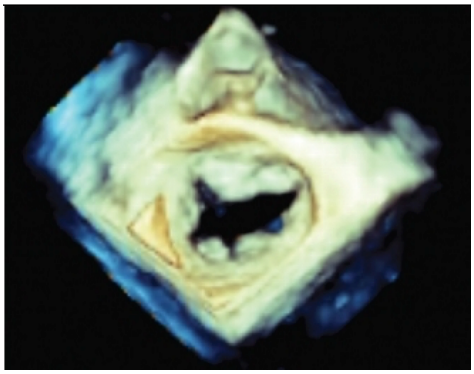
LOMA LINDA
UNIVERSITY
HEALTH

CARDIOTHORACIC ANESTHESIA MANUAL



2022 Revision

Loma Linda University Medical Center Department of Anesthesiology

Welcome to the cardiothoracic anesthesia rotation! The first month of the cardiac rotation will focus on the preoperative evaluation and intraoperative management of patients with complex cardiovascular disease. Preoperative evaluation should include a detailed understanding of the underlying disease process, timing of surgical intervention, and need for invasive hemodynamic monitors and vasoactive medications. Since cardiovascular disease poses significant anesthetic challenges; identifying hemodynamic goals for each patient provides a framework for induction of anesthesia and intraoperative management. Hemodynamic goals should be defined in terms of target heart rate, rhythm, contractility, preload, and afterload. Specifying these hemodynamic goals in the preoperative evaluation will enhance your understanding of each cardiac lesion.

Transesophageal echocardiography (TEE) is one of the tools used to guide intraoperative management and surgical decision making. The application of TEE is most robust when combined with a solid understanding of cardiovascular disease. Therefore, the basics of TEE will not be introduced until the second month of the rotation. During the second month, you should familiarize yourself with the basic TEE exam and seek opportunities to practice obtaining the basic views. Be sure to take advantage of the Toronto TEE simulation website and the TEE simulator in the departmental research lab. If you are interested in learning more TEE, we welcome you to join us for an advanced cardiothoracic anesthesia rotation.

Please review the cardiothoracic anesthesia manual for details about the structure of the rotation. The department website also includes a primer to assist you with setting up the OR, tip sheets, lectures, articles, guidelines, and other recommended readings to prepare you for this rotation. These readings emphasize the relationship between cardiothoracic pathology and anesthesia.

Your command of cardiothoracic pathology ultimately translates into the delivery of high quality care, please take time to read about the basics of cardiothoracic anesthesia and the specifics of each patient’s pathology every day.

We are all looking forward to working with you during your cardiothoracic anesthesia rotation!

Melissa McCabe, M.D.
Director, Cardiothoracic
Fellowship

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ROTATION STRUCTURE:

Call Requirements

Typically, four residents will be assigned to the cardiothoracic rotation each block. The cardiac anesthesia fellow may also be assigned in the cardiac OR. One resident will be on call every day and will be off on their post-call day. Expect to be on call two weekends per month: 1) Friday in-house call and Sunday home call and 2) Saturday home call.

Preoperative Preparation

Many of our patients are admitted prior to surgery. When an inpatient scheduled for surgery, see them before you leave for the day and discuss the anesthetic plan with the patient. Be aware, the cardiac schedule may change to accommodate urgent and emergent cases, please make sure you check the schedule for updates throughout the day.

If you are working with a fellow, **contact the fellow** and discuss the case before paging the attending. When you call/page your attending, please include a **detailed history** including **important comorbidities** and **relevant preoperative test results**, be sure to **discuss potential problems/concerns**, and clarify the **preferred anesthetic technique** and need for **vasoactive infusions**. Do not simply copy and paste the history and pre-op workup, but summarize the relevant information in a concise manner and discuss how this integrates into your anesthetic plan.

ROTATION OBJECTIVES:

After completing the cardiothoracic rotation, you should have a thorough understanding of complex cardiac disease and the tenets of perioperative management.

1. Perform a thorough preoperative evaluation including interpretation of cardiac test results: echocardiography, stress tests, and angiography.
2. Basic understanding of the tenets of medical management of coronary artery disease, valvular heart disease, and congenital heart disease patients.
3. Identification of intraoperative hemodynamic goals in terms of heart rate, rhythm, contractility, preload, and afterload for coronary artery disease, valvular lesions, and adult congenital heart disease.
4. Knowledge of perioperative CIED management guidelines.
5. Development of a safe and effective anesthetic plan for complex heart disease that maintains each patient's unique hemodynamic goals.
6. Thorough knowledge of the cardiovascular effects of intravenous and inhalation anesthetics.
7. Proficient in placement and interpretation of non-invasive and invasive monitoring equipment, including: arterial catheters, central venous lines, pulmonary arterial catheters, Vigileo/flow track, Clearsight, and Sedline.
8. Familiarity with transesophageal and transthoracic echocardiography, including placement of the transesophageal probe and proficiency with obtaining the 11-view basic exam as outlined by the ASE/SCA guidelines.
9. Understanding of the pharmacology of vasoactive and inotropic agents and indications for use.
10. Intraoperative management of cardiac transplantation.
11. Anesthetic considerations and intraoperative management of interventional cardiology procedures such as transcatheter aortic valve replacement, impella placement, and electrophysiology studies and ablations.

12. Management of anticoagulation during cardiopulmonary bypass including treatment of heparin resistance.
13. Pharmacology of protamine, recognition of protamine reactions, and the requirements for safe administration.
14. Fundamentals of cardiopulmonary bypass: cannulation sites, anticoagulation requirements, physiology, cardioplegia, and bypass circuitry.
15. Understand the common postoperative complications and the implications for long-term morbidity, and mortality associated with cardiothoracic surgery.
16. Understand the indications for placement of an aortic balloon pump as well as the physiology of augmentation and the appropriate timing for balloon trigger.
17. Proficiency in placement and positioning of double lumen tubes and bronchial blockers.
18. Evaluation and management of hypoxemia during one lung ventilation.
19. Multimodal analgesia for thoracic surgery including adjuvants like ofirmev and ketamine and regional anesthesia techniques – thoracic epidural placement and management.
20. Preparation and monitoring requirements for transfer to ICU. Ability to deliver clear and concise hand-off to facilitate a safe transfer of care.
21. Consideration for postoperative management, including techniques to facilitate “fast track” extubation.
22.

READING LIST

In addition to the articles located on the rotation website, we recommend the following textbooks:

1. *A Practical Approach to Cardiac Anesthesia:* FA Hensley Jr; 5th edition, 2012.
   ****Best resident level text****
2. *Kaplan’s Cardiac Anesthesia for Cardiac and Noncardiac Surgery:* JA Kaplan; 7th edition, 2016.
3. *Cardiopulmonary Bypass and Mechanical Support: Principles and Practice:* G Gravlee; 4th edition, 2015.
4. *Perioperative Two-Dimensional Transesophageal Echocardiography: A Practical Handbook:* A Vegas, 2012 edition.
   ****Quick reference for TEE****
5. *A Practical Approach to Transesophageal Echocardiography:* A Perrino; 3rd edition, 2013.
6. *Anesthesia for Congenital Heart Disease:* D Andropoulos; 3rd edition, 2015.
   ****Best CHD text****

PREOPERATIVE EVALUATION AND ROOM PREPARATION

Home Medications, Labs, and Premedication

Your preoperative evaluation should include review of the patient's home medications. Most home medications should be continued preoperatively, especially cardiac medications like beta-blockers, anti-hypertensives, and anti-arrhythmics. However, anticoagulants and antiplatelet agents should be discontinued. If you have any questions or concerns, please discuss them with your attending.

Preoperative labs should include: BMP, CBC, INR, +/- $HbgA_{1C}$, and type and cross. Remember, two independently drawn blood samples are needed for the type and cross and for the check type. Verify that the preoperative orders include 2 units of cross-matched PRBCs for adult patients and 1 unit of PRBCs for pediatric patients. The need for additional blood products should be discussed with your attending.

There are many options for premedication, each must be considered in context of the patients age, comorbidities, frailty, and hemodynamic stability. Midazolam and fentanyl are preferred for their quick onset and ease of titration; however, benzodiazepines should be eliminated in elderly (>70) to avoid postoperative delirium and reduced in frail patients due to prolonged duration of action. Most adult patients should receive midazolam 1-2 mg in the holding area, additional doses can be given in the room to facilitate placement of an awake arterial line. Alternatively, fentanyl may be titrated 25 mcg at a time. Remember, anesthesia start time should coincide with administration of premedication in the preoperative holding area if you remain with the patient and monitor throughout transfer to the OR. Preoperative evaluation, examination, and procedures should not be included in the anesthesia time.

Cardiac or Set-Up

As with all anesthetics, case preparation starts with the machine check and monitor setup. You will need at least four infusion pumps. At least one fluid warmer will be needed, but a second fluid warmer or rapid infuser may be necessary for complex redo or aortic cases.

Provide the scrub tech with your gown and gloves for central line placement. The circulating nurse will prep the neck for the central line and the scrub tech will assist you with gowning and gloving. Prepare the central line and/or the PA catheter as discussed with your attending. For most adult cardiac cases an 8.5 Fr 4-lumen CVL should be sufficient; PA catheters are only used when indicated by the patient's cardiovascular pathology.

When placing a PA catheter, please ask your attending or fellow for assistance with setup. While maintain sterility of the PA catheter, plug the CCO port into the monitor and perform the in-vitro calibration prior to flushing the catheter and removing the catheter from the grey housing. After calibration, connect the CVP transducer to the blue port, the PA transducer to the yellow port, and place a clave with flush syringe on the white VIP/RA port.

Adult Equipment

- Fluid warmer
- Infusion pumps: 4 infusion pumps at minimum
- Triple transducer (red - arterial, blue - central, yellow – PA/coronary sinus catheter)
- A-line kit and sterile gloves
- Central line kit, US probe cover, claves for each port, saline flush, and biopatch
- US probe for line placement, typically the hockey stick probe for the TEE machine
- PA catheter with completed in-vitro calibration (if needed)

- Burette with 500 cc NS for slow administration of medications
- 500 ml carrier on infusion pump with 1-2 spider connectors for drips (Carrier will be premade Amicar infusion set at 50ml/hr)
- SED-Line
- Secondary pulse oximeter attached to Massimo monitor
- Cerebral oximetry x 2
- Two temperature cables (T1: nasopharyngeal, T2: bladder or rectal)
- OG tube to suction out gastric contents prior to TEE probe placement
- TEE machine with TEE probe

Please refer to the cardiac primer for detailed information about OR set-up and the anticipated workflow for cardiac cases. As always, if you have questions, ask your fellow or attending.

Adult Medications

Induction Medications

- Midazolam 2 mg (for patients <70 years of age)
- Lidocaine 100 mg
- Fentanyl 1000 mcg
- Etomidate 20 mg or propofol 200 mg depending on attending preference
- Rocuronium 100 mg

The following should be immediately available:

- Ephedrine 5 mg/mL
- Phenylephrine 100 mcg/mL
- Vasopressin 1 unit/mL
- Epinephrine 5 mcg/mL
- Nitroglycerin 40 mcg/mL
- Esmolol 10 mg/mL
- Succinylcholine 20 mg/mL
- Atropine 0.4 mg/mL
- Calcium chloride 100 mg/mL
- Magnesium 1 gram/mL
- Sodium bicarbonate 1 mEq/mL

Pre-Made Cardiac Box (made by Pharmacy)

- Pick up pre-made box at OR Satellite Pharmacy on 3rd floor (**x17955**, open 6:00 AM - 2:30 PM). After hours **orders are filled by the A-level pharmacy, in the order you may request for medications to be delivered to Tube Station 40 in the "Notes to Pharmacy" section of the order navigator.** Tube station 40 is in the south hallway next to OR 1.

- Box will include:
  - Aminocaproic Acid 20 gram/500 mL NS (run as the carrier at 2 gram/h or 50 mL/h)
  - Norepinephrine 8 mg/250 mL D5W
  - Regular Insulin 100 units/100 mL NS

- Propofol 10mg/mL - 100mL bottle x 1
- Epinephrine 10 mcg/mL 5mL syringe x 1
- Phenylephrine 100 mcg/mL - 10mL syringe x 3
- Calcium Chloride 100 mg/mL - 10 mL syringe x 2
- Sodium Bicarbonate 50 mEq/50 mL - syringe/vial x 2
- Albumin 5% - 500 mL bottle x 1

Minimum Basic Infusions

- Aminocaproic acid 20 gram/500ml NS (run as carrier at 2gram/h or 50ml/hr)
- Norepinephrine 8 mg/250 mL set at 5 mcg/min
- Nitroglycerin 400 mcg/mL set at 0.25 mcg/kg/min
    - Remember to use the low adsorption pump tubing
- Insulin 100 units regular insulin in 100mL NS
    - **Any glucose >200 in adults usually warrants treatment**; consider bolusing 4 units and starting an infusion at 1-2 units per hour. Hyperglycemia during bypass can be difficult to treat as hypothermia increases insulin resistance and the cardioplegia solution contains dextrose. Therefore, it is important to trend glucose levels, especially when rewarming as the patient regains sensitivity to insulin.
    - Hyperkalemia can also be a problem during bypass, so the perfusionists may request 5-10 units of insulin to promote intracellular shift of potassium.
    - In most cases, it is reasonable to have an inotrope available, but not spiked: milrinone (20 mg/100 mL set at 0.3-0.5 mcg/kg/min), dobutamine (250 mg/250 mL set at 5 mcg/min), or epinephrine (8 mg/250 mL set at 5 mcg/min).

Anti-Fibrinolytics and Vasoactive Infusions

Drip selection is based on the patient's cardiac condition/function, surgical procedure, and attending preference. Please discuss which drips will be needed for the case with your attending. If your patient is diabetic, please have an insulin infusion available.

1. **Aminocaproic acid (Amicar):** is an anti-fibrinolytic agent, it inhibits the conversion of plasminogen to plasmin. Tranexamic acid is an alternative anti-fibrinolytic used when amicar is unavailable. Please refer to the tranexamic dosing section.
2. **Nitroglycerin (Tridil)**: available as a premixed bottle, 400 mcg/mL. Nitroglycerin is a venodilator that decreases LVEDP, increases CO, and coronary blood flow. Typical infusion rate ranges from 1 - 10 mcg/kg/min.
3. **Clevidipine (Cleviprex)**: available as a premixed bottle, 0.5 mg/mL. Clevidipine is a rapidly titratable calcium channel blocker. Start at 1 - 2 mg/hr, the rate may be titrated every 90 seconds up to a max of 16 mg/hr to obtain the desired reduction in blood pressure.
4. **Esmolol**: available in premixed bags, 2500 mg/ 250 mL. Esmolol is a β1 blocker used to reduce the HR and suppress arrhythmias, it may also be used to decrease the shearing

forces in patients with aortic aneurysm or dissection. Typical infusion rates are usually 50 - 300 mcg/kg/min.

5. **Dopamine**: available in a premixed bag, 1000 mcg/mL. Dopamine causes mesenteric and renal vasodilation via the dopamine receptor at 0.5 - 3 mcg/kg/min; increases CO; HR, and BP via β receptor at 3 - 10 mcg/kg/min; and vasoconstriction via the α receptor at doses >15 mcg/kg/min.
6. **Dobutamine**: available as a premixed bag, 1000 mcg/mL. Dobutamine is an inodilator, it increases myocardial contractility, CO and coronary blood flow via β_1 receptor agonism. Ideal for use in patients with systolic heart failure. Typical infusion rates range from 2 - 15 mcg/kg/min.
7. **Milrinone**: available in premixed bags, 200 mcg/mL. Milrinone is a phosphodiesterase inhibitor causing inodilation. It increases contractility and reduces both SVR and PVR. Useful in the setting of elevated pulmonary vascular resistance, right ventricular dysfunction, and improving lusitropy in hypertrophied left ventricles. Milrinone lowers PVR and reduces the workload of the RV. Typical infusion rate of 0.25-0.5 mcg/kg/min.
8. **Isoproterenol**: mix 2 mg in a 250 mL bag NS to create a 4 mcg/mL solution. Isoproterenol activates β_1 and β_2 receptors resulting in increased inotropy and chronotropy. Isoproterenol can be used to induce arrhythmias during EP studies or increase heart rate after cardiac transplantation. Typical infusion rates range from 0.01 - 0.05 mcg/kg/min.
9. **Epinephrine:** mix 8 mg in a 250 mL bag of NS, 32 mcg/mL. Epinephrine is a potent α and β agonist ($\beta > \alpha$) that increases inotropy and chronotropy – excellent for supporting right and left ventricular function. Typical infusion rates are 3 – 10 mcg/min.
10. **Norepinephrine**: mix 8 mg in a 250 mL bag of NS, 32 mcg/mL. Norepinephrine is an α and β agonist ($\alpha > \beta$) that increases systemic vascular resistance. Typical infusion rates are 3 – 10 mcg/min.
11. **Phenylephrine**: mix 40 mg in a 250 mL bag of NS, to create a 160 mcg/mL solution. Phenylephrine is an $\alpha 1$ agonist that produces vasoconstriction and reflex bradycardia. Consider using to support the blood pressure in patients with CAD, severe aortic stenosis, during LIMA harvest, or for off-pump CPB cases.
12. **Vasopressin**: mix 20 unit vial in 100ml bag of NS, to create 0.2 units/ml solution. Typical starting rate is 0.02 - 0.04 units/min. Vasopressin is a synthetic form of ADH however it is more specific for the V1 receptor versus the V2 receptor. V1 receptors are found in the vascular smooth muscle and binding causes vasoconstriction. V2 receptors are found in the renal collecting ducts and are responsible for water reabsorption. Vasopressin is useful in situations of pulmonary hypertension as it has little effect on pulmonary vasculature and may reduce PVR by triggering iNO release

Infusion Calculations

The infusion pumps automatically calculate the volumetric infusion rate for most standard concentration infusions based on the patient's weight (kg) and desired dose. However, if a non-standard infusion is needed, the volumetric rate may need to be calculated. For example, if you would like to infuse nitroglycerin at 2 mcg/kg/min for a 70 kg patient, the calculation for the volumetric infusion rate would be as follows:

$$\frac{mL}{hr} = \frac{\text{dose } (mcg/kg/min) \times \text{weight (kg)}}{\text{infusion concentration } (\frac{\text{mcg}}{\text{mL}})} \times 60\ min/hr$$

$$\frac{mL}{hr} = \frac{2\ mcg/kg/min * 70\ kg}{400\ mcg/mL} \times\ 60\ min/hr = 21\ mL/hr$$

INTRAOPERATIVE MANAGEMENT

Pre-Induction Care

Assist the patient with moving over the operating room table, place standard ASA monitors and provide supplemental oxygen. The EKG monitor should be set to a two-channel mode with leads II and V5 displayed. Consider titrating midazolam 1 - 2 mg and/or fentanyl 25 - 50 mcg for anxiolysis. The OR is very cold, shivering increases oxygen demand and can cause myocardial ischemia, please keep the patient covered as much as possible, use the bed warmer, and provide warm blankets. The patient will generally come with a large bore IV already in place for induction. Prepare for placement of the preinduction radial arterial line, if a radial harvest is planned, verify that line placement is not on the same side. For aortic surgery, the arterial line should generally be placed in the left arm. Occasionally, for impellas, axillary balloon pumps, or major aortic surgery a bilateral arterial line will be required. If you are doing a case with radial harvest or a complex aortic surgery, please verify the appropriate site for arterial line placement. Secure the arterial line with stat lock after placement. After the arterial line is placed, prepare for induction. Occasionally, a preinduction central line is indicated, but most central lines will be placed after induction.

Induction of Anesthesia

Inducing patients with severe cardiac disease can be tenuous, but with proper planning most patients can tolerate induction with only minor hemodynamic changes. **For patients at high risk for cardiovascular collapse, induction will be coordinated with the surgical team.** First and foremost, we must define the predominate cardiac lesion and establish hemodynamic goals for induction: heart rate, rhythm, preload, contractility, and afterload. It is also important to consider the risk of developing arrhythmia; R2 pads should be placed prior to induction for redo-sternotomy, severe aortic or mitral stenosis, left main coronary artery disease, or EF ~ 30%.

Induction medications should be titrated to facilitate optimal intubating conditions while maintaining the predefined hemodynamic goals. Typical medications include lidocaine, fentanyl 3 – 5 mcg/kg, and/or etomidate/propofol/sevoflurane, as well as rocuronium. Vasoactive medications should also be available to offset any undesired hemodynamic changes during induction. Consider having a peripheral phenylephrine infusion to help offset changes in SVR during induction for patients with critical aortic stenosis or left main disease.

After intubation, ventilator settings should aim to maintain normocapnia, as hypocapnia can increase coronary and cerebral vascular resistance. Few patients will be extubated in the OR, however, most patients are candidates for “fast track” extubation within two hours of arrival in the ICU. Facilitation of fast track extubation, precludes large doses of narcotics (fentanyl 25-100 mcg/kg) and necessitates appropriate dosing of neuromuscular blockers and reversal agents. “Fast tracking” promotes faster recovery, decreases the length of hospitalization, and reduces hospital costs.

Central Line Placement

Your case setup should include preparation for central line placement: gown and gloves, central line kit +/- pulmonary arterial catheter, and ultrasound. Typically, the central line will be placed after induction and intubation. Prepare the central line kit, position the patient, and ask the circulator to prep before scrubbing for line placement. Central lines will be placed in the right or left internal jugular vein using dynamic ultrasound guidance. Rarely, the internal jugular cannot be cannulated and a subclavian line will be placed instead. Inadvertent carotid puncture is the most common complication of central line placement, dynamic ultrasound guidance greatly reduces the risk when the needle is visualized well on ultrasound. After the vein is accessed and the wire is passed, ultrasound should be used to confirm the position of the wire prior vein dilation. Confirmatory images should be stored for documentation purposes. If there is any question about the position of the wire, pressure transduction should be used to confirm central venous access. All central lines should be sutured in place and covered with a biopatch and tegaderm. The tegaderm should not cover the sternal notch as this is an important anatomical landmark for the surgeons.

Sterility during central line placement is the first step for reducing catheter related infections. However, maintaining good central line hygiene after placement is equally important. If IV lines are connected after the central line drape is removed, each hub should be scrubbed with alcohol prior to connecting IV tubing. Each stopcock should be covered with a clave and all claves/port sites should be covered with the alcohol impregnated “blue caps.”

Maintenance of Anesthesia

Isoflurane and fentanyl will typically be used for maintenance of anesthesia. Nitrous oxide should be avoided as it may adversely affect myocardial blood flow and can result in expansion of air emboli.

Baseline arterial blood gas, ACT, and Quantra (TEG) should be drawn prior to incision. Blood should be in the room prior to sternotomy. For redo-patients, release 4 units of PRBCs and 4 units of FFP as the lung and right ventricle may have adhered to the sternum. Heparin will be provided by the perfusionist with a typical dose of 400 units/kg.

Before placing the birdcage and wings, pass an OG tube and suction the stomach prior to placement of the TEE probe. The fellow or attending will usually place the TEE probe, however you may place the probe with attending supervision. Put a bite block on the TEE probe to protect the patient’s teeth and the probe. Place ultrasound gel in the mouth and position TEE probe in the back of the mouth, use your left hand to lift the patient’s jaw or have an assistant provide a jaw thrust, and apply gentle pressure until the probe passes. If the probe does not pass easily, STOP and get assistance. Esophageal pathology can be a contraindication to TEE, please confirm with your attending before proceeding with TEE probe placement. that might put the patient at risk for perforation or bleeding. Handle the TEE probe with care, as the fiberoptic and ultrasonic coils are fragile.

The final preparation before skin incision is placing the so-called wings on each side of the bed with the birdcage ether screen over the head of the patient in preparation of draping. Check all

your lines, ventilation status, and monitors since this is your last opportunity to easily address anything amiss.

Limit crystalloid prior to bypass to less than a liter, excessive hemodilution can may exacerbate coagulopathy after bypass. For patients with a hemoglobin > 14, we may consider collecting a unit of blood prior to bypass. **** Please do not collect any blood without discussing with your attending. **** The anesthesia tech/perfusionist may provide a bag with CPD for blood collection. Place a rubber cap from the central line kit on the largest central line port, clean the port with alcohol and spike the needle from the CPD bag through cap. Use gravity to allow the blood to drain back, monitor the hemodynamics to ensure the patient tolerates the volume removal. After the blood is collected, place the blood on the agitator. Autologous blood harvest is avoided in severe aortic stenosis and/or critical left main disease.

While the patient is being prepped, it is a good time to make sure that the patient has received antibiotics: 1.5 grams Cefuroxime and 1 gram of Vancomycin for valve replacement or repairs. Verify that the temperature probes are working and correctly labeled: T1 is nasopharyngeal and T2 is the bladder temperature.

For CABG, the surgeons will request blood to fill the vein grafts. Draw 3-4 mL of heparin 1000 units/mL into a 60 mL syringe and aspirate 50 – 60 mL of blood from the patient's central line. The surgeons may also request nitroglycerine, draw 50 mL from the premixed nitroglycerine (100 mg/250 mL) infusion bottle. The scrub tech will provide a basin for transferring the blood and nitroglycerin to the surgical field; while maintaining sterility, slowly squirt the contents of the syringe into the basin.

Anti-fibrinolytic therapy with aminocaproic acid or tranexamic acid is routine for all adult cardiac patients.

Aminocaproic Dosing:
- First dose – prior to skin incision: 5 gram bolus
- Infusion – 2 gram/ hr infusion or 50ml/hr from 20gm/500ml NS premade bag

Tranexamic Acid Dosing (used only by Dr. Toporoff):

- Prepare an infusion: 1000 mg in 250mL NS (4 mg/mL)
- Low Dose: 10mg/kg IV bolus, 1mg/kg in CPB prime, 1mg/kg/h infusion
- High Dose: 10mg/kg IV bolus, 2mg/kg in CPB prime, 1mg/kg/h infusion

Surgery

Median sternotomy is very stimulating and has been associated with intraoperative recall. Preemptive titration of inhalational agents and fentanyl can help ensure adequate anesthesia and avoid undesirable changes in hemodynamics. Prior to sternotomy the surgeons will request "lungs down," suspend ventilation and disconnect the breathing bag or circuit. Start a timer once ventilation has been suspended and notify the surgeons when the lungs have been down for one minute. Resume ventilation when sternotomy is complete. Ventilation will be continued during sternotomy for redo cases, as the lungs may offer some protection from myocardial injury.

For a CABG, the internal mammary artery will be harvested after sternotomy. To aid surgical visualization, the surgeon will request that the table is tilted away and that tidal volumes are decreased. After the mammary has been harvested, the pericardium will be opened and the surgeons will start preparing for cannulation. The surgeons will request heparin administration. The respiratory therapists will provide heparin 400 units/kg. Notify respiratory therapy when heparin is administered to request an ACT.

Preparation for cannulation begins with opening the pericardium. The aortic cannula is placed first, during aortic cannulation systolic blood pressure should be around 100 mmHg to reduce the risk of aortic injury during cannulation. It is important to titrate the depth of anesthesia and/or vasodilators in anticipation of aortic cannulation. Placement of venous cannula(s) and antegrade/retrograde cardioplegia lines will follow aortic cannulation. High pressure tubing will be passed up from the surgical field to connect to our pressure transducer to monitor retrograde cardioplegia administration. With a gloved hand, use a male-male adapter to connect the high-pressure tubing line to the PA transducer stopcock. Flush the line when requested.

Consider insulin for diabetic patients or adults with a glucose, most patients will require an insulin bolus and infusion as cardioplegia contains dextrose and hypothermia promotes insulin resistance. A bolus of 4 units of insulin IV is a good starting point for most insulin naïve patients. Prepare an insulin infusion and start the infusion at 1-2 units per hour. Monitor glucose throughout bypass and anticipate additional titration. Pay special attention to the glucose level during rewarming, as normothermia restores insulin responsiveness.

Checklist for Commencing CPB

- Heparin has been administered and ACT > 400 seconds. If ACT < 400 seconds, CPB should not be initiated until additional heparin is administered or added to the pump prime.
- Aortic cannula should be free of air, unclamped, and free of kinks.
- Functional coronary sinus pressure line.
- Re-dose neuromuscular blockers, narcotics, and/or anesthetic agents if needed.
- After successful transition to CPB, hold ventilation, turn off alarms, initiate CPB mode, and TKO vasoactive drips (unless discussed otherwise).
- Empty the urometer and notify the perfusionist of the quantity of urine the pre-bypass.
- Confirm perfusionist has started isoflurane to maintain adequate anesthesia while on bypass. **REMEMBER, it is YOUR responsibility to ensure the patient is adequately anesthetized.**

Cardiopulmonary Bypass

During CPB it is important to monitor urine output, as it is an indicator of renal perfusion. If urine output is < 1 mL/kg/hr check the catheter and notify the perfusionist, so perfusion pressures can be improved and if indicated, diuretics can be given. Monitor the EKG for signs of electrical activity, and isoelectric EKG is a sign of adequate myocardial protection. Notify the surgeon of ventricular arrhythmias, as additional cardioplegia or defibrillation may be required. Mean arterial pressures should also be monitored in conjunction with the perfusionist. Observe the head for plethora as this may indicated inadequate venous drainage and can obstruct cerebral

blood flow. Blood gases and ACT will be drawn by the perfusionist and should be trended throughout bypass; acidemia, electrolyte, and glucose abnormalities should be corrected in conjunction with the perfusionist. Hematocrit should also be followed and transfusion may be considered.

During bypass, the respiratory therapist while give you the protamine. Protamine is one of the most dangerous medications in the heart room, inappropriate administration can be catastrophic. Separate the protamine from the rest of the medications to help prevent inadvertent administration.

Brief Check List for Monitoring During CPB

- Monitor EKG – notify surgeons of ventricular arrhythmias.
- Monitor processed EEG.
- Monitor MAP, the perfusionists aim for MAP >30 mmHg while “cold” (28 °C) and MAP >50 mmHg while “warm.”
- If MAP > 90 mmHg additional anesthetics or vasodilators (NTG / SNP) may be needed.
- Urine output should be >1 mL/kg/hr by flow, pressure, and/or diuretics.
- The perfusionist will continue checking ABGs and ACTs, continue to trend results.
- Ensure adequate anesthesia administration.
- Order FFP, platelets, and/or cryoprecipitate on an as needed basis, discuss with your attending.
- PRBCs, albumin, and crystalloid should be available for weaning from bypass.
- Bypass time should be utilized to complete charting, prepare for weaning bypass, and setting up for the next case.

Preparation for Separation of Cardiopulmonary Bypass

Cessation of cardiopulmonary bypass requires an organized approach and closed loop communication to ensure a safe transition. The patient must be warm and have a perfusing rhythm, monitors and alarms need to be function, ventilation needs to be resumed, and the adequacy of cardiac output requires continuous monitoring.

- **Warm:** Core temperature must be > 36°C. Temperature probes must be labeled correctly and functioning appropriately. Rewarming is a gradual process accomplished by warming the blood returning to the patient from the cardiopulmonary bypass circuit. Additional warming measures may be needed including: warming lamps, mattress warmers, and even increasing the room temperature. Discuss with your attending if nitroglycerine should be considered to expedite rewarming. Shivering should be managed with small doses of muscle relaxant.
- **Rhythm:** Sinus rhythm with a rate near 80 bpm is ideal, however, heart block and arrhythmias are common when recovering from cardioplegia.
    - Temporary epicardial pacing wires may be placed in the ventricle and/or the atrium. The surgeons will pass up cables that connect the epicardial leads to the pacemaker generator box (circulator will provide). For isolated ventricular leads, set the pacer to VVI with a rate of 80 bpm. If atrial and ventricular leads are placed, an initial setting of DDD with a rate of 80 bpm can be used until further

consultation with your attending.
    - Ventricular arrhythmias are common and may require multiple rounds of internal defibrillation. The perfusionist may give additional lidocaine and magnesium as well as amiodarone for resistant arrhythmias.
- **Monitors:** When the surgeon unclamps the aorta, zero the pressure lines. If using a PA catheter, change pressure transduction from the coronary sinus back to PA. Resume all monitors and alarms.
- **Ventilation:** When the surgeon requests, resume inhalation anesthesia along with ventilation. They may ask you to suction the lungs prior to ventilation.
- **Perfusion:** contractility, preload, and afterload must be adequate, if not treat with inotropes, volume, or vasoactive medications as appropriate
- For CABG, NTG is generally used to facilitate maintenance of graph patency. Discuss with your attending regarding NTG usage in this setting. If used, start NTG at 0.5 mcg/kg/min once the aortic cross clamp is removed and only if hemodynamics allow for initiation of a vasodilator.

Checklist for Termination of CPB

- Anesthesia attending notified and present
- Warm with core temperature >36 °C
- Review most recent ABG including potassium, calcium, and hemoglobin and ensure abnormalities have been addressed
- Adequate ventilation with both lungs expanding (if not, irrigate and suction)
- Perfusing cardiac rhythm with adequate ventricular rate
- Proper function of IV lines, drips, and availability of volume
- **Confirm that monitors are working properly and alarms are audible**
- Resume inhalation agent with ventilation
- Circulatory support devices and vasoactive drips functioning as needed
- Discontinue monitoring of coronary sinus pressure and resume PA pressure monitoring
- Discuss vasoactive and inotropic drips with anesthesia attending
- Check that protamine has been drawn up, but **DO NOT** administer until the surgeon requests.
- **DO NOT** prophylactically order platelets, fresh frozen plasma, or cryoprecipitate unless discussed with your attending

Post-CPB Check List

- If using a PA catheter, resume CO and SVO_2 monitoring
- Crystalloid, colloid, and PRBCs should be available; however, cell saver is preferred once the pump volume has been given
- The anesthesia attending and/or fellow need to be present for CPB – they will assess HR/rhythm, preload, afterload and contractility from invasive monitors and TEE imaging. The surgical intervention will also be evaluated using TEE.
- The anesthesia attending and/or fellow will coordinate volume maintenance with the perfusionist until the aortic cannula is removed. The surgeon or anesthesiologist will ask the perfusionist to give volume via the aortic cannula until the pump volume is depleted.

During this time, vasoactive boluses typically are unnecessary as hypotension is treated with volume. However, once the aortic cannula is removed, hemodynamic interventions are the sole responsibility of the anesthesia team.

- Protamine should only be given at the **REQUEST OF THE ATTENDING SURGEON** when the patient is stable hemodynamically. Start with a 10 mg test dose, wait 2 – 3 minutes to monitor for a protamine reaction before continuing with gradual administration. It can be given in the burette or via a very slow IV push. Protamine administration requires closed loop communication between the surgeon, anesthesiologist, and perfusionist. When the surgeon requests the "test dose" of protamine, respond with "protamine test" going in. After the test dose, the surgeon will ask you to proceed with protamine administration. When 50% of the protamine has been administered, notify the perfusionist, they should respond with "suckers off" indicating that the bypass suction is turned off. Also verify with the surgeon that it is okay to finish the protamine. Once the protamine is finished, announce that the protamine is all in.
- Re-dose anti-fibrinolytics after all the protamine has been given.
- ABG should be drawn ~10 minutes after weaning from bypass
- ACT and Quantra (TEG) should be drawn 10 minutes after protamine
- Provide the perfusionist with the urine output pre-bypass and during bypass.
- Volume status needs to be reassessed throughout the post-bypass period. The heart is less compliant after cooling and cardioplegia and many patients have diastolic dysfunction, so they will be very sensitive to changes in preload. Chest closure can also affect filling pressures and additional volume may be needed.
- PRBCs and FFP should be stored in the igloo, under the ice pack with the lid closed. Platelets, cryoprecipitate, autologous blood, and cell saver should not be stored in the igloo. The igloo cannot be sent to the ICU, only take blood products that are being actively infused.
- Extubation goals should be discussed with your attending. TOF and tetany should be assessed in the ICU and reversal medications should be dosed accordingly and administered in the ICU.

Off-Pump CABG

Although the hemodynamic goals of an OP-CABG are the same as a bypass CABG, fluid management is different. The heart is manipulated during bypass grafting and venous return is decreased; LAD grafts require little manipulation, whereas PDA grafts require substantial manipulation and severely impact venous return. Therefore, filling pressures must be optimized before the heart is manipulated. While the mammary is being taken down, 1 – 2 L of crystalloid should be given. If additional volume us needed, albumin should be considered. Vasoactive infusions may be required during mammary take down as well as when the heart is manipulated. Epicardial ventricular pacing wires should be considered in patients at risk for arrhythmias.

Communication between the surgeon and anesthesiologist is essential, the surgeon should alert the anesthesiologist when manipulating the heart. Preemptive administration of fluid and titration of vasoactive agents is ideal. The heart will be stabilized with an apical (Starfish) and anastomotic (Octopus) suction. Once the heart is in position for the anastomosis, forward flow should be maintained with volume and vasoactive agents. If flow cannot be optimized, severe restriction of venous return must be considered and an alternative approach may be required.

Manipulation of the bed may be sufficient to improve venous return.

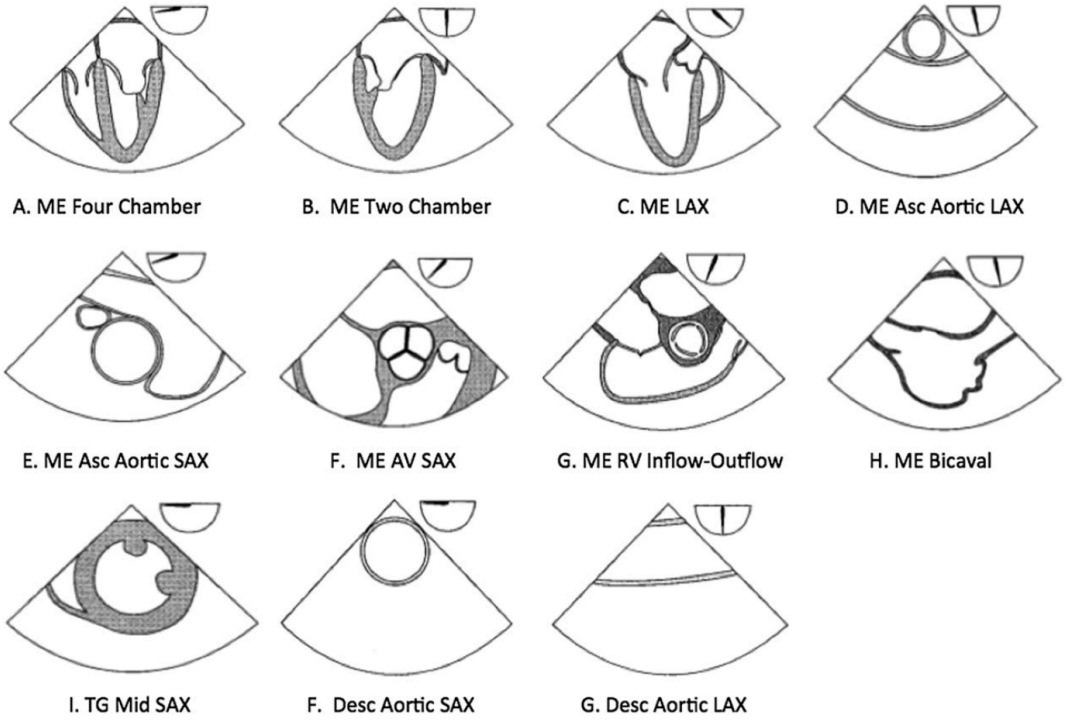
Heparinization is required, typically 200 units/kg, however, the full 400 units/kg should be available in the event bypass is needed. Goal ACT around is > 300 seconds. Antifibrinolytics are also used. If using amicar, a 10 gram loading dose is given and an additional 10 grams is given after protamine administration. For Tranexamic acid, a 10 mg/kg (up to 1000 mg) loading dose is given and an infusion is run at 1 mg/kg/hr and will run until the bag is empty or for up to 6 hours after protamine administration (whichever duration is shorter).

TRANSPORT

- Prepare supplies for transport: oral airway, mask, ETT, laryngoscope, medications for sedation/intubation, vasoactive medications, inotropes, emergency drugs, and volume for resuscitation (crystalloid or colloid)
- Always transport with vasopressor, vasodilator, and sedation bolus drugs
- Leave a volume line connected to the grey port of the central line and mark the push port so it is easily visible during transport
- Intubated patients should be transported with sedation, either propofol or dexmedetomidine infusion.
- Confirm with anesthesia attending before removing TEE probe
- Place OGT and empty the Foley catheter
- Disconnect the PA catheter oximetry and continuous cardiac output cables
- Infuse any blood products remaining in the warmer tubing then disconnect IV tubing from the warmer tubing.
- Prepare an ambu bag with end tidal monitoring, use PEEP valve if intraoperative PEEP requirements exceed 5 mmHg, verify oxygen tank has adequate volume for transport and open the valve.
- Sequentially transfer monitoring to the transport monitor. **DO NOT disconnect all the monitors at the same time.**
- Take defibrillator
- Upon arrival in ICU, sequentially transfer monitoring from the transport monitor to the ICU monitor. **DO NOT disconnect all the monitors at the same time.**
- Provide sign out to the ICU team using the transfer of care sheet
- Ensure that the patient is hemodynamically appropriate and ventilation is adequate before transferring care to the ICU team.
- Please return all anesthesia equipment to the anesthesia workroom and return the defibrillator to the operating room and plug into power source.
- Complete anesthesia documentation in LLEEP including the transfer of care and sign out follow-up notes.

ADULT APPENDIX

Basic TEE Views



Coronary Artery Perfusion Areas