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AmSECT experience

Adequacy of Perfusion in Pediatrics is Best Measured by….

Richard Melchior CCP, MPS, FPP
Children's Hospital of Philadelphia

What are the Current Perfusion Adequacy Indicators?

- Tissue Perfusion
  - ABP
  - SVO2
  - Lactate
  - ABG/VBG
  - Arterial Flow Rate
  - NIRS (Cerebral/Somatic)
- Gas Exchange
  - GDP (DO2, VO2, VCO2)
- Others
  - Urine Production
  - Outcomes

Arterial Blood Pressure

- AmSECT Guidelines for ABP

Standard 11.1: The Perfusionist, in collaboration with the physician-in-charge, shall define and communicate the intended treatment algorithm for blood pressure management prior to cardiopulmonary bypass (CPB), including acceptable ranges for blood pressure.15

Standard 11.2: The Perfusionist shall work closely with the surgical care team to maintain blood pressure according to protocol during CPB.

Guideline 11.1: Variance from intended and targeted blood pressure should be documented and communicated to the physician-in-charge to allow for changes in the blood pressure management plan.

Two Questions….

1. Why do we need to monitor ABP so closely?
2. What is the ideal ABP for each particular patient?

How important is the SVO2 Measurement?

Mixed Venous Saturation (SvO2)

- Fick Equation:
  - SvO2 = SaO2 – VO2/13.9 x Q x (Hb)
  - An increase in tissue extraction (VO2) or a decrease in arterial oxygen content (SaO2 x Hb) can be compensated by increasing arterial flow rates.
  - The normal SvO2 is 75%, which indicates that under normal conditions, tissues extract 25% of the oxygen delivered.
  - Normal Values on CPB
    - 65-75%

How Long Have You Utilized SVO2 Measurement?

- 30+ Years
- 20+ Years
- 10+ Years
- <5+ Years

The *Possible* End All, Be All Perfusion Adequacy Indicator…..

Lactate

Lactate

- AmSECT Guidelines on Lactate Measurement
  - Guideline 10.2: Appropriate blood flow rate should be determined by evaluation of:
  - Acid base balance
    - 1. Lactate burden

What Does a Measured Lactate Show Us?

- Oxygen Delivery ≠ Oxygen Consumption
- Inadequate aerobic energy supply, start to utilize anaerobic energy supply
- Anaerobic metabolism through pyruvate conversion to lactate
- Increased Anaerobic Metabolism increases Lactate Production

When to Measure Lactate?

- Pre-operative
- Perioperative
  - Baseline
  - After CPB Initiation
  - Pre CPB Termination
  - Post CPB Termination
  - Pre OR Departure
- Post-operative
  - ICU (Q3 for first 24 hours, 48hrs, 72hrs)

How Many People Utilize Lactate Measurement during CPB?

GDP Will Never Live up to the Good Ole' Indicators!

Two Questions….

1. Why do we need to monitor ABP so closely?
2. What is the ideal ABP for each particular patient?

Does hypothermia impair cerebrovascular autoregulation in neonates during cardiopulmonary bypass?

Brendan Smith[1] | Eric Vu[2] | Kathleen Kibler[2] | Craig Rusin[1] | Ronald B. Easley[2] | Dean Andropoulos[2] | Jeffrey Heinle[3] | Marek Czosnyka[4] | Daniel Licht[5] | Jennifer Lynch[6] | Ken Brady[1]

Pediatric Anesthesia. 2017;27:905–910.

- Hypothermia/hypotension causes impaired cerebral autoregulation
- Metabolic vs Pressure autoregulation
- Elevated RS02 can mask decreased cerebral blood flow
- Maintain ABP to lowest limit for cerebral autoregulation

Blood Pressure Excursions Below the Cerebral Autoregulation Threshold During Cardiac Surgery are Associated With Acute Kidney Injury*

Masahiro Ono, MD, PhD[1]; George J. Arnaoutakis, MD[1]; Derek M. Fine, MD[2]; Kenneth Brady, MD[3]; R. Blaine Easley, MD[3]; Yueying Zheng, MD[4]; Charles Brown, MD[5]; Nevin M. Katz, MD[1]; Morgan E. Grams, MD, MHS[2]; Charles W. Hogue, MD[5]

- MAP below limit of CBP autoregulation threshold was shown to be directly related to AKI.

Crit Care Med. 2013 Feb;41(2):464-71

Duration and magnitude of blood pressure below cerebral autoregulation threshold during cardiopulmonary bypass is associated with major morbidity and operative mortality

Masahiro Ono, MD, PhD,[a] Kenneth Brady, MD,[b] R. Blaine Easley, MD,[b] Charles Brown, MD,[c] Michael Kraut, MD, PhD,[d] Rebecca F. Gottesman, MD, PhD,[e] and Charles W. Hogue, Jr, MD[e]

Results: Of the 450 patients, 83 experienced major morbidity or operative mortality. The area under the curve of the product of the duration and magnitude of blood pressure below the limits of autoregulation was independently associated with major morbidity or operative mortality after cardiac surgery (odds ratio, 1.36; 95% confidence interval, 1.08-1.71; $P = .008$).

Conclusions: Blood pressure management during cardiopulmonary bypass using physiologic endpoints such as cerebral autoregulation monitoring might provide a method of optimizing organ perfusion and improving patient outcomes from cardiac surgery. (J Thorac Cardiovasc Surg 2014;147:483-9)

J Thorac Cardiovasc Surg 2014;147:483-9

Main Reasons for ABP Optimization

- Hypothermia and Cerebral Dysautoregulation
- AKI
- Better Outcomes

CHOP'S MAP Protocol

MAP	**30-55 mmHg (0-30 days; 0-5 kg)** **35-55 mmHg (1 month -1 yr; 5-10 kg)** **30-65 mmHg (1 yr-4 yr; 10-20 kg)** **40-70 mmHg (4 yr-10 yr; 20-40 kg)** **50-80 mmHg (11 yr+; >40 kg)**

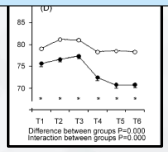
How important is the SVO2 Measurement?

Static blood-flow control during cardiopulmonary bypass is a compromise of oxygen delivery☆

Staffan Svenmarker [a,*], Sören Häggmark [a], Magnus Hultin [b], Anders Holmgren [a]

[a] Department of Surgical and Perioperative Science, Heart Centre, Umeå University Hospital, Umeå, Sweden

- Prospective, randomized study done on 100 adult CABG patients
- Dynamic Flow that maintained an SVO2>75% provided higher oxygen delivery to the patient for better organ preservation, which could provide increased margins of safety.



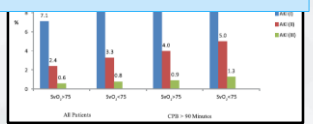
Original Paper

Perfusion

A retrospective analysis of the mixed venous oxygen saturation as the target for systemic blood flow control during cardiopulmonary bypass

SAGE

- Maintaining SVO2 >75% better outcomes than DO2 at >272 ml/min/m2.
- SVO2 >75% showed decreased AKI when compared GDP with DO2 at >272ml/min/m2.
- SVO2 >75% linked to lower lactate



SVO2 is Important!!

- Better Organ preservation with higher SVO2
- Decreased AKI with SVO2 >75%

SVO2 Limitations

- Does not provide regional measurements of tissue perfusion
- If distant capillaries are not being perfused, tissues may not get blood flow and SVO2 may increase. (Kirklin, Cardiac Surgery 1993, 81.)
- Single Ventricles, Possibly Falsely elevated
  - Do we need an increased SVO2 for this population? 80% or greater?

SVO2 is Still Important

- This measurement is key in a large picture perspective
  - Gross marker to optimize oxygen delivery
  - Reducing gross oxygen delivery inadequacy

Looking at the Big Picture Perfusion Adequacy Indicator…..

Lactate

Hyperlactatemia in patients undergoing adult cardiac surgery under cardiopulmonary bypass: Causative factors and its effect on surgical outcome

Rakesh Naik, Gladdy George[1], Sathappan Karuppiah[1], Madhu Andrew Philip[2]
Department of Cardiothoracic and Vascular Surgery, Sri Jayadeva Institute of Cardiovascular Sciences and Research, Bengaluru, Karnataka, Departments of [1]Anaesthesia and [2]Cardiothoracic Surgery, Christian Medical College and Hospital, Vellore, Tamil Nadu, India

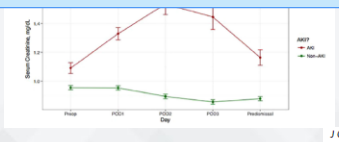
- Hyperlactatemia had significant association with post operative morbidity
- Detection hyperlactatemia in the perioperative period should be considered as an indicator of inadequate tissue oxygen delivery and should be aggressively corrected.

Ann Card Anaesth 2016;19:668-75.

Relationship between intraoperative serum lactate and hemoglobin levels on postoperative renal function in patients undergoing elective cardiac surgery

Steven C. Mitchell MS[1] | Anirudh Vinnakota MS[2] | Salil V. Deo MD[3] | Alan H. Markowitz MD[3] | Basar Sareyyupoglu MD[3] | Yakov Elgudin MD[3] | Benjamin Medalion MD[3] | Adam Tzagournis CCP[3] | Joseph Sabik MD[3] | Soon J. Park MD[3]

- Increased Lactate levels during CPB was indicative of AKI.



J Card Surg. 2018;33:316–321.

Central venous oxygen saturation and blood lactate levels during cardiopulmonary bypass are associated with outcome after pediatric cardiac surgery

Marco Ranucci[1*], Giuseppe Isgrò[1], Concetta Carlucci[1], Teresa De La Torre[1], Stefania Enginoli[1], Alessandro Frigiola[2], Surgical and Clinical Outcome REsearch (SCORE) Group[1]

The combination of a continuous monitoring of central venous oxygen saturation and serial measurements of blood lactate during cardiopulmonary bypass may offer a predictive index for major morbidity after cardiac operations in pediatric patients. Th

Ranucci *et al. Critical Care* 2010, **14**:R149

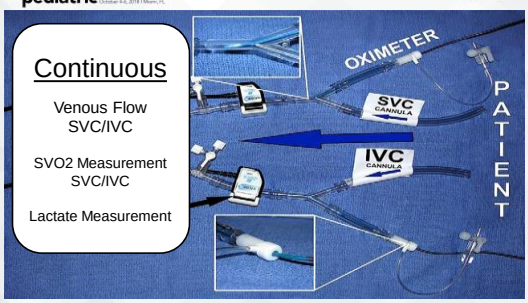
Lactate Measurement Contribution

- Linked to Major Morbidity and Mortality
- Increased Level Associated to AKI
- Monitoring can provide a Predictive Index

Lactate Limitations

- Delay in Elevated Lactate Level
  - Washout with DHCA, ICP, etc.
- Blood Product Utilization Elevation
  - Lactate of banked blood is 18-24+ dependent on age of blood/washed
- Perfusion Masking
  - Continuous CUF/ZBUF will lower lactate levels

Could Limitations with SvO2 & Lactate be Minimized?



Further Points of Contention

- Decades of Utilizing ABP, SVO2 as primary indicators with success
- Lactate is a solid measure of overall tissue perfusion
- GDP is limited in Pediatrics with pH Stat measurement (VCO2)
- Maximize all Basic Adequacy Parameters, DO2/GDP Achieved

In Conclusion

- Combination of the 3….
  - Maintain ABP to cerebral/somatic autoregulation threshold
  - SVO2 > 75%, SVO2 > 80% (Single Ventricle)
  - Lactate < 2.0mmol or <+1 from Baseline
  - Maintaining all other variables within Institutional CPB Protocols

Maximize to Optimize

True Honor to Share This Stage With Chelsea!

What is the most important perfusion adequacy indicator to monitor?

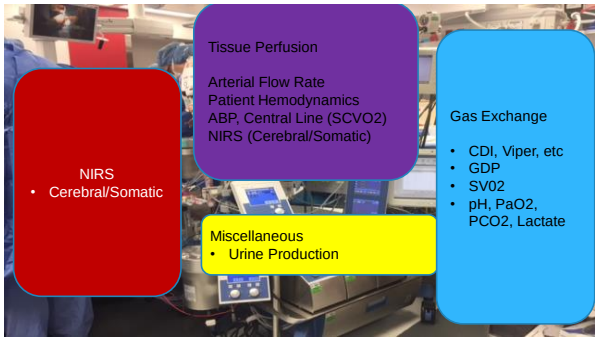
A. NIRS
B. Lactate
C. ABP
D. CPB Q
E. GDP
F. All of the Above

If you could pick a combination of indicators, which combination would you choose?

A. ABP, NIRS, Lactate
B. SVO2, NIRS, CPB Q
C. GDP, NIRS, ABP

If you could have a perfusion adequacy monitor for the future, which one would you prefer?

A. GDP for Pediatric CPB
B. Venous Cannula Q/SVO2/Lactate Measurement
C. More Accurate NIRS (Cerebral/Somatic)
D. Keep the Same that I utilize now



Conclusion With ABP

- Brady's Consortium
  - CPB and ABP – Increased ABP associated = better outcomes
  - Higher ABP on CPB - Regardless of CPB Flow = better outcomes
- Maintain Suggested/Higher ABP
  - Maintain Cerebral Auto-regulation
    - Neuroprotection
    - Less Incidence of Stroke
  - Main Organ Preservation
    - Reduction in AKI

Let's Do This Thing!!!!

<iframe width="560" height="315" src="https://www.youtube.com/embed/Yd85ozj0p8o" frameborder="0" allow="autoplay; encrypted-media" allowfullscreen></iframe>