ABSTRACTS

Evaluation of Cerebral Flow, Oxygenation and Metabolism Coupling during Cardiopulmonary Bypass using a novel optical imaging system

Agya Prempeh[1], Marianne Suwalski[2,3], Daniel Milej,[2,3] Mamadou Diop,[2,3] Keith St. Lawrence[2,3], John Murkin[1], Jason Chui[1]

1. Imaging Program, Lawson Health Research Institute, 268 Grosvenor St., London, ON, N6A 4V2, Canada
2. Department of Medical Biophysics, Western University, 1151 Richmond St., London, ON, N6A 3K7, Canada
3. Department of Anaesthesiology and Perioperative Medicine, University Hospital, 339 Windermere Rd, London, ON, N6A 5A5, Canada

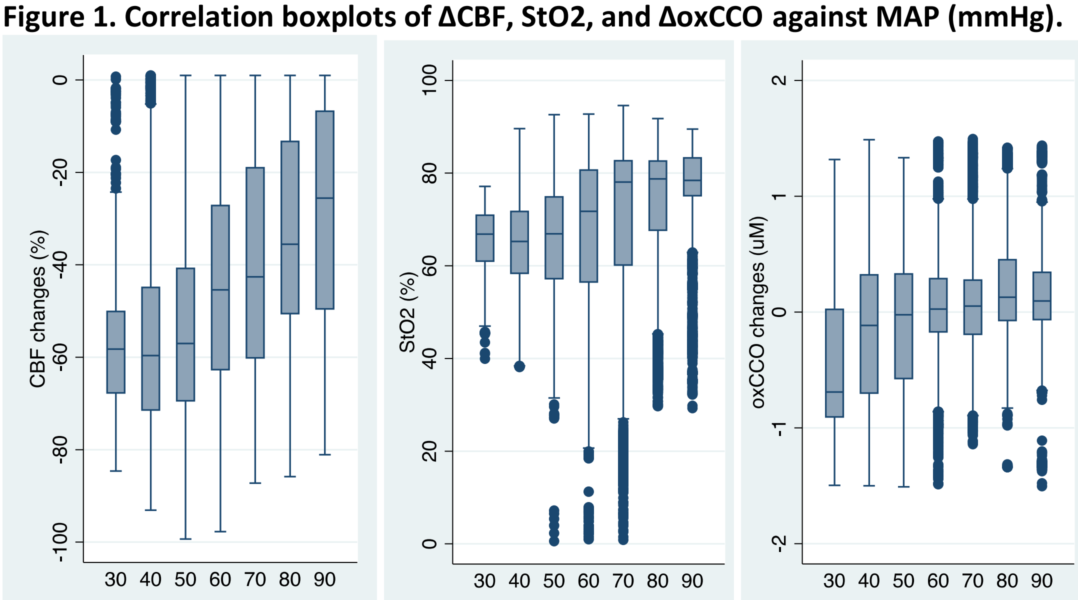
Background: Mean arterial pressure targets are used to maintain adequate cerebral blood flow (CBF) in patients undergoing cardiac surgery with cardiopulmonary bypass (CPB). However, fixed hemodynamic targets do not account for variability between patients and neurological injury occurs unpredictably in clinical setting. Prolonged periods of low CPB flow rate or hypotension leading to decreases in CBF, can impede cerebral metabolism, and can cause tissue damage[2,3]. It is important to have better understanding on the relationship between CBF, brain oxygenation and brain metabolism during hypotensive event

Methods: A novel hybrid optical system that combined diffuse correlation spectroscopy with broadband near-infrared spectroscopy was used to continuously monitor CBF, the oxidation state of cytochrome c oxidase (oxCCO) – a direct marker of oxidative metabolism, tissue saturation (S_tO_2), during cardiac surgery. Changes in oxCCO and CBF were evaluated during periods of intraoperative hypoperfusion, due to transient reductions in CPB flow.

Results: Nine adult cardiac surgical patients CPB were monitored. oxCCO and CBF levels are successfully monitored in all patients. During transient hypoperfusion events, CBF changes dropped with decrease in MAP, whereas StO2 remained stable until MAP dropped below 50 mmHg. oxCCO remained stable until MAP fell below 30 mmHg. (Fig 1)

Conclusions: These results demonstrated the ability of the hybrid system to provide continuous monitoring of brain health. During transient hypotensive events, CBF changes preceded StO2 changes, and followed by changes in oxCCO. Future work will investigate the relationship of these markers and the neurological complications associated with CPB.

Figure 1. Correlation boxplots of ΔCBF, StO2, and ΔoxCCO against MAP (mmHg).



Cerebral Autoregulation with Optical Monitoring during Cardiopulmonary Bypass

Marianne Suwalski,[1,2*] , Ajay Rajaram,[5] ,Daniel Milej,[1,2] Lawrence C.M. Yip,[1,] L. Ray Guo,[4] Michael W. A. Chu,[4] Mamadou Diop,[1,2] John Murkin,[3] Keith St. Lawrence[1,2] Jason Chui [3]

1. Imaging Program, Lawson Health Research Institute, 268 Grosvenor St., London, ON, N6A 4V2, Canada
2. Department of Medical Biophysics, Western University, 1151 Richmond St., London, ON, N6A 3K7, Canada
3. Department of Anaesthesiology and Perioperative Medicine, University Hospital, 339 Windermere Rd, London, ON, N6A 5A5, Canada
4. Department of Surgery, University Hospital, 339 Windermere Rd, London, ON, N6A 5A5, Canada
5. Boston Children's Hospital, Harvard Medical School, 300 Longwood Ave, Boston, MA 02115, USA.

Mean arterial pressure (MAP) targets are used to maintain adequate cerebral blood flow (CBF) in patients undergoing cardiac surgery with cardiopulmonary bypass (CPB). However, set targets do not account for cerebral autoregulation (CA) variability between patients[1]. Prolonged periods of CPB flow rate changes leading to decreases in CBF, can impede cerebral metabolism and can cause tissue damage[2,3]. Maintenance of CBF and perfusion with knowledge of limit of CA of individual patient is crucial to prevent severe neurological complications associated with CPB. Previous studies proposed using changes of cerebral tissue saturation (S_tO_2) against MAP to calculate cerebral oximetry autoregulation index (COx); however, S_tO_2 is still not a direct marker of cerebral blood flow. In this study, a novel hybrid diffuse correlation spectroscopy (DCS)/hyperspectral near-infrared spectroscopy (hsNIRS) system was used to continuously monitor CBF and S_tO_2 during cardiac surgery[3]. In addition to COx, the correlation index between MAP and CBF (CBFx) was also calculated to characterize autoregulation. The purpose of this study was to assess the feasibility of real-time intraoperative CA monitoring with optical techniques and to compare the autoregulation indices in adults undergoing cardiac surgery with CPB. Sixteen adult patients undergoing elective cardiothoracic surgery with CPB were monitored. during surgery. COx, and CBFx were calculated for 3 different periods: going on CPB, during CPB, and off CPB. Good agreement was observed between COx, and CBFx,(kappa=0.44, $p<0.001$). Intact CA in both COx and CBFx, defined as values ≤0.4, was present in 13 patients before going on CPB, 12 patients during CPB, and 13 patients off CPB. Impaired CA was present in 2 patients. These results demonstrated the ability of the hybrid system to provide continuous monitoring of brain health. Future work will investigate the relationship between impaired CA and cerebral metabolism, with the aim of reducing the incidence of neurological complications associated with CPB.

Reference

[1] Murkin et al. Cardio. and Vasc. Anesth., 2015; 5:1187-1193
[2] Murkin et al. Anesth. Analg. 1987;66: (9):825-32.
[3] Rajaram et al. Biomed Optics Express 2020;11:5967

Evaluating diagnostic test accuracy of cerebral oximeter to diagnose brain ischemia

Jason Chui[1], Agya Prempeh[1], Marianne Suwalski[2,3], Daniel Milej,[2,3] Mamadou Diop,[2,3] Keith St. Lawrence[2,3], John Murkin[1]

1. Department of Anaesthesiology and Perioperative Medicine, University Hospital, 339 Windermere Rd, London, ON, N6A 5A5, Canada
2. Imaging Program, Lawson Health Research Institute, 268 Grosvenor St., London, ON, N6A 4V2, Canada
3. Department of Medical Biophysics, Western University, 1151 Richmond St., London, ON, N6A 3K7, Canada

Background: Cerebral oximetry has been used clinically to monitor brain oxygen saturation and thereby to inform brain ischemia for more than two decades especially during cardiac surgery. However, the definition of cerebral desaturation and the diagnostic profile of cerebral oximetry to inform brain ischemia are yet to be determined.

Methods: We performed a prospective cohort study using a novel hybrid optical system that combined diffuse correlation spectroscopy with broadband near-infrared spectroscopy to continuously monitor tissue saturation (S_tO_2) and the oxidation state of cytochrome c oxidase (oxCCO) – a direct marker of oxidative metabolism, during cardiac surgery. An absolute drop of oxidation state of cytochrome c oxidase (oxCCO) < 0.5 µM is defined as brain ischemia. The best cut-off value of cerebral desaturation to diagnose brain ischemia is determined by receiver operating characteristic curve (ROC).

Results: Nine adult cardiac surgical patients were monitored with successful simultaneous recording levels of S_tO_2 and oxCCO. The diagnostic profiles of cerebral oximetry using different cut-off values to diagnose brain ischemia are listed in Table 1 and Figure 1. Cerebral oximetry appears to have high specificity but low sensitivity regardless of the cut-off values. The ROC area is 0.594 (95% CI: 0.589 - 0.599).

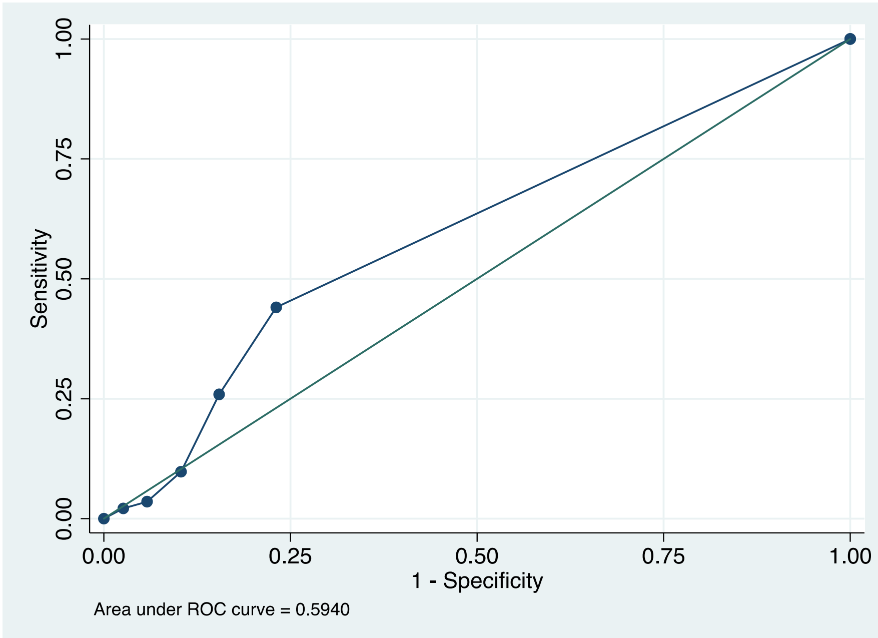
Conclusions: The diagnostic accuracy of cerebral desaturation to inform brain ischemia as defined by oxCCO was low. Further studies are required to evaluate the accuracy of cerebral desaturation as a marker to reflect brain ischemia.

Reference: J. M. Murkin, et al, Near-infrared spectroscopy as an index of brain and tissue oxygenation, Br J Anaesth. 2009 Dec;103 Suppl 1:i3-13

Table 1. Detailed report of sensitivity and specificity of different cut-off values of cerebral desaturation to diagnose brain ischemia

Cutpoint	Sensitivity	Specificity	Correctly Classified	LR+	LR-
< 60%	44.04%	76.90%	72.47%	1.9069	0.7276
< 55%	25.90%	84.55%	76.64%	1.6770	0.8763
< 50%	9.78%	89.66%	78.88%	0.9461	1.0062
< 45%	3.55%	94.21%	81.97%	0.6132	1.0238
< 40%	2.14%	97.39%	84.54%	0.8208	1.0048

Figure 1. Receiver-operating-curve of different cut-off values of cerebral desaturation to diagnose brain ischemia



Tips and Tricks for Volume Management in relation to Central Venous Pressure (CVP) in Minimally Invasive Extracorporeal Circulation (MiECC) Population.

Ignazio Condello[1].

[1] Department of Cardiac Surgery, Anthea Hospital, GVM Care & Research, Bari, Italy.

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Corresponding Author
Ignazio Condello, PhD
GVM Care & Research, Perfusion Service, Anthea Hospital,
Via Camillo Rosalba 35/37, 70124 Bari, Italy.
Tel. +39 080 5644560
ignicondello@hotmail.it

Background: In cardiac surgery, veno-dilation occurs shortly after the institution of cardiopulmonary bypass (CPB), necessitating fluid or vasoconstrictor administration to maintain adequate oxygen delivery. This phenomenon is highlighted in conventional CPB by the presence of the venous reservoir, which allows for the visualization of the dynamic volume during cardiac surgery. procedures and to visually perceive the veno-dilation phenomenon. The literature provides some consideration of central-venous pressure (CVP); in particular, any given CVP value will not accurately predict whether a patient will respond to fluids. This is true for all variables, including cardiac output, capillary refill time, central venous oxygen saturation, urine output, and blood lactate level. Nevertheless, when the CVP is low, there is a greater chance of an increase in cardiac output in response to fluids. In this context, we found some analogies of fluid management in relation to CVP during minimally invasive extracorporeal circulation (MIECC) techniques in particular for closed systems without the dynamic vision of venous volume in a hards-hell or soft-shell reservoir. This aspect is connected not only to the types of circuit, hardware, and safety systems of the console but also to the "tricks" and strategies of the perfusion operator and anesthetist during the procedures.
Methods: At our institution, 50 adults were scheduled for isolated elective coronary artery bypass grafting with MIECC volume management (type III). Baseline characteristics are reported in Table 1. Patients analyzed in this context were not critical, did not have endocarditis or septic shock, and reported good preoperatory hemodynamical stability without the use of diuretics and Swan-Ganz catheter. Anesthesia was induced with intravenous sufentanil (0.5 to 1 µg/kg) and midazolam (0.08 to 0.2 mg/kg), and tracheal intubation was facilitated with intravenous rocuronium (0.6 to 1 mg/kg). Anesthesia was maintained with propofol (2 to 5 mg/kg) and sufentanil (0.5 to 2.0 µg/kg), and the depth of anesthesia was monitored using bispectral index (BIS) values (BIS XP, Aspect Medical System, Newton, MA, USA). The dosage of propofol was titrated to maintain BIS values between 40 and 45. Normothermic blood cardioplegia (St Thomas solution) was used in all cases and repeated every 20 min. Oxygen delivery was calculated as follows: cardiac output × arterial oxygen concentration × 10. During the cross-clamp time, we observed and collected the CVP values and correlations for various situations for including blood flow, inlet of pump pressure, cardiac cavities (stretched or empty), and mean arterial pressure with solutions correlation and volume management strategies for ideal CVP (3 to 5 mm Hg).
Results: We share our approach for volume management (Table 2). During MIECC type III, we used a central cannulation with a single atrio caval cannula 32/40 Fr for the right atrium and 22

to 24 Fr arterial cannula for the ascending aorta (Fig. 1). Nevertheless, in the literature, there are no clear CVP nadirs on MIECC for volume management. Table 2 describes our approach to volume management in relation to CVP.

Conclusion: Our experience reported that tips and tricks for CVP nadirs between (3-5 mmHg) were effective for volume management in MiECC Type III. Nevertheless, further studies are needed to support the CVP nadirs during the MIECC approach.

Tables

Table 1. Clinical Characteristics of the Study Group.

	MIECC (N = 50)
Mean age, years	72.0 (63.7)
Body surface area, m^2	1.85
Median NYHA class	2
EuroSCORE II	1.5
Mean ± SEM pre-CPB hematocrit, %	34.6 ± 1.3
Pre-CPB hemoglobin, g/dl	11.4 ± 1.1
CPB time, min	63 ± 15.2
Aortic cross-clamp time, min	47 ± 9

Abbreviations: CPB, cardiopulmonary bypass; EuroSCORE, European System for Cardiac Operative Risk Evaluation; MIECC, minimally invasive extracorporeal circulation; NYHA, New York Heart Association; SEM, standard error of the mean.

Table 2. Situations and Solutions for Volume Management During MIECC Technologies.

	Situation	Solution
CVP 3 to 5 mm Hg Collected on 25 MIECC type III	Optimal blood flow Empty cavities MAP 50 to 70 mm Hg	Maintaining the parameters
CVP >5 mm Hg Collected on 5 MIECC type III	Low blood flow Cavities stretched on TEE monitoring with cannula cavitation (negative pressure in inlet pump) MAP <50 mm Hg	First: reducing pump revolutions (RPM) Second: reposition of the venous cannula with TEE monitoring Third: nadir (CVP 3 to 5 mm Hg), increase pump revolutions (RPM)
CVP >5 mm Hg Collected on 12 MIECC type III	Optimal blood flow Cavities stretched MAP >70 mm Hg	Active drainage in softshell venous reservoir And/or vasodilatation use Nadir (CVP 3 to 5 mm Hg)
CVP –1/2 Collected on 8 MIECC type III	Low flow Cavitation (negative pressure in venous line) Cavities empty MAP <50 mm Hg	First: reducing pump revolutions (RPM) Second: Trendelenburg position Third: adding liquids or vasoconstrictor use Fourth: nadir CVP (3 to 5 mm Hg), increase pump revolutions (RPM)

Abbreviations: CVP, central venous pressure; MAP, mean arterial pressure; MIECC, minimally invasive extracorporeal circulation; TEE, transesophageal echocardiography.

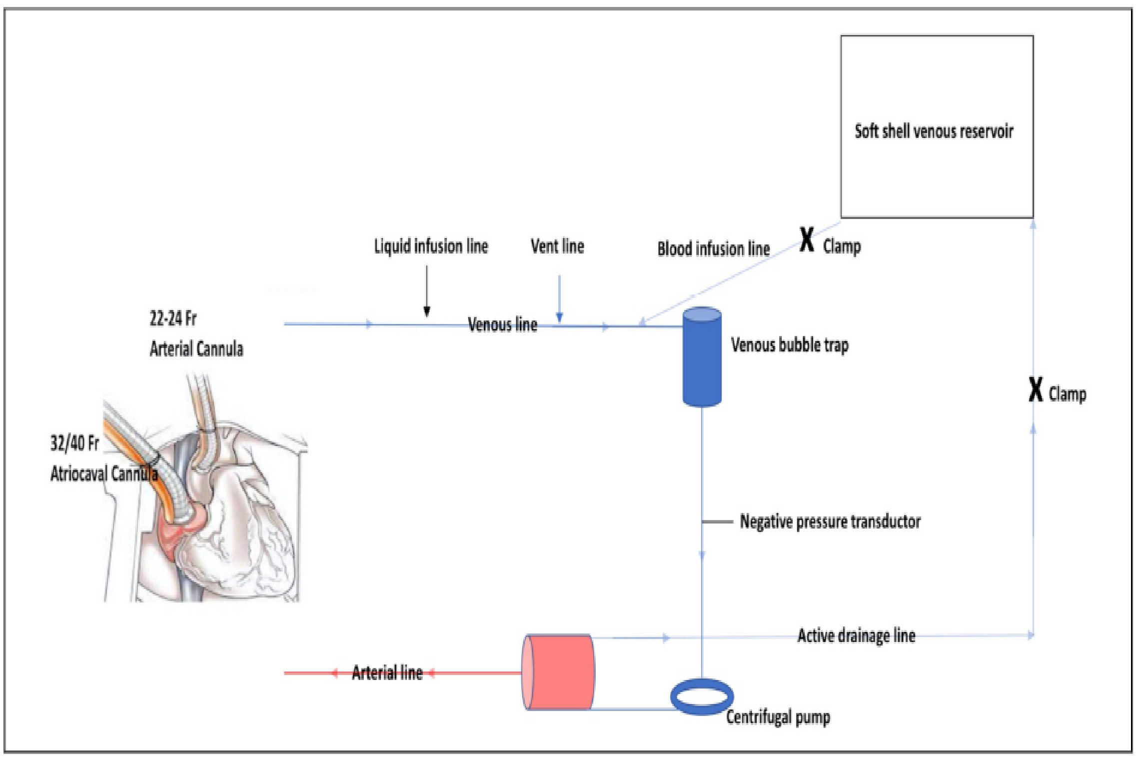

Fig. 1. Minimally invasive extracorporeal circulation type III sketch.