2018 AmSECT pediatric

October 4-6, 2018 | Miami, FL

Algorithmic Quantification of Prime and Perfusate Composition to Regulate Physiological Variables during Cardiopulmonary Bypass in Neonates and Infants

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October 4, 2018

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No Disclosures

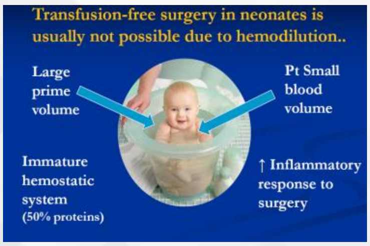
Objectives

- How to calculate variables of fluid dynamics to keep prime and perfusate in near normal physiologic phase
- Review of routine prime components, Essential Ratio's of the prime, Efficacy of Pre-BUF, Breakdown of Total Body Water
- PRBC's, FFP and ATIII
- Bidirectional Fluid loss/Wastage and impact on COP

Objectives

- Sodium Bicarbonate:
- Identify Acidic Biomarkers
  - pH stat and normal ranges of PCO2 during profound hypothermic perfusion
- Lactate clearance

Variables



Hemodilution

Non-Hemic Dilution

Hemic Variables

Non-Hemic Variables

Variables

- Non-Hemic Variables:
  - Colloid Osmotic Pressure
  - Isotonicity
  - Anion Gap
  - Sodium
  - AT III
  - Lactate
- Hemic Variables:
  - FFP
  - PRBC's

Non Hemic Variables - Circuitry

- The new concept or Evidence Based Clinical Practice recommends:
  - Reduction of static volume and Maintenance of fluid consistency
  - Even very less "CIRCUITRY REDUCTION" matters positively

Non Hemic Variables - Circuitry

- How to define a small or a big baby
- <u>Patient : Circuit</u> = Patient CBV > < EC Prime Volume
- Size, age and duration of surgery of the baby determines outcome (per STS)
- **Small Baby:** Patient CBV < EC Prime Volume
- **Big Baby:** Patient CBV > EC Prime Volume
- Circuit: Minimal Safe Required (Size:Length:Flow)

CPB - Circuit

- **Circuit Characteristics**
  - Miniaturized circuits
  - To accommodate forward and return flow
  - Def: The smallest possible circuit that can accommodate the required forward and return flow with appropriate size cannulae

I. Prime and Perfusate Composition

Prime or Perfusate Composition

- Isotonic solution (Plasmalyte A, Normosol-R, etc.
  - Not much variation in clinical practice
- Mannitol (Dosing - Not much variation in clinical practice)
- pRBC - Huge variation with reference target HCT
  - In the prime
  - During CPB at different hypothermic phases

Prime or Perfusate Composition-cont.

- Albumin (25%)
- FFP (+/-) – Huge variation in dosage and timing of administration
- Calcium – AABB recommendations!!??
  - Per AABB - 250mg/unit of PRBC
- Sodium Bicarbonate – Concerns in assessing acidic biomarkers and required/need/preferred administration

Description of the Topic

- During CPB in Neonates and Infants:
- How much we need to treat an abnormal variable
- How to calculate/to measure/to estimate
- More Physiological Fluid and flow Dynamics (prime and perfuate) is essential to achieve Homeostatic Hemodynamics

Homeostatic Hemodynamics

- Fluid composition or consistency or dynamics at all phases of CPB
- Very important during fluid addition
- This reflects on Function (Heart and the Lung)

"In Pediatric Cardiac Surgery you cannot too gentle and you cannot too accurate".

- Dwight McGoon, MD

Prime Composition

- Isotonic Solution (Plasmalyte-A or Normosol-R)
- PRBC's: Acceptable or adequate post-dilutional HCT
- +/- FFP (Dosage and Recommendation = Huge Variation)
- Isotonicity (Osmolarity)
- Oncotiity – Amount of Albumin 25% (Huge Variation)
- Calcium (AABB Recommendation)
- Mannitol and Acceptable or adequate Heparin
- Sodium Bicarbonate

Essential Ratio's of THE PRIME

- With reference Patient's weight
- Ratio 1: Baseline - RBC:Plasma (Patient's)
- Ratio 2: Prime: pRBC:FFP
- Ratio 3: Post-dilutional HCT: pRBC:FFP
- Ratio 4: [Heparin]:Total Priming Volume
- Ratio 5: COP:Albumin 25%
- Ratio 6: Calcium: Priming Volume
- Ratio 7: Isotonicity of the Total Priming Volume

Additional Variables

- Pre-BUF the circuit volume
- Physiologic Blood Gas of the prime(when?)
- Anion gap
- Lactate, Na, K, HCO_3, Anion Gap and Glucose levels
  - What happens after sometime or just before going on CPB)
- ***In summary: (= Hemic + Non-Hemic + Isotonic + Oncotic)***

Additional Variables

- Pre-BUF the circuit volume
- **Pre-BUF:** The Pre-BUF effluent volume to be removed should be in a 3:1 ratio to the volume of PRBC's added to the ECC (If PRBC is 200ml, the Effluent volume should be ~600ml)
- Sodium, Glucose, Potassium, Anion gap, HCO_3 and Lactate levels
- Physiologic Blood Gas of the prime

II. Breakdown of Total Body Water

Breakdown of Total Body Water

Total Body Water Breakdown Adult vs. Infant		Total Body Water	Extracellular			Intracellular
Adult	Infant		Extracellular	Plasma	Interstitial	
Adult (70Kg)	% Body Weight	60%	20%	5%	15%	40%
	Total Volume	42L	14L	3.5 L	10.5 L	28 L
Infant (5 Kg)	% Body Weight	70%	30%	5%	25%	40%
	Total Volume	3.5L	1.5L	250mL	1.25L	2 L

III. pRBC

Blood Prime

Weight Kg	Units Transfused CPB+POST CPB	Received Transfusion %	Target HCT %
0 – 6	2+1	100	35 – 40
7 - 10	1+1	78	30 - 35
7 - 10	NIL	22	25 - 30
11 - 15	0+1	15	25 -30
11 - 15	NIL	85	25 - 30
16 - 20	0+1	7	25 - 30
16 - 20	NIL	93	25 -30

Composition of pRBC

- RBC - Total mL? AABB: Per unit of PRBC: ~250-350mL
- Most often it's around 280mL
- AABB: 15mL of CPD per 100mL of PRBC [1.5mL / 10mL]
- CPD in 280mL of pRBC is around 42mL
- HCT around 60% [Range 58 – 62%]
- rRBC volume: 168mL (if the actual total volume 280ml)

Priming CPB circuit

- High glucose in bank blood
  - > 500 mg%
  - Increased osmolarity
  - High glucose damages hypoxic brains

- Acidic bank blood
  - Add Na HCO3
  - Increased osmolarity
  - Na > 145 mEq/L damages kidneys & brains

CPB prime and preBUF to achieve more physiologic perfusate

Blood Chemistry in Prime

Prime	pH	pCO2 mmHg	pO2 mmHg	Na mEq/L	K mEq/L	GLU mg/dl	LAC mmol/L	HCT %
PRBC Not Washed	< 6.80	129	27	129	16	>500	18.4	60
PRBC Cell Saver Washed	< 6.80	11	37	142	1.8	189	2.7	63
Reconstituted WB Prime No Pre-BUF	7.38	43	558	159	6.1	301	5.6	23
PRBC Prime/Pre-Buf	7.40	44	163	152	3	59	1.6	35
Baseline	7.47	31	121	135	3.6	102	0.8	35

Prime Osmolarity Calculation

- If Na = 140mEq/L and Glucose = 70mg/dl
- 2Na + Glucose - I = 350mOsm.L^{-}
- 2Na + Glucose/18 – II = 284mOsm.L^{-}
- (Na x 2) + (Glucose/18) + 15 – III = 299mOsm.L^{-}
- Either formula II or III is acceptable
- Higher glucose beneficial in maintaining Normo-Osmolarity

Isotonic and Oncotic Imbalance

- **Isotonic Imbalance:**
  - Fluid shift in and out of cells
- **Oncotic Imbalance:**
  - Extracellular (INTRAVASCULAR) and Interstitial fluid shift leads to edema and eventual organ failure

IV. FFP

Composition of FFP

Table II. Fresh-frozen plasma (FFP) content of electrolytes, etc. (mmol/l; an average 'unit' of FFP contains 300 ml).	
Na	165 (48 mmol/unit)
K	3·3 (1·0 mmol/unit)
Glucose	20
C[illegible]	1·8 (low)
Citrate	20
Lactate	3
pH	7·2–7·4
Phosphate	3·63 (high)

Ann Cardiothorac Surg 2015;2(3):331-338

These values were determined in the Pathology Laboratories of Southampton University Hospitals Trust.
The high sodium, glucose, citrate and phosphate levels derive from the anticoagulant preservative mixture, which also lowers the ionized calcium level.

Critical Care Med:
1986 Feb; 14(2):145-6.
We analyzed 35 samples of fresh frozen plasma (FFP), finding mean concentrations of 535 mg/dl glucose, 172 mEq/L sodium, 73 mEq/L chloride, 3.5 mEq/L potassium, 15 mEq/L bicarbonate, and 5.5 g/dl protein with 60% albumin.

Thus, FFP is a hyperosmolal, hyperglycemic, hypernatremic, and hypochloremic solution which may be a less effective volume expander than other albumin containing hypertonic solutions.

FFP in Prime

2011 Update to The Society of Thoracic Surgeons and the Society of Cardiovascular Anesthesiologists Blood Conservation Clinical Practice Guidelines*
The Society of Thoracic Surgeons Blood Conservation Guideline Task Force:

Plasma transfusions share many of the risks and Complications associated with RBC transfusions. Therefore, reduction or avoidance of plasma transfusions should be among objectives of blood conservation strategies
- **AT III concentrate is preferred for Heparin Resistance (20-25% of CPB patients shows Heparin Resistance)**
- **Prophylactic use of plasma in routine cardiac surgeries is not associated with reduced blood loss or less transfusion requirement, and this practice is not recommended**
- **FFP transfusion recommended only for factor deficiency**

Cost Analysis

- FFP:
  - A unit (280-320mL) price: $1,000
- AT III:
- Price per UNIT: Thrombate III: $4.50 per IU
  - ATryn: $2.34 per International Unit

Cost Analysis

- Formula:

Units Neede… …weight

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- Form… …ve

Units Needed = [desired %AT - baseline %AT] x weight / 1.4

For Example: 10 Kg

50 UNITS/KG = 10x50 = 500 UNITS = 500 X 4.5 = $2250

100 UNITS/KG = 10X100 = 1000 UNITS = 1000 X 4.5 = $4500

BASELINE ATIII: 40%

REQUIRED FOR CPB: 70%

DIFFERENCE: 70% - 40% = 30%

30 X 10 / 1.4 = $214

Non-Hemic Variable

V. Bidirectional loss/Wastage of COP

Estimate the COP loss

HCT : PLASMA

30% : 70% (1 : 2.3)

25% : 58.5% (70 - 11.5) - I

When you increase HCT back to 30%, PLASMA component drops to 47%

30%:47% (58.5-11.5) – II

Fluid administration from anesthesia – III

While weaning from bypass, loss in the circuit volume - IV

When and How to Measure or Estimate Albumin Redosing during CPB?

Estimate the COP loss

HCT : PLASMA
30% : 70% (1 : 2.3)
25% : 58.5% (70 - 11.5) - I
When you increase HCT back to 30%, PLASMA component drops to 47%
30%:47% (58.5-11.5) – II
If you calculated to maintain 4g/dl of Albumin; after bidirectional loss, it would be ~2g/dl

VI. COP

Remember

bi-directional loss or

4-dimensional loss

VII. Sodium Bicarbonate

Acidic Biomarkers

$NaHCO_3$

- Are we giving appropriate required correction or overcorrecting the deficit?
- Triggers to add $NaHCO_3$
  - pCO_2 Levels within physiological limits (Alpha stat and pH stat)
  - Reservoir level, Temperature, HCO_3^- - level (Not Deficit)
  - Role of protein buffer (Hemoglobin and Albumin)
  - Role of intra-cellular acidosis

$NaHCO_3$

- Rationalize the administration of sodium bicarbonate during profound hypothermic perfusion (PHP)
- Keeping the acidic-biomarkers (pH, pCO_2, HCO_3 and base deficit) within near normal physiological limits
- Preventing hypernatremia during PHP-CPB in neonates and infants

pH stat - Normothermic

ACID BASE STAT	pCO2 NORMO	pCO2 Hypothermic
ALPHA	35-45	35-45
pH	70-75	30-40

Additional Info

- **During PH stat:**
  - **Administration** of NaHCO3 is inevitable to maintain the pH, HCO3 and BE within normal limits
  - **Literature says** NaHCO3 fails to function as a buffer below 28°C
  - **Temperature corrected** pCO2 levels around 40 - 45mmHg causing the perfusate to be hypercarbic and acidotic requiring more NaHCO3

How to Treat Base Deficit

- **In the prime**
- **During CPB**
- **During profound hypothermic CPB**
- **pH Stat; base deficit correction sodium levels**
- **pH Stat; range of pCO2 to prevent hypercarbic influenced acidosis**

Modifications – Acidic Biomarkers

PH stat	PCO2 mmHg Temp Corrected	PCO2 mmHg Temp Not - Corrected	ETCO2 mmHg	HCO3 mEq/L	BE mEq/L
CONTROL GROUP (n = 20)					
7.25 – 7.30	40 - 45	80 - 100	35 - 40	28 - 32	-2 to +2
STUDY GROUP (n = 20)					
7.35 – 7.40	30 - 35	60 - 70	30 - 33	20 - 22	Ignored

NaHCO3 – ABM – Na - Osmolarity

PH PH stat Temp Corrected	PCO2 mmHg Temp Corrected	PCO2 mmHg Temp Not - Corrected	ETCO2 mmHg	HCO3 mEq/L	BE mEq/L	Na mEq/L	Osmolar Moles/Lit
CONTROL GROUP (n = 20)							
7.25 – 7.30	40 - 45	80 - 100	35 - 40	28 - 32	-2 to +2	153±5	354±8
STUDY GROUP (n = 20)							
7.35 – 7.40	30 - 35	60 - 70	30 - 33	20 - 22	Ignored	138±3	304±8

$NaHCO_3$

- $NaHCO_3$ was administered only after normalizing non-HCO_3 variables referred as acidic biomarkers (pCO2, glucose, lactate, anion-gap (COP?) and reservoir volume)
- Didn't administer if the sodium level was 145mEq/L and above

IX. Lactate

Lactate

Internal:
Intracellular vs. Extracellular
External:
Transfusion

Lactate

- Three types (Physiologic, Fluid addition and Intracellular)
- Physiologic - Ischemic generated
- Addition: Due to addition of pRBC and Sudden return of cavity volume
- Concerning Impact on the Hemodynamics
- Lactate clearance – Only Perfusionist can do without compromising the perfusate composition

Summary

- Calculate variables of fluid dynamics to keep prime and perfusate in near normal physiologic phase
- Quantification of routine prime components is essential
- Bidirectional Fluid loss/Wastage and impact on COP
- Sodium Bicarbonate: Identify Acidic Biomarkers
- pH stat and normal ranges of pCO2 during profound hypothermic perfusion
- Lactate clearance

Thanks