Perfusion Monitoring during Cardiopulmonary Bypass: Which Parameter is Best?

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CONFLICTS OF INTEREST

• None to declare
IF YOU HAD ONLY ONE MONITOR AVAILABLE, WHICH WOULD YOU CHOOSE?
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<th>Perfusion Parameters: How to Choose?</th>
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NEAR-INFRARED SPECTROSCOPY:
WHAT IS IT?
HOW EFFECTIVE IS IT?
HOW CAN I USE IT?
NIRS: NEAR-INFRARED SPECTROSCOPY

** Photos sourced from manufacturers’ website **
NIRS: NEAR-INFRARED SPECTROSCOPY

- Wavelength range 700-900 nm
  - Isobestic point oxy/deoxy Hb 810 nm
- Utilizes 1 Emitter and 2 Detector Diodes
  - Difference between signal at both detectors utilized to account for absorbance by superficial tissues
  - Algorithm differs among manufacturers
- Measures approx. 2.5-3 cm tissue depth

Picture 1 courtesy of Shimadzu Corp.
Picture 2 sourced from Lab Times (http://www.labtimes.org/labtimes/method/methods/2007_03.lasso)
NIRS: NEAR-INFRARED SPECTROSCOPY

• Non-pulsatile, predominantly wave reflectance (not transmission, like SpO₂)
• Principally venous blood – thus measurement of cerebral venous saturation
  • Assumption usually 70% venous/30% arterial blood
• Kim, et al. demonstrated good correlation of rScO₂ to jugular venous bulb saturation under conditions of hyper/hypocarbia and hypoxia (healthy volunteers)
• Manufacturer-Dependent Algorithm

CASE

• 70-y/o female for emergent ascending aorta replacement graft +/- AVR due to a Type A aortic dissection.
• Patient arrives hemodynamically stable, GCS 15, with no neurologic deficits.
• Anesthetic induction, initial intraoperative course unremarkable.
• Aortic cannula located in the right subclavian artery, single venous cannula in the right atrium.
• Baseline rScO₂ 65% bilaterally
CASE

• 10 Minutes after initiation of CPB, abrupt fall in rScO$_2$ to <20 bilaterally
• Possible etiologies?
  • Embolic phenomena
  • Cannula malposition (perfusion of false lumen?)
  • O2 delivery
  • Extension of dissection
• Ultrasound of bilateral carotid arteries demonstrated dissection flap, with likely perfusion of false lumen
• Circulatory arrest initiated (core temperature 30 C) and anterograde perfusion catheters placed in the right brachiocephalic and left common carotid artery. rScO$_2$ remained < 20 bilaterally.
• Doppler US revealed no flow, despite placement under direct sight.
• Problem with pump flow to anterograde catheters; after reinitiation of flow, rScO$_2$ immediately increased to within 20% of baseline.
AT-RISK POPULATION

- Risk of debilitating neurological injury after cardiac surgery: 1.6-5%\textsuperscript{1,2}
- Patients requiring CABG often have concomitant cerebrovascular disease
- Embolic phenomena well-described
- Hypertension: shift of cerebral autoregulation curve to the right
- Increased susceptibility to watershed infarcts
- Multiple comorbidities (diabetes, hyperlipidemia, tobacco use, sleep apnea)

\textsuperscript{2} Tarakji KG, et. al. Temporal onset, risk factors and outcomes associated with stroke after coronary artery bypass grafting. JAMA. 2011;305:381–90.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{brain_mri}
\caption{Brain MRI showing ischemic changes.}
\end{figure}
NIRS AND OUTCOMES: SHOW ME THE EVIDENCE

- CASE REPORTS: multiple starting late 90s – early 00s
- OBSERVATIONAL STUDIES: multiple, most retrospective
- 2011 Heringlake, et al. (Anesthesiology)
  - 1178 patients undergoing CABG, valve repair, aortic arch repair, combined procedures
  - Morbidity and mortality increased in patients with low baseline rScO₂
- 2004 Yao, et al. (Journal of Cardiothoracic and Vascular Anesthesia)
  - 101 patients undergoing cardiac surgery with CPB.
  - Patients with nadir rScO₂<35% higher risk of postop MMSE and ASEM impairment
  - Similar outcome in patients with rScO₂<40% for >10 minutes
  - No intervention for low rScO₂
NIRS AND OUTCOMES:
SHOW ME THE EVIDENCE

- RANDOMIZED, CONTROLLED TRIALS
  - 2007 Murkin, et al. (Anesthesia & Analgesia)
    - 200 patients undergoing CABG with CPB
    - Blinded control rSO2 vs. rSO2 with treatment protocol for >25% decrease from baseline
    - Control: higher number of major morbidity or mortality (death, >48h ventilation, stroke, MI, re-op), longer ICU stay, longer hospital stay
  - 2009 Slater, et al. (Annals of Thoracic Surgery)
    - 265 patients undergoing CABG with CPB.
    - Larger battery of neuropsychologic tests
    - Patients with rSO2 desaturation score > 3000% higher risk of early postop cognitive decline
    - Patients with rSO2 desaturation score > 3000% 3x risk of prolonged hospital stay
    - Poor adherence to intervention protocol
NIRS AND OUTCOMES: SHOW ME THE EVIDENCE

- FEASIBILITY STUDIES
- 2016 Deschamp, et al. (Anesthesiology)
  - 201 patients at 8 Canadian hospitals undergoing high-risk cardiac surgery
  - 57% (control) – 70% (intervention) of patients exhibited rSO2 desaturations (>10%)
  - Successful reversal of 97% of desaturations using treatment algorithm
  - No difference in adverse outcomes at 30 days between groups
- 2016 Subramanian, et al. (Anesthesia & Analgesia)
  - 235 patients at 8 US hospitals undergoing CABG or valvular surgery
  - 50-75% of patients exhibited rSO2 desaturations (>20%); 10% were not identified by clinicians
  - In the identified events, treatment algorithm reversed desaturation in the majority of cases
APPLICATIONS: ADULT CARDIAC SURGERY

• Detects otherwise clinically silent episodes of ischemia or reduced perfusion
  • Known cerebrovascular disease (h/o TIA, CVI)
  • Known carotid stenosis
  • Poorly-controlled hypertension
  • Other risk factors: diabetes, tobacco use, sleep apnea???
• Aortic cannula malposition
• Detects venous congestion
• Deep hypothermic circulatory arrest: how effective is anterograde perfusion?
APPLICATIONS: PEDIATRIC

• Cerebral Oximetry
  • Complex physiology and repairs in congenital heart surgery, often with right-to-left shunt
  • Cerebral circulation especially sensitive to changes in $P_{CO_2}$
  • Aortic cannula size and position

• Regional organ oximetry
  • Possible due to superficial location of kidney, liver, splanchnic circulation in neonatal and pediatric population
  • Important in complex corrective surgeries with possible regional perfusion differences
  • May help with early detection of low-output syndrome after cardiac surgery

• Pediatric Intensive Care
APPLICATIONS: NON-CARDIAC SURGERY

- Trauma
- Cardiopulmonary resuscitation: measure of adequacy of resuscitation
- Hypothermic Injuries: ECMO
- ICU: ECMO, LVAD, Post-cardiac surgery
PITFALLS

• Cortical measurement
• Trend measurement, not absolute
  • Differences in patient anatomy (thickness of skull, subcutaneous edema, scalp or subdural/epidural hematomata)
  • Distribution of arterial and venous blood in the sample volume
  • Can appear normal in non-metabolizing or dead tissue due to sequestration of venous capillary blood (Schwartz, et al)
• Frontal lobe measurement
• Ischemic vs. Hemorrhagic Phenomena

TAKE-HOME MESSAGES: NIRS

- End-organ monitor!
- Can help detect otherwise clinically silent episodes of brain hypoperfusion or ischemia
- Studies demonstrate trend in reduction of poor neurological outcomes, mortality, major morbidity, reduction in ICU/hospital stay
- Strongly consider use in patients with higher-risk procedures, risk factors for cerebral hypoperfusion
- Noninvasive and easy to use: ask yourself, “Why Not?”
IF YOU HAD ONLY ONE MONITOR AVAILABLE, WHICH WOULD YOU CHOOSE?
Questions????

Thank you for your attention!