Introduction to Cardiopulmonary Bypass

TSDA Boot Camp
Sept. 12-15, 2019
Chapel Hill, NC
Boot Camp CPB Faculty

- George L., Hicks, Jr. MD, Course Leader
- John Alexander, MD
- Ron Angona, CCP
- Lewis Britton, MD
- Harold Burkhart, MD
- Rachel Gambino, CCP
- Ahmed Gazi, MD
- Brent Keeling, MD
- Rita Milewski, MD
- Sarah Shumway, MD
- Richard Tallman, PhD
Why CPB

- To facilitate a surgical intervention
- Provide a motionless field
- Provide a bloodless field
Patient populations

• Coronary Artery Disease (CAD)
• Valve Disease
• Congenital Heart Defects
• Dissections

• Aneurysms
  – aortic, ventricular, giant cerebral
• Transplants
  – heart, liver, lung, trachea
• Other
  – limb cancer, hypothermic rescue
Extracorporeal Circuit

• An artificial external blood pathway with artificial organs

• 3.5 - 4 M² of plastics and metals
Tubing Characteristics

- Transparent
- Resilient
- Flexible
- Kink resistant
- Blood compatible
- Can be sterilized
Tubing Size vs. Volume

- ID 1/4 inch = 9.65 ml/foot
- ID 3/8 inch = 21.71 ml/foot
- ID 1/2 inch = 38.61 ml/foot
- (8 foot venous line = 309 ml)
Venous Tubing

- Minimum 10 mmHg pressure drop

- 1/4 inch = 0.9 lpm

- 3/8 inch = 4.0 lpm

- 1/2 inch = 7.0 lpm
Arterial Tubing

- Velocities less than 200 cm/sec result in acceptable hemolysis rates

- 1/4 inch = 3.4 lpm maximum flow

- 3/8 inch = 7.0 lpm maximum flow
Cannulas

- **Arterial**
  - Return blood to the body
    - Aortic
    - Femoral

- **Venous**
  - Drain blood from the body
    - 2 stage
    - Bicaval
    - Femoral
Reservoir

- Allow for large fluid shifts
- Open (Hard Shell)
- Closed (Bag)
Reservoir

- Allow for large fluid shifts
- Open (Hard Shell)
- Closed (Bag)
Reservoir

- Allow for large fluid shifts
- Open (Hard Shell)
- Closed (Bag)
Reservoir

- Allow for large fluid shifts
- Open (Hard Shell)
- Closed (Bag)
Reservoir

- Allow for large fluid shifts
- Open (Hard Shell)
- Closed (Bag)
Reservoir

- Allow for large fluid shifts
- Open (Hard Shell)
- Closed (Bag)
Arterial Blood Pump

- Roller
- Centrifugal
Arterial Blood Pump

- Roller
- Centrifugal
Arterial Blood Pump

- Roller
- Centrifugal
Oxygenator

- Artificial Lung
- Micro-porous
  - Hollow Fiber
  - Flat Plate
- True Membrane
Oxygenator

- Artificial Lung
- Micro-porous
  - Hollow Fiber
  - Flat Plate
- True Membrane
Oxygenator

- Artificial Lung
- Micro-porous
  - Hollow Fiber
  - Flat Plate
- True Membrane
Oxygenator

- Artificial Lung
- Micro-porous
  - Hollow Fiber
  - Flat Plate
- True Membrane
Oxygenator

- Artificial Lung
- Micro-porous
  - Hollow Fiber
  - Flat Plate
- True Membrane
Heat Exchanger

- Stainless steel, aluminum, or plastic
- Induce hypothermia
- Return normothermia
- Hyperthermic Isolated limb
Heat Exchanger

- Stainless steel, aluminum, or plastic
- Induce hypothermia
- Return normothermia
- Hyperthermic Isolated limb
Heat Exchanger

- Stainless steel, aluminum, or plastic
- Induce hypothermia
- Return normothermia
- Hyperthermic Isolated limb
Heat Exchanger

- Stainless steel, aluminum, or plastic
- Induce hypothermia
- Return normothermia
- Hyperthermic Isolated limb
Heat Exchanger

- Stainless steel, aluminum, or plastic
- Induce hypothermia
- Return normothermia
- Hyperthermic Isolated limb
Filter

- Remove emboli
  - 30-40 µ pore size
  - Gaseous
  - Particulate

- Remove leukocytes
Cardioplegia

• Provides myocardial protection
• Motionless and bloodless surgical field
• Uses potassium to stop electrical impulses and contractions
• Cools the heart to decrease oxygen demands
Safety

- Low level alarm
- Air bubble detector
- Arterial line pressure
- Temperature monitor
- Venous oxygen saturation monitor
- $\text{FiO}_2$ gas analyzer
- Battery back up power
Safety

• Checklist

• Clear three-way communication between the surgeon, anesthesiologist and perfusionist
Hemodynamics

Before CPB there is electrical activity on the EKG,
pulsatile arterial blood pressure,
and positive pressures from blood present in the right side of the
Hemodynamics

On CPB, the heart's electrical activity can be suspended,

Therefore the arterial blood pressure will be nonpulsatile

And the right side of the heart will be empty
CPB Physiology

- Hemodilution
- Hypotension
- Hypothermia
- Blood gas control
Hemodilution

- Decreased viscosity results in increased tissue perfusion
- Routine procedures: Hematocrit > 21%
- Patient Age
- Jehovah Witness
Hypotension

- CPB is “controlled shock”
- Sudden hemodilution with vasodilatation
- Fluid shift increases blood viscosity
- Hypothermia increases blood viscosity
- Released catecholamines = vasoconstriction
Hypothermia

- Reduces metabolism and oxygen demand
- Allows less blood trauma
- Myocardial protection
- Systemic organ protection
- Provides a margin of safety in the event of equipment failure
Hypothermia

- Types
  - Mild 37° - 32°C < 5 min 32°
  - Moderate 32° - 28° < 20 min 28°
  - Deep 28 ° - 18 ° < 45 min 18 °
  - Profound < 18 ° < 60 min

Acceptable Circ. Arrest
Hypothermia

• Outgassing
• Occurs at tissue level when cooling
• Occurs at heat exchanger when rewarming
• Maintain a 12°C gradient
• Cool at a rate of 1°C per minute
• Rewarm at a rate of 1°C per three minutes
• Protein denaturation occurs at 42°C
Blood Gas Strategies

• pH stat maintain normal temperature corrected values for pH and PaCO₂
• As blood temperature decreases, CO₂ becomes more soluble
• To maintain a constant pH and PaCO₂, CO₂ must be added
Blood Gas Strategies

- Alpha stat maintains a constant OH-/H+ ratio
- The fraction of unprotonated imidazole groups (alpha) remains constant
- Total CO$_2$ remains constant
- pH changes as temperature changes
Seven Steps for CPB
Step One for CPB

- Heparin
Step Two for CPB

- Expose the heart
- Check BP and aorta
Steps for Initiating CPB

• Cardiac Exposure
• Lines up to table
• Pericardial cradle/sutures
• HEPARIN (3mg/kg) ACT>400sec
• Prepare aorta
• Aortic cannulation sutures
  – 2 Concentric 2-0 Ethibond stitches with sliders
  – Outer suture with two pledgets
Step Three for CPB

- Check ACT
- Cannulation of aorta
- Check if aortic cannula is safe
Initiating CPB

- Aortic Cannulation
  - #11 Blade and cannula insertion
  - Snare both stitches securely and tie to cannula
  - Remove all air
  - Connect cannula to arterial line
  - Ask for pulse pressure
  - Ask for perfusion arterial line test
  - Secure aortic cannula (skin stitch and/or towel)
Step Four for CPB

- Atrial (venous) Cannulation
- Remove venous clamp
- Command “On bypass”
- Turn lungs off
Initiating CPB

- Venous Cannualtion
  - Single Prolene or Ethibond stitch for RA appendage or body followed by slider
  - Make incision/dilate
  - Insert cannula with hand over the IVC for accurate positioning
- Secure cannula with slider and tie
- Connect ot venous line
- Initiate CPB
Step Five for CPB

- Inspect the heart
- Place cardioplegia cannulae (retro/ante)
- Reduce pump flow/Clamp aorta
- Resume full flow/Check line pressure
- Start cardioplegia
- Set pt temperature with perfusionist
Step Six for CPB

- Release cross-clamp after warm cardioplegia
- Remove all air from heart
- Begin respirations (start lungs)
- Check for be certain there is
  - Good contractility
  - No bleeding
  - Stable heart rhythm
  - Desired patient temperature
Step Seven for CPB

- Wean slowly from CPB
- When stable:
  - Clamp venous line and remove
  - Remove vent/cardioplegia
  - Begin Protamine assessing BP, CVP, BP
  - Be alert for hemodynamic reactions
  - Remove arterial cannula
Weaning from CPB

• Check list before weaning
  – No bleeding from inaccessible areas
  – Body Temperature (36-37C)
  – Stable heart rhythm
  – Lung function normal in insp/expiration
  – Good myocardial contractility
Weaning from CPB

- Ask perfusionist if he/she is ready
- Reduce CPB to half flow observing preload, afterload and contractility (TEE)
- If no RV/LV dilatation, ask perfusionist to come off CPB
- Add volume to assess ventricular compliance
- Assess need for pharmacologic support depending on preload after load and contractility
Emergencies in CPB

- Massive Air Embolism
- Aortic Dissection with cannulation
- Clotted Oxygenator
- Severe Protamine Reaction
- Inadequate CPB flow
- Inadequate CPB oxygenation
Massive Air Embolism

- Recognition
- Stop CPB
- Place pt in steep head-down position
- Remove aortic cannula from asc. Aorta
- Purge asc. aorta of air and refill arterial line
- Begin retrograde SVC perfusion (20°C@1-2l/min for 2-3 min until air is cleared
- Return cannula to aorta for systemic cooling and ?pharmacologic brain protection
- Post-op-Hyperbaric O₂ rx, hyperventilation, ?hypertension
Aortic Dissection - Cannula induced

• Signs
  – Sudden increase in arterial line pressure
  – Profound drop in systemic pressure
  – Decreased venous return to CPB
Aortic Dissection-Cannula Induced

- Stop CPB
- Clamp arterial and venous lines
- Confirm diagnosis (visual or TEE evidence)
  - Flaccid aorta, expanding hematoma, dissection flap
- Rule out kinked or obstructed art line
- Remove arterial cannula to alternate site
- Initiate cooling for DHCA and open aortic repair/replacement
Clotted Oxygenator

- Decreasing PaO$_2$ with metabolic acidosis
  - Check O$_2$ supply/blender
  - Rule out oxygenator thrombus
- Emergency oxygenator change-out may be necessary
Severe Protamine Reaction

- Anaphylactic reaction with pulm HTN, edema and systemic hypotension
  - 100%O$_2$, IV fluids, steroids, antihistamines, vasoconstrictors and bronchodilators
  - Resume CPB if RV failure, severe pulm edema present
  - Epinephrine, vasopressin via LA line
Inadequate CPB Flow

- Directly proportional to venous saturation/acid-base status
- Possible reasons:
  - Inadequate CPB volume
  - Aortic dissection
  - Cannula problems (aortic or venous)
  - Oxygenator thrombus
  - Pump head malfunction
References

• Cardiopulmonary Bypass-Principles and Practice  Gravlee GP 2nd Edit Lippincott
• Cardiopulmonary Bypass Mora CT 1995 Springer