VA ECMO for Lung Transplantation at VGH

Background

Mechanical cardiopulmonary support (ECLS) with cardiopulmonary bypass (CPB) is necessary during a minority of our lung transplant cases at VGH (up to 40%). VA ECMO is an alternative to CPB with both advantages and disadvantages. CPB and VA ECMO both require cannulation of large vascular structures, a pump and an oxygenator. The main difference between CPB and VA ECMO is that VA ECMO does not contain a venous reservoir or cardiotomy suction lines. Without a venous reservoir, blood is in constant motion with less stasis and therefore permitting a lower ACT (200-260) with less associated bleeding, transfusion requirements and associated complications. The lack of an air-blood interface is thought to lead to less activation of inflammatory mediators with less associated primary graft dysfunction (PGD) and less postoperative organ dysfunction including less renal injury (Aigner et al., 2007; Bittner et al., 2007; Diso et al., 2010).

As a result of fewer perceived complications associated with VA ECMO many high volume transplant centres in North America and Europe have switched to VA ECMO as their preferred mode of cardiopulmonary support. Data from these centres, however, needs to be evaluated with caution as all these studies are retrospective and without randomization. In Munich, they have found that CPB had greater transfusion requirements and longer hospital length of stay without a mortality benefit (Hoechter et al. 2015). In Hanover, they also found greater transfusions, greater need for dialysis and a mortality benefit (Ius et al. 2012). At the University of Pittsburgh Medical Center (UPMC) they found a decrease in re intubation and tracheostomy rates and need for postoperative dialysis in the ECMO group without any difference in transfusion rates, PGD rates, or mortality rates (Bermudez et al., 2014). The University of Toronto group found a decrease in blood product requirements, ventilation time, and hospital stay but no statistically significant difference in mortality (Machuca et al. 2015).

Despite all the proven benefits of ECMO there is a high degree of safety and versatility built into CPB support. The venous reservoir makes air entrainment a non issue while any air entrainment on VA ECMO can have catastrophic consequences. A venous reservoir allows for fast and easy volume administration and cell salvage through cardiotomy suction which proves highly beneficial in the setting of acute hemorrhage or in cases with extensive bleeding such as with challenging pleural dissections. In cases with heavy bleeding cell salvage is utilized which in turn can lead to dilutional coagulopathy and thrombocytopenia. Therefore in cases with expected large blood losses VA ECMO may be less advantageous. CPB also has an advantage with respect to cardiac decompression. VA ECMO may not provide adequate cardiac decompression in the setting of limited or difficult dissections, a crowded mediastinum or elevated pulmonary artery pressures with right ventricular enlargement. CPB is also necessary in cases requiring a concurrent cardiac procedure.

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Cannula and Cannulation Sites

- Standard central cannulation at ascending aorta and right atrial appendage
- Peripheral (femoral) cannulation if central cannulation contraindicated
    - Calcified aorta
    - Redo sternotomy with extensive scarring at cannulation sites
    - Pre-induction ECMO required
    - Bilateral thoracotomy surgical approach
    - Peripheral cannulation if postoperative VA ECMO highly anticipated

Indications for Conversion to CPB from VA ECMO

- Inadequate drainage from sequestration and cannula position, or kinking
- Inability to maintain adequate flows and partial pulmonary perfusion
- Severe ongoing hemorrhage with inability to maintain adequate ECMO flows
- Air entrainment into ECMO circuit (vascular injury or perforation)

Protocol for Conversion to CPB

- Anaesthesia will give additional heparin to achieve an ACT > 400.
- CPB pump brought into the room. CPB lines passed in a sterile fashion into surgical field. Adapters passed to the surgeon.
- Anesthesiologist prepares for temporary cessation of VA ECMO by supporting cardiac function (rate, rhythm, inotropy), vasomotor tone and volume status.
- Perfusionist comes off VA ECMO, lines are cut and spliced into CPB circuit.

Possible Contraindications VA ECMO

- Other scheduled open cardiac procedures at time of transplantation.

Anesthetic Modifications

- Largely unchanged from a standard double lung transplant setup
- An additional cardiac anesthesiologist must be immediately available if VA ECMO is required.
- Vascular access
    - Perfusion is unable to add volume to the VA ECMO circuit (high risk of air emboli) therefore anesthesia must maintain normovolemia with fluid administration through the patient's established vascular access. Multiple large bore IV cannula or central large bore access (MAC catheter 9 Fr or 8 Fr cordus) is necessary especially if bleeding occurs or venous drainage is compromised with mediastinal retraction.
    - Consider having the rapid infuser in the room primed and attached
    - Consider left-sided neck lines in case RIJ access required for postoperative VV ECMO
- Anesthetic modality
    - Total intravenous anesthesia (TIVA) is preferred with propofol because of the unreliable delivery of sevoflurane through the oxygenator.

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    - In cases of decreased pump flow for partial pulmonary perfusion or hypovolemia, volatile anesthesia delivered through the hybrid pump could be inadequate to maintain a reliable depth of anesthesia.
- Heparinization
    - The VA ECMO setup including cannulae and circuit are heparin coated. We have agreed upon partial heparinization for these cases with a target ACT of 200-220. During weaning from VA ECMO the target ACT will be greater than 250.
    - Initial heparin dose of 80-100 U/kg (5500-7000 U for 70 kg patient)
    - Heparin infusion of 1000 units per hour delivered through central line
    - ACT and ABG checked at least every 30 minutes from the femoral line
    - If emergency transition to CPB required, additional heparin will be administered to a target ACT > 400 and an ACT checked if time permitting. 10,000 units of heparin is present in the venous reservoir.

Management of ECMO Flow and Ventilation

- Stage 1: cannulation to reperfusion of first allograft
    - Full ECMO flow as calculated by perfusion
    - No requirement for mechanical ventilation
- Stage 2: reperfusion of first allograft until separation from ECMO
    - Partial ECMO flow in order to establish partial perfusion through new allograft. Confirm partial flow by pulsatility of PA trace. Flow should not fall below 2 LPM. If RPMs need to be dropped to maintain pulsatility or full flow this is an indication that volume administration or cannula/mediastinal repositioning required.
    - Mechanical ventilation of allograft in a protective manner with conservative FiO2 (<60%)
- Stage 3: weaning from VA ECMO (see Appendix 1)
    - Additional heparin given to maintain ACT 250-300. An ACT > 250 must be documented prior to weaning.
    - Establish two-lung ventilation according to best practice in a protective manner.
        - Gentle and full requirement of allografts
        - Tidal volume < 8 mL/kg, FiO2 < 70%; RR and I:E adjusted according to requirements
        - Consideration of inhaled nitric oxide
        - Airways suctioned, bronchoscopy as necessary
    - Start to wean as normal by decreasing the pump flow in 1 LPM increments. Perfusion will wean the FiO2 and sweep rate as required.
    - If patient parameters are acceptable, separate from ECMO. Arterial and venous lines will be clamped, RPM at zero, gas flow off.
    - Anesthesiologist to assess gas exchange with an ABG at the 5 minute mark. During this period the perfusionist will flash the lines every 30 seconds by opening the venous line, increasing RPMs, opening the arterial line and transfusing about 100 mL of circuit blood. This is to prevent the blood from becoming stagnant in the circuit and clotting.

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- A repeat ABG will be drawn at 10 and possibly 15 minutes if gas exchange and/or hemodynamics are not sustainable from native cardiac and pulmonary function. For example, if an FiO2 > 70% is required then postoperative VV ECMO should be considered.
- At 15 minutes following the separation from ECMO the patient MUST either be de-cannulated or full ECMO flow reinstated whilst peripheral VA or VV ECMO is established.

Other Considerations

- Clear and frequent communication between surgery, perfusion and anesthesia is critical to the success of VA ECMO.
- Low flow emergency. This is often initially declared by the perfusionist, however other indicators may include mixed venous desaturation (low SvO2), cerebral desaturation, or other markers of impaired perfusion including a rising lactate. Continuous cardiac output monitoring is not helpful.
  - Causes of a low flow state may include: hypovolemia, cannula malposition, impaired venous drainage from mediastinal retraction, vasoplegia, circuit/oxygenator clot.
  - Treatment measures may include correcting the potential etiologies as mentioned above including volume administration
  - Having immediate access to colloid and blood products as necessary is a MUST.
- Salvaged blood is not immediately available to be returned to the patient (no pump suction or venous reservoir). Cell salvaged blood is devoid of clotting factors and heparin. In case of excessive surgical bleeding be prepared to administer volume more frequently and in greater amounts. Be prepared to administer heparin more frequently. Be prepared for more pronounced coagulopathy and need for additional transfusion products. Consider more frequent monitoring of coagulation. A second anesthesiologist and anesthesia assistant is critical in this circumstance.
- Antifibrinolytic therapy: Hyperfibrinolysis is a potential concern during VA ECMO. Low dose, prophylactic tranexamic acid may reduce intraoperative bleeding in this setting. The routine administration of TXA is not recommended but if felt necessary 10-15 mg/kg TXA (1-2 grams) is a good starting point. Additional TXA can be administered if evidence of hyperfibrinolysis is present on ROTEM.

Appendix 1: Weaning from VA ECMO Rationale

- VA ECMO weaning differs from CPB weaning in the ability to reliably assess native lung gas exchange because a transient separation from VA ECMO (or low flow state) is not safe due to incomplete heparinization and risk of thromboembolism. To facilitate a timely wean from VA ECMO in the operating room a simplified protocol is warranted. The issue with assessment during partial VA ECMO flow is in avoiding either over- or underestimation of native lung function. Native lung function can be underestimated if

the oxygenator is “turned off” while on partial flow (producing complete shunt) and overestimated if oxygenator settings are set too high (FiO2 100%, high sweep speed). Expert opinion is lacking with regards to assessing native lung function while weaning from VA ECMO. To reconcile this issue we recommend setting the oxygenator to the minimum settings while weaning to maintain acceptable arterial oxygenation and pH (arterial PaO2 90-120, PaCO2 35-45, pH > 7.35). If native cardiac function and metabolic rate remain unchanged and no metabolic derangements exist then this minimal oxygenator support will ensure no venous admixture is shunted to the arterial system while on partial VA ECMO flow during weaning. More sophisticated weaning alternatives exist and likely provide more objective assessment of native lung function but are onerous, time consuming and potentially impractical in the operating room environment. Training perfusion, surgery and anesthesia on a simplified protocol will likely ensure stronger adherence, understanding and overall acceptance into local culture.

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