Post Cardiopulmonary Bypass Complications:
The Common and the Outliers

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How Do We ATTACK Post CBP Complications

1. ICU Perspective
2. Organ Systems Approach
3. Diagnoses
1885: von Frey & Gruber developed the first device to oxygenate blood extracorporally for perfusing isolated organs

1915: Richards & Drinker report use of a screen oxygenator (gravity drawn blood flow down a cloth in an oxygen rich atmosphere)

1916: McLean & Howell discover Heparin
History of CPB

Russians Brukhonenko and Tchetchuline 1929
History of CPB

Gibbons, 1953

◆ 4 Patients attempted
◆ 3 Intraoperative mortalities
◆ 1 Survivor (almost died, but almost!)

1937 Modified Extracorporeal Circuit
Modern CPB Systems

Maquet.com, 2018

Downloaded from researchgate.net, 2018
Neurological Concerns

- Stroke: Embolic and Hemorrhagic
- Cognitive Dysfunction & Delirium
- DHCA and Rates of Rewarming
- CO2 & Selected Flow to the Brain
- Air to the Brain
- Tranexamic Acid and Seizures
Embolic/Thromboembolic/Hemorrhagic CVA Predictors?

- Infective Endocarditis and Pre-existing Vegetations
- Atherosclerotic Disease: Aortic and/or Carotid
- Intraoperative Debris: debrided annuli, calcified valves, intraventricular thrombi
- Air Embolism
- Repeated Exposure to Heparin / HIT
Intraoperative Screening / Predictors

◆ Cerebral Oximetry
◆ Complexity of Procedure: Arch reconstruction, duration of CPB run, manipulations of the Aorta
◆ Hypotension and/or Low Flow states
◆ Anemia
Presentations in the CVICU

❖ Delayed Emergence / Persistent Coma
❖ Seizure / Myoclonus
❖ Hemianopsia
❖ Hemiparesis
❖ Aphasia
CVA???

Initial Response

- Stroke Team? NIHSS
- Imaging? Stable? With or without contrast? MRI?
- “Neurointerventionalists”
  - Limited to Basilar or Anterior Circulatory Occlusion
- Watershed
Pt is a 67M, HTN, HLD, severe Aortic Stenosis; planned minimally invasive AVRt via mini-thoracotomy. Complicated by ascending dissection, necessitating sternotomy and ascending replacement. Antifibrinolytic = TXA. Further complicated by severe coagulopathy requiring multiple products and activated Factor VII; vasoplegia on multiple pressors and methylene blue; delayed closure... Closed POD 1; sedatives weaned late POD 1. Initial neuro exam with Myoclonus.
Intracranial Hemorrhage

- **NEUROSURGERY**
- Surgical Interventions for ICH
  - Ventriculostomy
  - Craniotomy
- **INITIAL** Medical Management
  - Coagulopathies
  - Mycotic?
  - Blood Pressure
  - Temperature
  - Glucose
Postperfusion Syndrome and Delirium

- “PUMP HEAD” and Postperfusion Syndrome
- Post-Operative Cognitive Decline
- Delirium – biggly real and hugely bad!
  - Associated with longer pump run
  - Hyperactive vs Hypoactive
  - Temporary and Permanent
  - Increased Mortality (12.5% vs 4.5% without)
  - Readmits (47.6% vs 32.6% without)
  - Concentration and Sleep
  - **Prevention is Key** if possible

Effects of DHCA and Rewarming Rate

◆ Systemic effects of hypothermia
  ▪ Inflammatory
  ▪ Coagulopathy
  ▪ Metabolic

◆ Rewarming technique – SPEED MATTERS!!!
GAS GAS GAS!!! O2 & CO2

- Hyperoxia – Free Radicals
  - Oxidative Injury
  - Delirium? From Oxygen???

- CO2 can be PROTECTIVE?
  - Brain?
  - Yes
  - No

Tranexamic Acid (TXA) and Seizures

- Antifibrinolytic – Replaced Aminocaproic Acid (EACA)
- Head to Head: TXA has more seizures, EACA worse renal complications
  - Dose dependence
  - Renal function at baseline

- Treatment
  - Propofol, Benzodiazepenes
  - Keppra long term???

Cardiac Complications of CPB

- Ventricular Failure, dilation, failure to separate from pump
- Inflammatory Response
- Vasoplegia (inflammatory and pharmacological (ACEi))
- Intracardiac Thrombus and Pulmonary Thromboembolism
Ventricular Failure / Failure to Separate from CPB

➢ Etiology:
  ➢ Left causes Right and Right causes Left
  ➢ Tamponade
  ➢ Pulmonary Embolism
  ➢ Often associated with prolonged CPB pump runs (significant complement activation)
  ➢ Technically challenging cases
  ➢ Returning to pump (bleed, valve or graft repair)
Ventricular Failure

- Monitoring and Recognition
- LV Failure
  - Immediate evidence of inadequate perfusion
  - Decreased MAP, narrowing Pulse Pressure (PP)
- RV Failure
  - Rising CVP, narrowing PP, new Tricuspid Regurg
- Echocardiogram
  - Ventricular dilation
  - Ventricular wall motion abnormalities
  - Septal wall
RV Failure & Tamponade on Echo

RV

LV

Pericardial Effusion

Liver

Right Ventricular Compression

RA

LA

LV
Figure 1: Management of acute right heart failure.
(CVP: Central Venous Pressure; RV: Right Ventricle; PDE: Phosphodiesterase; RVAD: Right Ventricular Assist Device; ECMO: Extracorporeal Membrane Oxygenation with Centrifugal Pump; NO: Nitrite Oxide).
Managing Acute Heart Failure

- KISS: \( \text{CO} = \text{SV} \times \text{HR} \)
- Optimize Preload
  - Thou Shalt Giveth, or Thou Shalt Taketh Away!!!
  - Is there a “Happy CVP or PAD”???
- Optimize Afterload
  - Pressors or Dilators (systemic and pulmonary)
  - Afterload Effects on Ventricular Geometry
- Inotropy & Lusitropy
- Mechanical Support
Mechanical Support

- Left or Right Ventricular Assist Devices (LVAD/RVAD)
  - Heartmate II and III, Heartware, Impella, Tandem Heart
- Extracorporeal Membrane Oxygenator (ECMO)
  - Veno-Arterial (VA), Veno-Veno (VV), RVAD
- Intra-Aortic Balloon Pump
Vasoplegic Syndrome – Causes and Fixes

- Vasoplegic Syndrome: inflammatory response and associated with overproduction of nitric oxide (NO)
  - Pressors: Norepinephrine, Vasopressin (VANCS Trial)
  - Methylene Blue: early = better
  - Steroids – Not so much

- Angiotensin Converting Enzyme Inhibitors...
Rare Cardiac Thromboemboli from CPB

• Intracardiac Thrombosis (ICT) and Pulmonary Thromboembolism
• Pathological mechanisms poorly understood
• Commonalities in a case review study: CHF (50%), Platelet Transfusion (37.5%), CPB duration > 3 hrs (37.5%), Aortic Injury (27.1%)
• Mortality 85.4% despite interventions

Pulmonary Sequelae of CBP

◆ Derecruitment
  ◆ Lungs “Down”
  ◆ Inadequate ventilation or PEEP on transfer
  ◆ Lobar Collapse or consolidation

◆ Volume overload
  ◆ Wet lungs

◆ Transfusions

◆ SIRS

◆ ARDS
ARDS CXR & CT
GI Complications of CPB - Bleed

- Early Upper GIB most common of all GI complications
- May be iatrogenic as complication of TEE
- Heparinization
  - undiagnosed erosions, ulcerations, microbleed
  - Rebound Heparinization
- Management (when to pull the consult trigger)
  - Low Hanging Fruit: correct coags, rewarm, avoid instrumentation
  - Transfuse prn (anemia &/or thrombocytopenia); DDaVP?
  - EGD: cautery, local Epinephrine
GI Complications of CPB - Ileus

Slideshare.net, 2018
Pt is a 71F with history of Aortic Stenosis, CAD, paroxysmal atrial fib, asthma, COPD, HTN, HLD, GERD, Rheumatoid Arth, uncomplicated AVRt with CABG x2 (LIMA-LAD, SVG-OM). Baseline EF 30% & normal RV. IABP placed in OR for “sluggish” EF. Myoclonus on POD 1 (no clear etiology and resolved). IABP d/c’d POD 4. From POD 4 – 7, off pressors, bumex drip.

Worsening hemodynamics late POD 8 into 9, acidosis, refractory tachycardia, increase pressor use, abd tender…
GI Complications of CPB – Ischemic Bowel

- Causes: thrombi, hypoperfusion / low flow, pressors
- Exam: pain out of proportion
- Hemodynamics
- Worsening acidosis
- Airway pressures, Compartments
- Very High Mortality
- Management
  - Almost exclusively surgical!

Researchgate.net, 2018
GI Complications of CPB - ???

➢ Pt is 65F, history of CAD, NSTEMI, HTN, HLD, CKD 3, now POD 1 s/p CABG x3; extubated, no drips. Persistent postop Nausea refractory to Zofran & Reglan now w epigastric pains radiating to the back, dry heaving, Febrile... SBP 92, tachycardic, tachypneic, UOP 20cc/kg/hr.

➢ Labs reveal a leukocytosis, resolving transaminitis and added-on amylase is twice the upper limit of normal and lipase is four times the upper limit of normal

➢ Acute Pancreatitis???
GI Complications – Pancreatitis (rare)

- Etiology – usually ischemic; choledolithiasis, sludge or microlithiasis; hypercalcemia, drug (amiodarone).
- Huge SIRS response and may cause MODS
- Diagnosis: exam, labs, US, CT, MR
- Treat based on etiology


Uptodate.com, 2018
GI Complications of CPB – Gall Bladder

◆ Acalculous Cholecystitis
◆ Ischemic is most likely culprit
◆ Exam and US/CT for the diagnosis
◆ Perc Drain is most often treatment (+/- Abx)
GI Complications of CPB – Hepatic Injury

• Etiology: Ischemia and/or RV Failure
• Exam: Jaundiced
• Labs:
  • Transient transaminitis
  • Total Bilirubin lags and takes time to peak
• Management: unfortunately, supportive!
CPB Influences on Blood

- Dilution / Bleeding / Vol expansion
  - Crystalloid, colloid
  - coagulopathies due to factor depletion

- Temperature influences - hypothermic coagulopathies
  - decreased enzyme activities within the clotting cascade
  - impairs platelet aggregation from reduction of Thrombaxane A3

- Acidosis: interferes with the production of complexes resulting in reduction of factor Xa/Va activity. (50% reduction at pH 7.2)

CPB Influences on Blood

- Inflammatory Influences
  - Complement activation – aka Antibody Triggered Response
  - Multiple pathways
    - Activation of C3a and C5a in the alternative pathway
    - Mitigation of Lectin pathway with heparin coated tubing
    - Hypothermia is now shown to increase pro-inflammatory cytokines
  - Methylprednisilone?? (SIRS – Steroids In caRdiac Surgery)

Song DD, Effects of Normothermia Versus Hypothermia on Serum Complement Activation and Cytokine Production During Simulated Cardiopulmonary Bypass. Abstract, Downloaded from digitalcommons.murraystate.edu, 2018
CPB Influences on Blood

◆ Rebound heparinization

◆ AT III Deficiency
  ◆ Difficulty in achieving desired ACT
  ◆ Defined in CVICU as > 25 units/kg/hr

◆ Heparin Induced Thrombocytopenia
Renal Sequelae from CPB

- Acute Kidney Injury is most likely due to Acute Tubular Necrosis
- Consequence of hypoperfusion: hypovolemia and/or hypotension, low cardiac output state
- Renal Artery Vasoconstriction (with or without stenosis)
- Hypothermia
- Emboli / Atheroembolic Disease
- SIRS response

- Incidence of AKI is rising though mortality has decreased

AKI / ATN Management

➢ Reverse insult

➢ Optimize hemodynamics and minimize nephrotoxic agents

➢ Tincture of Time

➢ Mechanically clear: dialysis
Vascular Misadventures of CPB

- Mediastinal Cannulation Sights, suture lines
  - bleed, tamponade, arrhythmias/ECG changes

- Groin Misadventures – some may not be ours!!!
  - Retroperitoneal Bleed
  - Pseudoaneurysm
67M with severe atherosclerotic disease “everywhere”, CAD, transferred with Impella CP in R groin for cardiogenic shock – which was removed.
Medicine of the Highest Order