



## Cardiothoracic Anesthesia: Goals and Objectives

### Goals

1. CA 1 and 2 residents are assigned to Cardiothoracic cases for 2 months to develop competency in the *routine* perioperative anesthetic management of *uncomplicated* cardiac surgery involving cardiopulmonary bypass, off-pump CABG, and thoracic non-cardiac procedures.
2. The ability to independently practice uncomplicated cases with the assistance of cardiac team members is the expected outcome of the CA 1 and 2 rotation.
3. CA 3 residents may be assigned to Cardiothoracic cases for 1 to 6 months to develop competency in the perioperative anesthetic management of *uncomplicated* and *complicated* cardiac surgery involving cardiopulmonary bypass, off-pump CABG, and thoracic non-cardiac procedures.
4. The ability to practice more complicated cases such as thoracic aorta repair, circulatory arrest, congenital heart repair, emergency procedures, and complicated off pump procedures is the expected outcome of the CA 3 rotation.

### Objectives

#### Patient Care

1. CA 1-2
  - a. Complete a pre-operative cardiac consultation in patient's with cardiac disease including
    - i. CAD
    - ii. Mitral Valve Disease
    - iii. Aortic Valve Disease
  - b. Identify co-morbid diseases and indicate plan for intra-operative management on consult for:
    - i. Diabetes Mellitus
    - ii. Renal Failure
    - iii. Obesity
    - iv. Previous cardiac surgery
  - c. Set-up the heart room for a routine coronary procedure
  - d. Select induction anesthetics in a patient with ischemic heart disease and normal systolic LV function
  - e. Select induction anesthetics in a patient with valvular heart disease
  - f. Recognize hypotension and treat until corrected
  - g. Recognize atrial fibrillation and determine if treatment is necessary
  - h. Recognize third degree heart block and treat
  - i. Recognize Ventricular fibrillation and determine the appropriate treatment
  - j. Diagnose low cardiac output and determine appropriate treatment
  - k. Administer heparin in a dose sufficient for cardiopulmonary bypass

- l. Identify post-operative complications and writes note on anesthesia record
- m. Demonstrate the following technical skills or abilities
  - i. Interpret various chest radiographs and identify
    1. heart size
    2. pulmonary edema
    3. pleural effusion
    4. tumor density
  - ii. Place an arterial line using aseptic technique
  - iii. Place a central venous access line using
    1. pre-procedure ultrasound
    2. real-time ultrasound
    3. landmark technique
  - iv. Set-up and zero transducers to atmospheric pressure
  - v. Properly position a PA catheter using transduced pressure waveforms
  - vi. Measure PAOP
  - vii. Perform thermodilution cardiac output
  - viii. Adjust patient's ST-T wave measurement points on monitor
  - ix. Perform ACT measurement
  - x. Administer heparin in a dose sufficient to initiate CPB
  - xi. Discontinue ventilator after full flow established on CPB
  - xii. Set-up and program an infusion pump for the following medications:
    1. Epinephrine
    2. Phenylephrine
    3. Propofol
    4. Insulin
  - xiii. Set-up a temporary pacemaker for A, V, or AV pacing
  - xiv. Set-up transcutaneous pacemaker
  - xv. Administer protamine in a dose sufficient to reverse heparin effect
2. CA 3
  - a. Complete CA 1-2 objectives for Patient Care
  - b. Select induction anesthetics in a patient with dilated cardiomyopathy
  - c. Indicate intra-operative monitors planned for descending TAA repair on pre-op consult
  - d. Perform a pre-operative anesthetic consultation for an emergency cardiac procedure
  - e. Initiate a treatment algorithm for low CO not responsive to epinephrine
  - f. Administer heparin in a dose sufficient to initiate CPB in a patient with heparin resistance
  - g. Complete the following skills
    - i. Set-up infusion pumps for:
      1. Milrinone
      2. Norepinephrine
      3. Vasopressin
      4. Natricor
      5. Amiodarone

## Medical Knowledge

1. Reading Assignments:
  - a. Miller Chapters: 49, 16, 30, and 5A for CA 1-2
  - b. Miller Chapters: 31, 32, 50, 10, 14, 23, 28, 46, 61, and 75 for CA 3
  - c. Introduction to Cardiac Anesthesia handout
2. Complete written Self Evaluation:
  - a. List at least 5 factors associated with increased risk for perioperative MI, stroke, or death in the cardiac surgery patient.
    - i. 1.
    - ii. 2.
    - iii. 3.
    - iv. 4.
    - v. 5.
  - b. Indicate a dose (?/kg) expected to produce unconsciousness for each of the listed drugs. List one advantage and one disadvantage associated with each drug when used as an induction agent.
    - i. Fentanyl - Dose: \_\_\_\_\_ /kg
      1. Advantage: \_\_\_\_\_  
\_\_\_\_\_
      2. Disadvantage: \_\_\_\_\_  
\_\_\_\_\_
    - ii. Etomidate - Dose: \_\_\_\_\_ /kg
      1. Advantage: \_\_\_\_\_  
\_\_\_\_\_
      2. Disadvantage: \_\_\_\_\_  
\_\_\_\_\_
    - iii. Thiopental - Dose: \_\_\_\_\_ /kg
      1. Advantage: \_\_\_\_\_  
\_\_\_\_\_
      2. Disadvantage: \_\_\_\_\_  
\_\_\_\_\_
    - iv. Midazolam - Dose: \_\_\_\_\_ /kg
      1. Advantage: \_\_\_\_\_  
\_\_\_\_\_
      2. Disadvantage: \_\_\_\_\_  
\_\_\_\_\_
  - c. List three factors each that could increase or decrease myocardial oxygen supply .
    - i. Increase myocardial oxygen supply
      1. A)
      2. B)
      3. C)
    - ii. Decrease myocardial oxygen supply
      1. A)

2. B)
3. C)
- d. List three factors each that could increase or decrease myocardial oxygen utilization.
  - i. Increase myocardial oxygen utilization
    1. A)
    2. B)
    3. C)
  - ii. Decrease myocardial oxygen utilization
    1. A)
    2. B)
    3. C)
- e. The pulmonary artery catheter has been used to aid in the determination of LV compliance, LV preload, SVR, PVR, and contractility. Complete the equations used to define these terms:
  1. Compliance =
  2. LV preload =
  3. SVR =
  4. PVR =
- f. List 5 facts concerning the characteristics or activity of heparin. You may include effective dose, source of derivation, chemical properties, factors affecting metabolism, mechanism of action, causes for drug inactivity, etc.
  1. A)
  2. B)
  3. C)
  4. D)
  5. E)
- g. Trace the extracorporeal path of blood during cardiopulmonary bypass, starting at the right atrium.
  - i. Right atrium - venous cannula -
- h. List six assessments that require vigilance during cardiopulmonary bypass?
  1. Mean arterial pressure
  - 2.
  - 3.
  - 4.
  - 5.
  - 6.
- i. List some of the drugs that might be required for weaning and the indication for their use.
  1. Epinephrine: Used to increase contractility and cardiac output
  2. B)
  3. C)
  4. D)
  5. E)

- j. Draw and label the pressure/volume loops of one patient with severe aortic stenosis and one normal patient
  - i. Aortic Stenosis
  - ii. Normal
- k. How do the following hemodynamic variables change as mitral stenosis progressively worsens?
  - i. Cardiac Output:
  - ii. Pulmonary artery diastolic pressure:
  - iii. Pulmonary artery wedge pressure:
  - iv. LVEDV:
- l. Using TEE, wall motion abnormalities are detected by centrally directed movement and myocardial thickening during systole. List and define criteria used for grading severity of regional wall motion abnormalities detected by TEE cardiac imaging from least severe to most severe.
  - i. Hypokinesis: Mild, Moderate or Severe
  - ii. B)
  - iii.
3. Oral Presentations by topic: Complete 30% after 1 month (CA1-2), 60% after 2 months (CA1-2), 90% after 6 months(CA3)
  - a. Coronary Artery Disease
    - i. List 4 co-morbidities or risk factors associated with CAD.
    - ii. Define one grading system of functional limitation associated with CAD.
    - iii. List three medications used for prevention of anginal symptoms.
    - iv. Define the expected duration of action of the following Beta blockers: esmolol, metoprolol, and inderal.
    - v. Name one toxicity associated with nitroglycerin
    - vi. Nitroglycerin dilates what part of the coronary circulation?
    - vii. Name three indications for calcium channel blockers.
    - viii. List 4 steps in a treatment algorithm for acute myocardial ischemia.
  - b. Congestive Heart Failure
    - i. Define three or more physical signs and symptoms of congestive heart failure.
    - ii. Describe three differences (anatomic, physiologic, or functional) between the failing heart and a normal heart.
    - iii. List three pharmacologic treatment modalities for chronic CHF
    - iv. List two signs or symptoms of digitalis toxicity.
    - v. Define the mechanism of action of PGEI as used in heart failure.
    - vi. Define two indications for nitric oxide use in acute heart failure.
  - c. Valvular heart disease
    - i. List the distinguishing auscultatory features of the following conditions:
      1. Aortic Stenosis
      2. Aortic Insufficiency
      3. Mitral Stenosis
      4. Mitral Insufficiency
      5. Tricuspid insufficiency

6. Tricuspid stenosis
- ii. List one specific criteria for defining severe disease ( valve orifice area, regurgitant orifice area or valve gradient) for each of the following conditions:
  1. Aortic Stenosis
  2. Aortic Insufficiency
  3. Mitral Stenosis
  4. Mitral Insufficiency
  5. Tricuspid insufficiency
  6. Tricuspid stenosis
- iii. Draw and label pressure volume loops for each of the following:
  1. Aortic Stenosis
  2. Aortic Insufficiency
  3. Mitral Stenosis
  4. Mitral Insufficiency
  5. Tricuspid insufficiency
  6. Tricuspid stenosis
- iv. Tolerance for increase or decrease in HR, MAP, SVR (afterload), or LV filling (preload) in patients with severe valvular heart disease vary according to the lesion. Define the hemodynamic goals using these terms for:
  1. Aortic Stenosis
  2. Aortic Insufficiency
  3. Mitral Stenosis
  4. Mitral Insufficiency
  5. Tricuspid insufficiency
  6. Tricuspid stenosis
- d. Chronic Hypertension
  - i. Name one difference between aldactone and HCTZ.
  - ii. Define the mechanism of action of clonidine and dexmedetomidine, including anesthetic effects.
  - iii. Name one first choice PO drug for mild to moderate hypertension in diabetics.
  - iv. Name one adverse effect associated with ACE Inhibitors and ARB drugs associated with anesthetic induction
- e. Cardiac studies
  - i. List 4 physiologic parameters or anatomic findings that you would expect in a pre-operative echocardiography report.
  - ii. List 4 physiologic parameters or anatomic findings that you would expect in a pre-operative cardiac catheterization report.
  - iii. Define the normal pressure range for CVP:
  - iv. Define the normal pressure range for RV:
  - v. Define the normal pressure range for PA:
  - vi. Define the normal pressure range for PCW:
  - vii. Define the normal pressure range for LA:
  - viii. Define the normal pressure range for LV:
  - ix. Define the formula for calculating Ejection Fraction.

- x. Define significant coronary artery stenosis by cardiac catheterization criteria.
- xi. Define the effects of ischemia and infarction on a Thallium Scan.

f. **Anatomy and Physiology**

- i. Name the branches of Left Main and Right Main coronary arteries and define their regional distribution.
- ii. List three anatomic differences between the right and left ventricle.
- iii. Define the blood supply of the sinus node and AV node.
- iv. Name the primary energy substrate used in cardiac contraction.
- v. Name the arteries originating in the aortic arch.
- vi. List three factors that could decrease cardiac output.
- vii. List three factors affecting coronary artery blood flow.
- viii. List three factors affecting myocardial oxygen supply.
- ix. List three factors affecting myocardial oxygen demand.
- x. The Frank-Starling curve defines the relationship between what two variables?
- xi. Define one formula for calculating ejection fraction.
- xii. Define the formula for systemic vascular resistance
- xiii. Define the formula for calculating compliance.
- xiv. Define the formula for calculating coronary perfusion pressure
- xv. As temperature decreases, what happens to the pCO<sub>2</sub> in vivo?

g. **Pharmacology**

- i. List one advantage and one disadvantage to using Halothane, Isoflurane, Sevoflurane, Desflurane, and Nitrous Oxide
- ii. List the induction doses of Midazolam, Propofol, and Etomidate (mg/kg) expected to produce unconsciousness when combined with a bolus dose of 5 µg/kg of fentanyl
- iii. List the typical concentrations and doses for an IV bolus dose of ephedrine, epinephrine, phenylephrine, atropine, nitroprusside, and nitroglycerin
- iv. List one similarity and one difference between atropine and scopolamine
- v. List two antibiotics expected to produce significant hypotension when administered in < 10 minutes
- vi. Define the final common pathway involved in Nitroprusside toxicity
- vii. List two adverse effects of nitroglycerin
- viii. List one treatment of methhemoglobinemia
- ix. List two differences between furosemide and mannitol
- x. List the most likely EEG effects of high dose fentanyl
- xi. List three drugs used to increase SVR and indicate the one preferred when PAP pressure elevation is a problem
- xii. Define the expected changes in CO, SVR, and PAP following administration of Milrinone
- xiii. List two ECG findings used to diagnose WPW syndrome
- xiv. List three drugs used intra-operatively for treating acute symptomatic SVT and rapid rate atrial fibrillation
- xv. List three drugs used intra-operatively for treatment of ventricular fibrillation
  - ii. List the indication, loading dose, infusion rate, and 1 possible adverse outcome

with:

1. Milrinone
2. Norepinephrine
3. Vasopressin
4. Natricor
5. Amiodarone

#### h. Equipment and Monitoring

- i. List three different methodologies for measuring blood pressure (arterial or venous).
- ii. Draw a central aortic, radial artery and a dorsalis pedis artery pressure waveform on one scale and indicate SBP, DBP, and MAP.
- iii. List two factors that cause increased resonance.
- iv. List three factors that cause dampening.
- v. List 2 limitations of NIBP monitoring in a cardiac patient.
- vi. Explain the significance of the following waves on the CVP waveform :
  1. "Cannon A-wave"
  2. Large v-wave
  3. Loss of a-wave,
  4. "M" configuration,
  5. Loss of y-descent.
- vii. Describe the indications of CVP versus PAC placement.
- viii. List 4 indications for TEE monitoring.
- ix. List two changes that could occur during acute LV ischemia using
  1. ECG
  2. PA catheter
  3. TEE
- x. List three progressive changes on the ECG that are likely to occur during acute Hyperkalemia.
- xi. Recognize different arrhythmias on the ECG.
- xii. List three different ECG filter settings on the HP Vigilent Monitor and indicate which setting would be useful to visualize pacemaker spikes
- xiii. Describe the effects of ventilation and West's zone positioning on the interpretation of PCWP.
- xiv. List four conditions in which there is an increased PCWP yet either a decreased intravascular fluid status or a decreased LVEDV.
- xv. Describe the limitations of PCWP as a volume monitor.
- xvi. Use PAC in the decision making process during and after separation from CPB.
- xvii. Define Ischemia by ECG voltage criteria
- xviii. Which leads are most sensitive for ischemia detection intraoperatively
- xix. Define effects of changes in K, Ca, and acidosis on ECG
- xx. Describe advantages and complications of external jugular, internal jugular, and subclavian vein cannulation.
- xxi. Describe components of central venous waveform

- xxii. Are there contraindications of CVP placement?
- xxiii. What does CVP pressures tell the clinician
- xxiv. Define the complications of PA catheter placement
- xxv. Describe how cardiac output is measured using a PA catheter and what effects the calculation.
- xxvi. In the CA-1 and CA-2 months, the residents are not expected to perform an intra-operative TEE exam. However, residents will be expected to verbally answer the following questions.
  - 1. What are the indications for TEE?
  - 2. How is LV function assessed?
  - 3. How does wall motion change during ischemia?
  - 4. How is valvular function assessed?
  - 5. What is the limitation for diagnosing aortic dissection?
  - 6. How is the ascending aorta best imaged?
  - 7. What are the contraindications to TEE placement?
- xxvii. What is the “Zero” reference for transducer systems?
- xxviii. Name the factors affecting intra-arterial pressure measurements:
  - 1. damping
  - 2. resonance
- xxix. List a condition causing pulsus paradoxus
- xxx. Define  $P_a$  occlusion  $P/P_a$  wedge  $P/LVEDP$  gradients/Mean PCWP
- xxxi. Define the determinants of mixed venous oxygen saturation
- xxxii. List 3 causes of increased mixed venous oxygen saturation
- xxxiii. Discuss the management of patient with LBBB requiring PA catheter
- xxxiv. Discuss the management of pulmonary artery rupture
- xxxv. Compare thermodilution with Fick methodology for CO determination
- xxxvi. Compare the effectiveness of CVP, PA Cath, and transesophageal echo in estimating LV volume
- xxxvii. Calculate the vascular indices of SVR and PVR
- xxxviii. Calculate Shunt fraction
- xxxix. List an effect of methemoglobinemia on pulse oximetry
  - xl. How is microshock hazard monitored
  - xli. List the changeable parameters on temporary pacemakers
  - xlii. List three mechanisms of pacemaker failure
  - xliii. Discuss the effects of temperature on blood gas measurements
- i. Anesthetics and Anesthetic Management
  - i. What is the interaction of opioids and benzodiazepines?
  - ii. What are the hemodynamic effects of high dose narcotic induction?
  - iii. Differentiate cardiovascular effects of the inhalation agents
  - iv. Define the hemodynamic effects of benzodiazepines
  - v. Discuss the role of ketamine in patients with cardiac disease
  - vi. Differentiate cardiovascular effects of muscle relaxants
  - vii. Define the hemodynamic effects of propofol

- viii. Discuss the unique differences in the anesthetic management of:
1. Severe aortic stenosis
  2. Hypertrophic cardiomyopathy
  3. Ischemic heart disease with dilated cardiomyopathy
  4. Emergency: new onset VSD
  5. Pericardial tamponade with diastolic compression of right ventricle
  6. Intra-cardiac tumor
  7. Circulatory arrest
  8. Thoracic aortic dissection
  9. Thoracoabdominal aneurysm

j. Anti-fibrinolysis, Anti-coagulation and Transfusion Therapy

- i. What is the mechanism of action of heparin?
- ii. How is heparin effect monitored?
- iii. What is heparin resistance and how can it be recognized and treated?
- iv. What is heparin-induced thrombocytopenia and how can it be recognized?
- v. What is the mechanism of action of protamine?
- vi. How is it administered and monitored?
- vii. What is a protamine reaction? How can a protamine reaction be recognized? How can the risk of a protamine reaction be reduced?
- viii. Discuss the differences in measurements of coagulation: PT, PTT, TT, and ACT
- ix. Name three antifibrinolytics and indicate the one with the greatest anti-kallikrein effect
- x. Define the loading dose and infusion rate of Amicar and aprotinin
- xi. List 3 adverse events associated with PRBC transfusion
- xii. What are the types of hemolytic transfusion reaction?
- xiii. How are hemolytic transfusion reactions identified and treated?
- xiv. List 4 parameters used to assess coagulation using the Thromboelastogram
- xv. List 3 causes and treatments of post-bypass coagulopathy
- xvi. Define the viral risks of colloid therapy
- xvii. List one post-transfusion risk each for albumin and hetastarch
- xviii. Define the hematologic effects of using cell saved blood
- xix. List four steps that occur during normal platelet activation in vivo
- xx. Define the mechanism of action of plavix
- xxi. Name 4 drugs known to produce platelet dysfunction
- xxii. Transfusion of one unit of platelets is expected to increase the platelet count by what amount?
- xxiii. Discuss the recognition and management of transfusion reaction

k. Cardiopulmonary Bypass

- i. Draw the path of blood flow during CPB
- ii. List two types of oxygenators used during CPB
- iii. List two types of pumps used during CPB
- iv. List four components of cardioplegia
- v. List three causes why cardioplegia administration might fail to arrest the heart

- vi. Contrast Alpha stat vs pH stat techniques during CPB
- vii. What is the effect of blood viscosity, rheology, and hypothermia on blood pressure?
- viii. List ten monitoring goals and objectives during CPB (ie. monitor MAP and maintain pressure between 50 and 80 mmHg)
- ix. Evaluate causes and provide treatment for refractory hypotension
- x. Evaluate causes and provide treatment for refractory hypertension
- xi. List four treatments of post-CPB bronchospasm
- xii. List three treatments for a patient with hyperkalemia at the time of aortic cross clamp removal
- xiii. List three alternatives to heparin in a patient with heparin induced thrombocytopenia
- xiv. Define the effects of cold agglutinins on extracorporeal circulation (CPB)

#### 1. Other topics

- i. ACLS certification (pre-requisite)
- ii. List 5 differences in the anesthetic management of off pump coronary artery bypass procedures compared to on-pump CABG
- iii. Label a short axis (0°) transgastric view of the LV as viewed by transesophageal echocardiography
- iv. Label a long axis (90°) transgastric view of the LV as viewed by transesophageal echocardiography
- v. Draw and label a short axis (0°) mid-esophageal view of the LV (Four chamber) as viewed by transesophageal echocardiography
- vi. List one indication and two contraindications for using an Intra-aortic balloon pump
- vii. Draw the aortic arch and descending aorta showing the proper position for an IABP
- viii. Draw an arterial pulse wave and label the timing points for inflation and deflation of the balloon pump
- ix. List the 4 anastomotic sites for an RVAD and an LVAD
- x. Draw the normal neonatal cardiovascular blood flow pathway
- xi. Name 2 congenital heart defects with right to left shunt
- xii. Name 2 congenital heart defects with left to right shunt
- xiii. Define a “TET spell”
- xiv. List two treatments for a TET spell occurring pre-induction
- xv. List 4 complications immediately following ligation of a PDA

### 3. Interpersonal and Communication Skills

- a. Establish and maintain professional relationships with the cardiothoracic surgery patients, their families and the operating room staff involved with their care.
- b. Identify the special needs of communicating with patients having acute coronary syndrome
- c. Identify the special needs of cardiothoracic surgery patients who may have difficulty or be unable to communicate with their caregivers.

#### **4. Practice-Based learning and Improvement**

- a. Describe an evidenced-based approach to the selective use of PA catheters in cardiac surgery
- b. Justify placement of a mixed venous continuous cardiac output PA catheter based on the results of a literature review
- c. Self-monitor the effectiveness of arterial line placement and make adjustments in technique to improve success rate

#### **5. Professionalism**

- a. Maintain focus on patient care activities during stressful times
- b. Maintain honesty at all times
- c. Prepare for cases in a timely manner for first cases of the day
- d. Learn from experience

#### **6. Systems-based Practice**

- a. Explain your role in relation to other members of the cardiac care team in the OR
- b. Justify the expense of using a PA catheter for routine CABG
- c. Prepare a concise report of the intra-operative course that is passed on to the post-operative cardiac care team