CCAS CPB Workshop Curriculum Outline

Perfusion: What you might not know

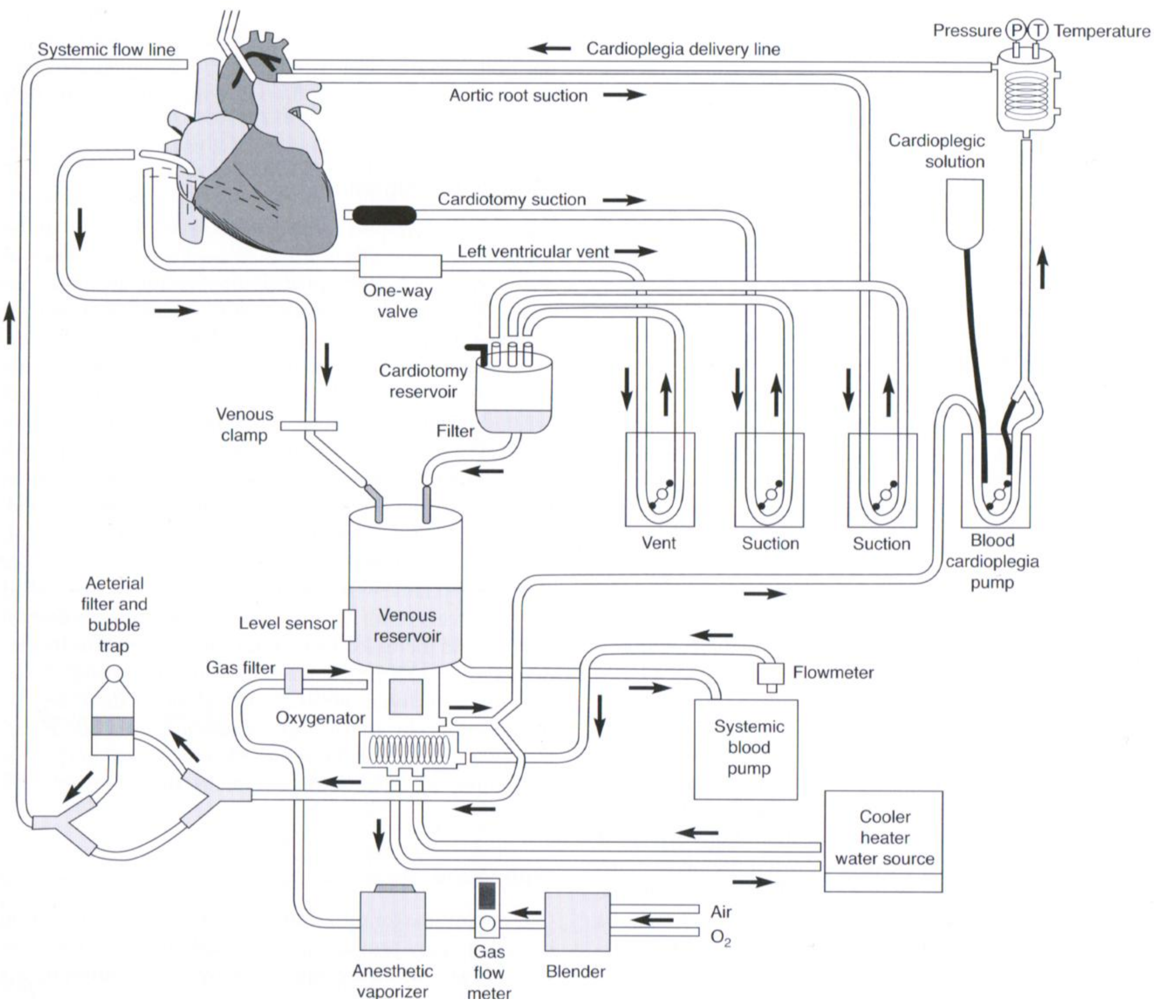
Scott Lawson, CCP
Carrie Striker, CCP

Disclosure: Nothing to disclose

Objectives:
* Demonstrate how the cardiopulmonary bypass machine works and be able to help trouble-shoot problems.
* Explain some of the different techniques of cardiopulmonary bypass.

I. Heart Lung Machine Brief Overview

a. Review blood flow through the heart lung machine



(Andropoulos, D. Anesthesia for Congenital Heart Disease. 2nd Ed. 2010, p. 96)

II. Anatomy of the Pump

a. Propulsion
   i. Arterial Pump
      1. Roller Pump
      2. Centrifugal Pump
   ii. Cardioplegia Pump
   iii. MUF Pump
   iv. Vent Pump(s)
   v. Field Sucker Pump (s)
   vi. Vacuum: Negative pressure on the venous line for drainage purposes
b. Ventilation and Oxygenation
   i. Blender – Oxygenation Fraction
   ii. Sweep Gas – Ventilation
   iii. Exogenous CO_2
   iv. Vaporizer – Volatile anesthetics
c. Monitoring
   i. Pressures: Arterial, Cardioplegia, MUF
   ii. Blood Flow: Pump Display, Doppler reading
   iii. Saturations: Venous, Arterial, Somatic/Cerebral, Flank/Renal
   iv. Temperatures: Arterial, Venous, Cardioplegia, MUF
      1. Temperature Control:
         a. Heater Cooler
   v. Air bubble Protection: Bubble Detector, Level Detector
   vi. Blood Gas/Electrolyte/Hemoglobin and Hematocrit/ACT/Whole Blood Hemostasis Testing: Point of Care Blood Gas and Activated Clotting Time machine, In-line monitoring (CDI, Saturation/Hematocrit), TEG or ROTEM
d. Disposables
   i. Venous Reservoir
   ii. Oxygenator
      1. Integrated Arterial Line Filter
      2. Standalone Arterial Line Filter
   iii. Arterial Venous Loop Size
   iv. Arterial Raceway size for Roller Pump
   v. Tubing
   vi. Cardioplegia
   vii. Hemoconcentrator
   viii. Cannulae
e. Route of Blood Flow through the actual Heart Lung Machine

III. Perfusionist Pre-Bypass Considerations

a. Selection of Disposables

   i. Calculation of Cardiac Output (CO) using patient height, weight and BSA (Appendix A)

      1. $$\textbf{Body Surface Area (BSA)} = \sqrt{\frac{(\text{Height (cm) x Weight (kg)}}{3636}}$$

         $$\textbf{Cardiac Output}\left(\frac{L}{min}\right) = Cardiac\ Index\ x\ BSA$$

         Cardiac Index = 1.8 – 3.0 L/min/m^2

         a. Determine oxygenator, venous reservoir, and arterial venous loop based on CO, cardiac lesion, suspected patient physiology and proposed surgical repair (see Appendix B)

b. Priming of the Pump

   i. Fluids to clear prime CPB circuit: Crystalloids: Plasmalyte, Normasol

   ii. Determine clear prime volume based on prime volume of disposables chosen

   iii. Calculation of Estimated Blood Volume (EBV) and Post-dilutional HCT

EBV:		
	Weight (kg) ≥ 40:	65mL/kg
	Weight (kg) ≥ 20:	75mL/kg
	Weight (kg) ≥ 10:	85mL/kg
	Weight (kg) ≥ 4:	90mL/kg
	Weight (kg) ≥ 1:	100mL/kg

$$\textbf{Post dilutional HCT}\ (\%) = \frac{\text{EBV x HCT(patient)}}{\text{EBV + Clear Prime Volume}}$$

      1. Determine necessary amount of pRBCs to maintain appropriate HCT

   iv. Colloid osmotic pressure

      1. FFP for coagulation factors and maintenance of colloid osmotic pressure
      2. Albumin

   v. Buffer prime: sodium bicarbonate and/ or pre-BUF

   vi. Drugs: heparin, antibiotics, possible steroids, cardioplegia solution (depolarizing/intracellular), mannitol, antifibrinolytics

IV. Conduct of CPB: What is the Perfusionist looking for?

a. Initiation of Flow

   i. Appropriate Cannula Placement

      1. Arterial: looking for appropriate arterial pressure to confirm cannula placement.

            a. High pressure spike may indicate placement of the aortic cannula in a false lumen and/or possible dissection.
        2. Venous: enough return to get reasonable cardiac output as determined by perfusion adequacy indicators
    ii. Oxygenation
        1. Look for blood color difference between arterial and venous to ensure oxygenator and oxygen source is working. Blood gas confirmation if necessary.

b. Peri-CPB
    i. Maintenance of Physiology
        1. Following venous, cerebral and renal saturations
            a. If low, may increase flow, give pRBCS, pH-stat v. alpha-stat gas strategy, increase MAP
        2. Manipulation of Patient Pressures
            a. Maintenance of calculated cardiac output
                i. Specific indices
                ii. Depends on patient's physiology
                iii. Perfusion adequacy markers
                iv. Appropriate saturations
        3. Look for development of metabolic acidosis (blood gasses or inline monitoring)
            a. Increase flow, give pRBCs, decrease temperature, alter gas strategy (pH-stat v. alpha stat)
                i. pH-stat: temperature corrected blood gases requiring exogenous CO_2
                ii. alpha-stat: blood gases measured at 37ºC
    ii. Cardioplegic arrest
        1. Antegrade: promote flow down the coronaries by slightly increasing the cardioplegia pump flow rate and pressure to gently close the aortic valve if not obtaining an arrest
        2. Retrograde: monitor coronary sinus pressures
        3. Re-dose: follow EKG or field movement for reemergence of activity

c. Coming off CPB:
    i. Clamp venous line to begin loading the patient's heart with volume
        1. Use MAP, CVP and heart appearance as guide
    ii. Drop flow in increments to transition flow responsibilities to the heart
    iii. Modified Ultrafiltration (MUF)
        1. Arterial to Venous MUF: ensuring negative pressure is not exerted on the arterial line causing air cavitation at the aortic cannula

    2. Use MAP, CVP, saturations and heart appearance as guide for fluid removal
    3. End-points of MUF: increase Hgb, decrease in CVP, increase in MAP

V. Conduct of Bypass: How can the anesthesiologist help?

a. Initiation of Flow
    i. Before full flow:
        1. Anesthesiologist: maintain oxygenation and ventilation
b. Peri-CPB:
    i. Balance of Pressures:
        1. Lowering the Pressure
            a. Anesthesiologist: Vasodilators (nipride, nitroglycerine, nicardipine)
            b. Perfusionist: Volatile Anesthetic (Iso, sevo), dropping flow, pH stat strategy
        2. Increasing the Pressure
            a. Anesthesiologist: Pressors
            b. Perfusionist: Increasing flow, phenylephrine, alpha stat gas strategy
    ii. Metabolic Augmentation of Flow
        1. Acidosis
            a. Anesthesiologist: Drop MAPs to increase flow, inspect surgical field for obvious mechanical deviations, communication with perfusionist to surgeon
            b. Perfusionist: Increase Flow, increase oxygenation, give red blood cells to increase Hgb, alter gas strategy (MAPCA manipulation) , investigate cannula placement, decrease temperature
c. Coming off CPB:
    i. Oxygenation and Ventilation Transition from pump to patient
    ii. MUF: Communicate with Perfusionist regarding pressure manipulation
    iii. Medications
    iv. Volume: Help from the pump, cell saver

Appendix A: Calculation of Cardiac Output on Cardiopulmonary Bypass

$$BSA = \sqrt{\frac{(Weight * Height)}{3636}}$$

$$CO = 2500(mL/\min/m^2) * BSA(m^2)$$

	PERFUSIONISTA, FUTURA				CAVC REPAIR/ BYPASS/ TEE	
AGE	1 Y 4 M		Pre-Op Labs			
WEIGHT (kg)	9	Kg	Hgb		Na	
HEIGHT (cm)	72	cm	Hct		K	
BSA (m2)	0.42	m^2	Plts		Cl	
EBV (ml)	810	ml	WBC		CO2	
FLOW (ml/min) @ 2.5 Index	1061	ml/min	PT		AG	
3/4 FLOW	795	ml/min	APTT		Glucose	
1/2 FLOW	530	ml/min	RSV		BUN	
1/4 FLOW	265	ml/min	Blood Type		Creat	
					Ca	
DRUGS						
Mannitol (0.5g/kg)	4.5	g	(250mg/ml)	18.0	ml	
Heparin (300units/kg)	2,700	units	(1000u/1 ml)	2.7	ml	
Solu-Medrol (30mg/kg)	270	mg				
Kefzol (50mg/kg)	450	mg				
Amicar (100mg/kg)	900	mg	(250mg/ml)	3.6	ml	
Tranexamic acid (10 mg/kg)	90	mg	(100 mg/ml)	0.9	ml	
Lasix (0.25mg/kg)	2.3	mg	(10mg/ml)	0.23	ml	
Phenlyephrine HCl (2-10 µg/Kg) (Std concentration	18.0	µg (2µg/Kg)	(24µg/ml)	0.75	ml	
K+ Dose from CP bag (1mEq/L ?)	1.4	mEq	17		ml	
K+ Dose from 50 ml bag	1.4	mEq	6.8		ml	
DEL NIDO CARDIOPLEGIA	*10 ML/KG DOSE*		*20 ML/KG DOSE*			
BLOOD	18	(10 ml/kg) ml blood	36		(20 ml/kg) ml blood	
DEL NIDO SOLN + BLOOD	90	(20 ml/kg) ml CP+blood	180		(20 ml/kg) ml	
MEAN VALVE DIAMETERS					Patient Location:	
MITRAL VALVE			14.4-15.2		SDS	
PULMONIC VALVE			10.7-11.3			
TRICUSPID VALVE			17.3-18.2			
AORTIC VALVE			9.5-10.1			

Appendix B: Determining Cardiopulmonary Bypass Equipment Selection

Equipment Selection

Full Flow = 1061 mL/min

Oxygenator+	Capiox RX 05 w/ Xcoating	Lilliput 2 w/ Phosphorylcholine inert surface	Optimin $SMAR_XT$ surface modified	Optima $SMAR_XT$ surface modified
Approximate blood flow cc/min	Max flow: 1500 ml/min (manufac. recommend.)	Max flow: 2300 ml/min (manufac. recommend.) to 3300 ml/min (A.A.M.I Standard)	Max flow: 5000 ml/min (manufac. recommend.)	Flow over 5000 ml/min (manufac. recommend.)
A-V loop	3/16" x ¼" up to 1000 ml/min ¼" x ¼" up to 1400 ml/min	¼" x ¼" up to 1400 ml/min ¼" x 3/8" up to 3000 ml/min	3/8"x 3/8" up to 5000 ml/min	3/8"x 3/8" up to 5000 ml/min 3/8" x ½" over 5000 ml/min
Tubing +	Infant pack using primarily ¼" tubing $SMAR_XT$ surface modified	Infant pack using primarily ¼" tubing $SMAR_XT$ surface modified	Pediatric/adult pack using primarily 3/8" tubing $SMAR_XT$ surface modified	Pediatric/adult pack using primarily 3/8" tubing $SMAR_XT$ surface modified
Pump raceway tubing	3/16" @ < 600 mls/min or ¼" @ > 600 mls/min	¼" @ <2500 mls/min or 3/8"@ > 2500 mls/min	3/8" @ < 5000 mls/min	3/8" @ <5000 mls/min or ½" >5000 mls/min
Bubble trap +	Terumo Capiox 50 cc	Terumo Capiox 50 cc	Terumo Capiox 150 cc	Terumo Capiox 150 cc
Cardiotomy /Venous Reservoir & safe operating level (SOL)	1100 cc capacity SOL = 50 cc	1800 cc capacity SOL = 100 cc	3000 cc capacity SOL = 200 cc	3000 cc capacity SOL = 400 cc
Cardioplegia set +	Custom Infant CSC14 4:1 w/ Buretrol $SMAR_XT$ surface modified	Custom Infant CSC14 4:1 w/ Buretrol $SMAR_XT$ surface modified	Custom Adult CSC14 4:1 w/ 2 Buretrols $SMAR_XT$ surface modified	Custom Adult CSC14 4:1 w/ 2 Buretrols $SMAR_XT$ surface modified
Ventricular venting	¼" w/ valve (vacuum relief check valve may be modified to accommodate high flow)	¼" w/ valve (vacuum relief check valve may be modified to accommodate high flow)	¼" w/ valve modified or 3/8" collapsible	¼" w/ valve modified or 3/8" collapsible
Hemoconcentrator +	Asahi PAN 03	Asahi PAN 06	Asahi PAN 06	Asahi PAN 06
Approx. circuit	400 cc	700 cc	1500 cc	1800 cc