Cardiac Transplant Protocol for Anesthesia

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When a potential heart donor has been identified, the transplant coordinator will notify the attending cardiac anesthesiologist on call. The OR control desk will notify the senior anesthesia resident on call. In addition, the TEE resident will be notified. The recipient patient should be admitted to the CTICU for preoperative preparation. All relevant medical information regarding the recipient should be readily available in the CTICU. If OR 18 is available, this is the preferred room.

Preoperative Considerations

Line placement:

- May be done either in the CTICU or in the OR or some combination.
- Arterial line: The left brachial artery is the preferred site in case the right axillary artery will be used for arterial cannulation. The radial and femoral arteries are acceptable alternatives, keeping in mind that radial lines can be damped in the period immediately following separation from cardiopulmonary bypass. Check with the surgeon to make sure the femoral artery will not be used for arterial cannulation if a femoral arterial line is being considered.
- Peripheral IVs: Two large bore peripheral lines should be placed.
- Central lines: Use ultrasound to scan the right IJ prior to prep. These patients may have had multiple IJ sticks in the past, and may have thrombosed veins or other abnormal anatomy. A MAC catheter is placed as an introducer. We have sometimes placed femoral dialysis catheters for access if the patient has impending renal failure.
- A CCO PA catheter is placed. Keep in mind that many of these patients have a left bundle branch block and can go into complete heart block with advancement of the PA catheter. (Have pacing options available in this situation.)

Other Preop Issues:

- If the patient has an AICD and/or pacemaker make sure the EP service has been called to turn off the defibrillator and reprogram the pacemaker if necessary. This can be done in an ICU preop, or in the OR during line placement.
- If the patient is on a continuous inotrope infusion, continue this until CPB is initiated.
- It is generally a good idea to have respiratory therapy set up an ICU ventilator ready for inhaled epoprostenol in the room behind your anesthesia machine. If the decision is made to use inhaled iEPO, the attending anesthesiologist needs to put an EMR order in or give a verbal order to the OR pharmacist. Use of iEPO is not mandatory but should be strongly considered upon the presence of abnormal preoperative right ventricular function and/or significantly elevated pulmonary vascular resistance.

- If the patient is on Coumadin, and has not received vitamin K, have 10 mg available to give in the OR. Put in a 50-100 ml bag and infuse over 15 minutes. If the INR ≥ 2.0, the use of IV bottled Prothrombin Complex Concentrate may be indicated in the post pump period.
- Make sure all blood and blood products are ordered. Six units PRBCs are ordered and prepared as a standard for these cases. Preparation and use of cryoprecipitate, FFP and platelets will be individualized based on each patient's preoperative and postoperative coagulation studies. Refer to the CASECAG post–CPB transfusion algorithms for guidance on use of hemostatic blood components.
- Two doses of IV Solumedrol 500 mg is typically ordered preop by the transplant team and should come to the OR with the patient.
- Consider giving a dose of Reglan and Pepcid if the patient is not NPO (this is generally the case).

Operating Room Set-up

- The setup is similar to the standard cardiac setup. Drips to be ordered include: neosynephrine, epinephrine, dobutamine, norepinephrine, dopamine, vasopressin, milrinone, NTG, regular insulin, TXA. (Have milrinone , dobutamine, dopamine available but not opened or spiked – use will vary with patient and attending preferences.) Methylene blue (1-2 mg/kg) has sometimes been used in the past, but you don't need to set it up ahead of time. Make sure you have at least 3 bags of KCL 40 meq (in 100 ml).
- You will need a lot of Alaris pumps – usually a bank of 5 will be provided by the workroom staff, and the patient will come with several more from the ICU.
- TEE machine and probe.
- An underbody water circulating pad or forced air convective blanket based warming system will be used for each OHT patient.
- IV tubings - 2 for peripheral lines.; 2 lines for MAC catheter - at least one of these should be on a hot line with blood tubing; VIP line on mini dripper; triple set for A-line and PA catheter. Also, have Level-1 or Belmont set up (check with your attending).
- Cerebral oximetry.

Anesthetic Induction/Maintenance

- Most anesthesiologists will induce with etomidate, midazolam, fentanyl. Muscle relaxation is typically with rocuronium or succinyl choline. Other intravenous anesthetic agents may include propofol. Full stomach precautions should be used as needed.
- It may be beneficial to start dopamine or epinephrine (in low dose) to support the heart during induction and the prebypass period.
- Maintenance is with either inhalational agent or TIVA. An example TIVA regimen (Ed Avery's) would be to combine Fentanyl (50 µg/ml) 40 mls plus Midazolam (1 mg/ml) 10 mls together in a 60 ml syringe (total volume 50

mls with a fentanyl concentration of 40 µg/ml and a midazolam concentration of 0.2 mg/ml); this is delivered as an infusion via a syringe pump at a rate of 10-15 mls/hr. Alternatively, the fentanyl + midazolam infusion can be run at 5 mls/hr along with a propofol infusion of 50 µg/kg/min.

- Most of these patients will not tolerate laying flat so anesthetic induction may have to be initiated with the patient in a head-up position. The Trendelenburg position is rarely necessary for central line placement in this patient population.

- Antibiotics should be given prior to skin incision. Most of these patients will get either cefuroxime and vancomycin or vancomycin and Zosyn. Discuss with surgical team.

- TXA protocol used.

- Solumedrol 500 mg IV should be given around the time of anesthesia induction.

- Hypotension can be multifactorial, but is frequently related to the use of ACE inhibitors, ARB's, and milrinone. The vasodilatation induced by these agents can exacerbate anesthetic induced vasodilatation. Frequently an inotrope such as epinephrine will help to support the blood pressure as well as maintain the cardiac output until the patient can be put on bypass. An agent such as vasopressin or norepinephrine may be needed if the SVR remains excessively low. Methylene blue 2 mg/kg over 10-20 minutes is also sometimes helpful in the setting of vasoplegia. A maintenance infusion of methylene blue can also be initiated at a dose of 1-1.5 mg/kg/hr. TEE can be useful to assess volume status and changes in contractility.

- If the time from anesthetic induction to institution of cardiopulmonary bypass is going to be prolonged (e.g. donor heart on delay, difficult sternal reentry on redo) most patients will benefit from inotropic support. This improves renal and other organ perfusion, and helps to prevent the development of metabolic acidosis.

- Prior to CPB, discuss management of the PA with the surgeon. Some surgeons request that it be pulled back to 15-20 cm. Other surgeons want the PA catheter left in the field – they will feed it through the donor heart for you. Either way, you will have to move your drips from the VIP to the sideport of one of your central lines. Also turn stopcocks on CVP and PA transducers so that there is no flow into sterile sheath or field.

Cardiopulmonary Bypass

- This period is managed as with any type of cardiac case. Vasopressors may be needed for blood pressure support in many instances.
- Tight glucose control is important and the blood glucose should be kept below 180 mg/dl with insulin boluses or an infusion. Because of the steroid load, almost all patients will require an insulin drip.
- Potassium will tend to drop because of the insulin infusion and any mannitol induced diuresis. Since no cardioplegia is administered during heart transplants, you will most likely have to supplement potassium on pump.
- Order and have in room the desired blood products, in preparation for coming off pump.
- If inhaled epoprostenol is planned, it should be prepared for use. Remember that once you come off pump and are using the ICU ventilator, you will have to switch to TIVA.
- **Solumedrol 500 mg should be given after aortic crossclamp removal.**
- Prior to separation from cardiopulmonary bypass preemptive inotropic support should be started (i.e. epinephrine at 0.05-0.1 mcg/kg/min). This is especially important if the ischemic time is greater than 3 hours.
- Prior to separation from bypass TEE should be used to confirm adequate de-airing of the heart. Air has a tendency to make it's way down the right coronary artery leading to right ventricular dysfunction. If this does occur, the systemic pressure should be raised to at least 80-90 mmHg to drive the air bubbles through the coronary circulation. This should be followed by a recovery period while still on bypass.

Separation from Bypass

- Once the heart is ejecting, and the SVC cannula has been removed, float the PA catheter back into position.
- In most cases, the patient's cardiac status should be much improved following transplantation. Preservation of right ventricular function becomes a major priority. This goes along with aggressive management of pulmonary hypertension.
    - We generally start Epi (.05- 0.1 mcg/kg/min) prior to coming off pump.
    - Inhaled epoprostenol and/or milrinone may also be used to reduce PA pressures and support RV function.
    - Dobutamine can be used as an alternative or in addition to Epi (start at 5 mcg/kg/min).
    - The patient should be mildly hyperventilated (PaCO2 of 35) to also reduce pulmonary vascular resistance, and to compensate for lactic acidosis.
- The right heart is monitored in several ways. The CVP is monitored continuously. The right heart can be seen on the surgical field. TEE is used to monitor size and function of the RV, and to assess for tricuspid regurgitation. If there is evidence that the right heart is failing, then it must be promptly addressed

(e.g. increasing epinephrine dose, adding milrinone, assessing that oxygenation and ventilation is adequate.

- Pressor support is frequently needed for vasodilatation related to ACE inhibitors, long bypass times, etc.
- Many patients (especially redos and device explants) will be coagulopathic. Keeping the patient warm (under body heating matress, fluid warmers, increased ambient temperature) can prevent exacerbation of any ongoing coagulopathy.

Coagulation Issues:

- Bleeding post bypass can be significant. There can be surgical bleeding from one of the many suture lines. Some patients are redo-sternotomies. Many patients are on Coumadin preop. Patients with right heart failure may not have normal production of liver dependant coagulation factors. Then there is the usual dilutional effect of CPB, and washing out of clotting factors by the Cell Saver.
- When patients have been on preoperative coumadin, Vitamin K is administered, but this won't help the acute coagulopathy issue. FFP is the mainstay of treatment. Another adjunct is Kcentra (a 4 factor prothrombin complex concentrate). Dosing is as follows:

Pre-treatment INR	2–<4	4–6	>6
Dose* of Kcentra (units† of Factor IX)/ kg body weight	25	35	50
Maximum dose‡ (units of Factor IX)	Not to exceed 2500	Not to exceed 3500	Not to exceed 5000

Note: Dosing is based on body weight, but maxes out at 100 kg.

Kcentra comes as 500 and 1000 unit vials. Administer at rate of 350 ml/hr.

- Even when patients are not on preexisting blood thinners, FFP and platelets will most likely be required post CPB because of dilutional issues. Cryoprecipitate or fibrinogen concentrate will be administered based on fibrinogen levels or ongoing coagulopathy.
- Coagulation status is monitored by use of core lab results, TEG, and ACT. Also, see Ed Avery's protocols.

<u>TEE Post Implantation</u>:

- LV and RV function are monitored by TEE. Tricuspid regurgitation may worsen if the RV dilates.
- Suture lines can be assessed to look for areas of stenosis – by visualization and by color flow.

Lactic Acidosis Post Transplant:

- Lactic acidosis is very common post transplant – >90% of patients. It starts near the time of initiation of inotropes, peaks at 4-8 hrs later, and lasts 12-24 hrs.
- It has been hypothesized that the LA commonly seen in HTX is due to a Type B mechanism (Aerobic) – specifically as a result of beta 2 stimulation of glycolysis in skeletal muscles by the commonly used inotropes such as epi. LA after heart transplant seems to occur despite good cardiac index and oxygen delivery, and is correlated with onset and dose of inotropes.
- An additional factor may be the use of high dose steroids. Steroids are known to increase beta 2 receptor numbers and function – so thus may exacerbate the effect of the administered B2 agonists.
- Decreases in hepatic or renal function will also slow clearance of lactate.
- Treatment:
    - Hyperventilation. (This must be continued in ICU postop!)
    - Weaning B2 agonists as appropriate.
    - Na Bicarb treatment is controversial. It may be better to administer Na Bicarb by slow drip rather than bolus, so that generated CO2 can be ventilated out of the system. For example – take a 100 ml NS bag, remove some fluid, and add 2 amps bicarb. Attach a mini-dripper, and drip slowly. No need to drip through a pump.

Glucose and Potassium Issues Post Pump:

- Glucose will climb post pump – from the combined effects of Beta Agonist and steroid administration
- Serum potassium will drop post pump from the combined effects of insulin, Beta agonist, diuresis and hyperventilation.
- Insulin drip will need to be up titrated as needed. However, beware bolusing more insulin if the potassium is < 4.0 meq/l.
- It is not uncommon to require large dose of potassium to maintain K > 4.0 meq/l post pump – 80-120 meq. Have a 40 meq KCL bag on an Alaris pump module, ready to go.
- Because of glucose, potassium and lactic acidosis issues post pump, it is a good idea to check ABGs every 20-30 minutes post pump.