative blood product transfusions during cardiac surgery. *Perfusion*. 2018 Jan;33(1):62–70.

SELF ASSESSMENT

SECTION 5

1. How does a cardioplegic solution help to maintain myocardial tissue viability?

a. It provides glucose for oxidative metabolism. ☐
b. It provides potassium for myocardial muscle contraction. ☐
c. It helps preserve ATP stores and decreases intramyocardial acidosis. ☐
d. It helps block Na/K pumps, thus allows a decrease in ATP use. ☐

2. During CPB, the perfusionist is responsible for the following, EXCEPT:

a. Ensuring that the circuit tubing is free from air, prior to going on CPB. ☐
b. Ensuring that the tubing is connected to pumps, so as to avoid venous air-lock. ☐
c. Maintaining adequate level of anesthesia with narcotic administration. ☐
d. Ensuring the correlation between aortic and radial arterial pressure. ☐

3. The primary objectives of CPB are to provide adequate ventilation, maintain circulation and perfusion, and regulate temperature.

a. True ☐
b. False ☐

4. What is the correct mechanism of action of a cardioplegic solution in the myocardium?

a. It provides a source of potassium ions for the heart to maintain Na/K pump function. ☐
b. It stops the formation of ATP. ☐
c. It provides excess potassium ions, which abolish transmembrane gradient and inhibit repolarization. ☐
d. It inhibits the cellular uptake of glucose and potassium ions. ☐

5. During complete CPB, what is the way to deal an unexpected electrical activity of the heart?

a. Excess blood is squeezed out of the heart by hand. ☐
b. The surgeon asks the perfusionist to administer additional cardioplegic solution. ☐
c. The surgeon asks the anesthesiologist to administer additional muscle relaxant. ☐
d. The surgeon repositions the retrograde arterial cannula. ☐

6. When can one turn off ventilation of the lungs during CPB?

a. Following insertion of the SVC cannula ☐
b. Following administration of heparin ☐
c. After the aminocaproic acid infusion finishes ☐
d. Following clamping of the aorta ☐

Reference: Cardiopulmonary bypass quiz questions [Internet]. Available at: https://www.slideshare.net/brankaazickurtovic/cardiopulmonary-bypass-quiz-questions. Accessed on Apr 3, 2018.

Answers: **1**–c; **2**–c; **3**–a; **4**–c; **5**–b; **6**–d.

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Configurability takes form: Terumo® System 1 adapts to evolving practices.

[1] Data on file.

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