Fellow's Reference for ECMO-related Queries

Prepared by Alvey, Abu-Sayf, Al-Jasmi, Razvi, Abrencillo

How to use this document:

1. This is not a substitute to learning ECMO-related physiology or understanding oxygen consumption and delivery. In fact, it is hard to understand the differentials if you do not read-up on ECMO. Resources are available in camtasia folder on recorded lectures, power point presentations under shared folders and on-line resources (www.elso.org).
2. This document is by no means a complete representation to solutions to any one problem noted below as each problem tend to be intertwined with another.
3. The document is not an algorithm but rather an "aide to thinking". Hopefully, to help us generate plausible etiologies with the ultimate goal of properly triaging queries, facilitating interventions and/or involving multidisciplinary teams.

Glossary of Terms

Sweep gas: determines CO_2 elimination. CO_2 elimination is dependent Fresh gas flow rate but independent on blood flow rate
Flow rate: determines oxygenation. Oxygenation is dependent on blood flow rate but not fresh gas flow rate
Bladder Chamber: a reservoir for blood before the pump used to catch air and help provide constant volume to the pump
Centrifugal pump: imparts centrifugal force to fluid/blood causing increase in pressure and kinetic energy radially. This ultimately cause displacement of fluid which creates a suction effect
Oxygenator: "external lungs"; this is where gas exchange happens. The system is usually divided to pre and post oxygenator
Oxygen rated flow: manufacturer-set-predicted PaO_2 on post oxygenator blood at a given flow and hemoglobin
Delta P: Pressure gradient across the oxygenator (pre and post).
Re-circulation: blood that goes around the circuit and not delivered to patient
Chattering: Low amplitude shaking of tubes representing high variation in flow
Cavitation: intermittent collapse of the vessel which may lead to hemolysis
Cilley Test: Increase FiO_2 to 1.0 with no other changes. Positive test is rapid increase to SaO_2 100%

Problem	Symptoms/Signs	Differential	Possible Solutions	Who to involve
Decreasing Patient PO2. Think of: Increase O2 consumption, decrease O2 delivery, decrease exchange *As a general rule an <u>arterial Sats of 85%</u> patients on VV ECMO is <u>acceptable</u> if the <u>patient is **perfusing**</u> (no worsening organ dysfunction, not forming lactate)*	Cyanosis Acidosis Lethargy Poor perfusion Worsening PO2 and O2sat on ABG	**Problems related to Increase O2 consumption:** Seizures, Sepsis, Agitation **Problems related ECMO:** Inadequate blood flow, Sweeper gas line malfunction, Oxygenator failing, FiO2 of sweep gas low **Problems related to the Native lung:** Pneumothorax, ET tube malfunction, pleural effusion, hypervolemia, increased shunting **Problems related to CO:** Abdominal compartment, decreased CO, Pericardial tamponade, Suspected cardiac shunt vs valvular defect, acute right heart failure, **O2 carrying capacity:** Anemia, Methemoglobinemia (from NO or Nitroprusside) **Recirculation:** Most common in Jugular-Femoral and Femoral-Femoral VV circuit .Least common in Femoral- Jugular VV circuit	Treat underlying cause Increase the flow, Replace or fix the line, Replace the oxygenator, Increase FiO2 *know the native lung parameters and compliance before the acute event, resting lung strategy may worsen hypoxemia and increase shunting and pulm pressures* Diuresis, reintubation, increasing PEEP or FiO2, extreme caution on invasive procedures *Review the last echo and the Arterial line parameters before the event* Consider repeating Echo and vasopressors, consider possible conversion to VA ECMO *Although the cardiac literature asks for Hb > 10, there is no data to support against or for transfusion with Hb < 7.0 unless it is a method to increase CO.* Transfusion of prbc, methylene blue Consider switching circuit or even adding another venous line. AVLON catheter might be considered.	Fellow/Primary team with RT to make medical decision involving increasing vent support Call Perfusion and CTS for gas, recirculation and oxygenator problem **Before placing any tubes (catastrophic bleed), if stable, please contact CT surgery. If unstable, call CVICU, team to help out** Call CT surgery if lines needed to be added or changed
	Patient looks well	Improved CO (Hemodynamics is improved therefore pushing more blood to the recovering lung)	Consider ECMO weaning	

Problem	Symptoms/Signs	Differential	Possible Solutions	Who to involve
PO2 is increasing	Cyanosis Acidosis Poor perfusion Hemodynamic instability	**Problems related to O2 consumption/delivery:** Sepsis with peripheral shunting, tissue death with decreased O2 consumption, central shunting	Treat the underlying reason, monitor clinically for fasciitis, gangrene or worsening sepsis, central shunt is hard to treat	**Before placing any tubes (catastrophic bleed), if stable, please contact CT surgery. If unstable, call CVICU, team to help out**
		Problems related increasing ECMO flow secondary to decrease CO: MI, cardiac stunning, cardiac tamponade (air,fluid), Lung (air,fluid), hypovolemia	Treat underlying cause, increase ECMO flow, consider converting to VA, administer volume or blood	
	Patient is looking well	Improving native lung compliance (better TV, lower pressures)	Consider lowering FiO2 on the ECMO and start weaning	
		Cardiac stunned with adequate VA flow	Continue ECMO Full support	
Decreasing CO2	Patient is apneic and alkalotic	CO2 in sweep gas too low	Increase CO2 in sweep	Call Perfusion to adjust CO2 in the blender or to change the flow
		Sweep gas flow too high	Decrease flow	
		Overventilation	Adjust vent settings to decrease MV	
		Improving lung function	Check compliance on vent and ABG while on 100% FiO2 (Cilley Test) on vent to assess lung recovery → consider weaning	Call RT for Vent changes
	Patient tachypneic	CO2 in sweep gas is too high or Sweep gas flow too low (acidemia with compensatory tachypnea)	Decrease CO2 in sweep gas or Increase gas flow	
		Underventilation	Ensure ETT in position Adjust vent to increase MV	

Problem	Symptoms/Signs	Differential	Possible Solutions	Who to involve
Increasing PCO2	Tachypnea, acidosis, agitation, hypertension	Oxygenator failure CO2 in sweep gas too high or Sweep gas flow too low Patient agitated Increased metabolic activity ETT positioning problem and/or Increasing airway pressures in ventilator	Look at oxygenation, delta P across membrane (prob clot if high) Decrease CO2 in sweep gas or decrease gas flow Address source of agitation look for signs of sepsis, overfeeding Adjust ET and/or look for pneumothorax, hemothorax, effusion	Call Perfusion to adjust CO2 in the blender or to change the flow Call RT for Vent changes
Coagulation problems – difficulty maintaining PTT	Too High Too Low	Error in lab testing, lab was drawn incorrectly, error in heparin dosing Decrease in coagulation factors DIC Lab error, collection error, dosing error Recent transfusion of blood products Heparin resistance	Double check heparin dose, location lab was drawn, etc. Assess for Vit K deficiency, liver dysfunction, consumptive coagulopathy r/o sepsis, r/o circuit coagulopathy (diagnosis of exclusion) Double check heparin dose, location lab was drawn, etc. Recheck PTT after completion of transfusion Assess for antithrombin deficiency (esp in malnutrition, liver/renal failure) and supplement with FFP or factor concentrate; look for drug interactions	RN and Pharmacy for additional blood draws/ work-up and for dosing error respectively If circuit is cause – call Perfusion and CT surgery for a circuit change

Problem	Symptoms/Signs	Differential	Possible Solutions	Who to involve
Bleeding	Visible bleeding, expanding hematoma, drop in Hgb, MAPs decreased, signs of hypoperfusion	Coagulopathy: iatrogenic from anticoags vs consumptic (DIC vs circuit). Bleeding from surgical site hypertension	Decrease heparin dosing Assess for sepsis, circuit coagulopathy (diagnosis of exclusion) Hold pressure. Consider Amicar, FFP, platelets control BP	Call CT surgery. Coordinate with CVICU team for threshold of transfusion
Hemolysis	Plasma free hemoglobin > 50 mg/dl, Tea colored urine	Pump Over occluded, clots in patient, clots or kinks in system, centrifugal pump issue	Change pump and inspect for clots in kinks in circuit, hemofilter or patient	CT surgery and Perfusion to help with possibly changing lines or pumps respectively
Hypertension	Increased BP	Fluid overload, pain, agitation, idiopathic, improved Cardiac Output(VA ECMO), high pump flow(VA ECMO), steroid use	Diuretics/CVVHD, treat pain, sedatives, anxiolytics, Anti HTN meds, Decreased ECMO flow	MICU team
Hypotension	Decrease BP	Massive Hemorrhage Hypovolemia, capillary leak syndrome, sepsis Low pump flow	**Emergency!!!** Supportive resuscitation Treat underlying cause Increase pump flow if adequate arterial volume	For massive bleeding CVICU to be involved STAT and CT surgery to be involved immediately
Arterial line tracing flat (loss of pulsatility)	VA ecmo: patient well perfused VA ecmo: patient not perfusing VV ecmo: not good	Too much ecmo support or profound depression of CO Code or precode situation Code or precode situation	Maybe appropriate if “resting” the myocardium NO chest compression ACLS	If patient is sick, all services should be notified and critical care team at bedside
Decreased Urine Output	Oliguria/anuria	Hypotension, Hypovolemia, decreased CO, ATN	Treat underlying cause, might need to augment CO (watch out for hypoxia i.e. more de-oxgenated blood pushed to sick lung), consider HD	MICU team in coordination with CT surgery if planning to place a dialysis catheter

Problem	Symptoms/Signs	Differential	Possible Solutions	Who to involve
Seizure	Repetitive involuntary movements, Increased BP, Decreased SVO2, Cyanosis, Hypoxia	Ischemic brain injury, Cerebral edema, Infarction, Intracranial hemorrhage	Anticonvulsants, treat the underlying cause. Must rule out brain bleed	MICU team
Oxygenator Failure	Low pump atrial PO2, Decreased PCO2 clearance Increased pressure gradient across membrane (normal delta P = 20 to 40mmHg). Leads to hemolysis, elevated fibrin split products, worsening thrombocytopenia	Low FiO2, high PaCO2, Sweep gas line to oxygenator is loose, disconnected or cracked Oxygenator Clotting off, air in the top of oxygenator or blood leaking from the exhaust gas port due to membrane leak or complete rupture Oxygen rated flow/Efficiency exceeded	Increase FiO2 and check oxygen tank, increase sweep Gas if not at maximum, reattach gas line to oxygenator Replace oxygenator Check manufacture rated oxygenator flow and decrease blood flow if indicated	Involve Perfusion for replacement of oxygenator or increase change gas setting
Low Flow	Negative pressure alarm (Bladder or venous line pressure alarm) Positive pressure alarm (oxygenator alarm)	Venous/Cephalic catheter malposition or kinked, clot in the system Intravascular volume depletion Inadequate venous return due to patient condition(pericardial tamponade, pneumothorax, increase IA pressure) Pressure alarm limit set too low, pressure transducer malfunction, flow is adjusted too high Malposition and kinks in the tubing/cannula, Clot in oxygenator system, clot in art line filter, wrong alarm setting, alarm malfunction	Catheter needs to be repositioned, check for clots Consider fluid bolus Address the underlying issue. Can bolus in the meantime Adjustment of alarms, flush transducer, lower flows Remove kinks, check cannula position, inspect for clots and replace as needed, check alarm settings	Call CT surgery for readjustment **Before placing any tubes (catastrophic bleed), if stable, please contact CT surgery. If unstable, call CVICU, team to help out** Call Perfusion for alarms and flow adjustments

Short et. Al. ECMO Specialist Training Manual. *Chapter 25. Trouble Shooting: The What-If's of ECMO*. Feb 2010.

Problem	Symptoms/Signs	Differential	Possible Solutions	Who to involve
Exchanger water heater	Blood in water line	Crack in heat exchanger water/blood seal	**Emergency!!!** turn off the heater immediately, replace the heat exchanger	Involve Perfusion as soon as possible if blood is in the water line
	Water dripping	Leak	Change circuit	
	Temperature alarm: Consider if patient is cold or Hot (patient will usually follow the temp set it ECMO)	Temp set wrong, heater pump malfunction, large amount of cold water adder to reservoir, tem adjusted, water level low, consider new fevers	Check set temperature, replacement of water heater, add water to heater, check exhaust fan, check connections and plugs of water heating unit	
Air in Circuit	Preoxygenator(air in venous line)	Open/Cracked stopcocks, connectors in venous lines	Air aspiration from bladder, top of oxygenator	Any Air in the system, Perfusion needs to be involved
	Oxygenator	Air from IV infusion, air leak (venous line oxygenator, bladder), priming problem	Air aspiration (risk of embolism), oxygenator replacement, monitor for recurrence	
	Post-Oxygenator	Air from IV infusion lines, leak from venous line passing through oxygenator, gas outlet obstruction	Aspirate, stop airleak, replace oxygenator, calmp ECMO if risk of air reaching the patient	
	Arterial Line	Massive air pumped from venous side	**VA ECMO Emergency!!!** arterial line needs to be manually kinked to stop air flow into arterial system	
Pump Failure	Pump without power, Pump shutting off	Unplugged, battery malfunction, specific switches off, unsecured lids, alarms and knobs not in proper setting	Check connections, use portable power supply, hand cranking , reset the system, check for air and switches	Involve Perfusion STAT
	overheated pump	Wet connections	Check connections	
	Pump rotating but no flow	Malfunction, inadequate seal	Adjust occlusion/seal	

Problem	Symptoms/Signs	Differential	Possible Solutions	Who to involve
Negative Pressure Monitor Failure at the bladder box (venous blood reservoir)	Cavitation (space free of fluid) as pump turns Pump not stopping when venous line clamped No alarms Blood on floor	Obstruction just after bladder (kicks or clots), malfunction of bladder or pressure transducer Equipment or wrong alarm threshold Leak in bladder	Inspect for obstruction prior to pump, change bladder, re-zero pressures, inspect pressure transducer lines, Change bladder	Ask nurse to inspect for clots close to the bladder. Call Perfusion to inspect bladder, lines and pressure settings
Pump Failure	Pump without power Pump shutting off overheated pump Pump rotating but no flow	Unplugged, battery malfunction, specific switches not on Unsecured lids, alarms and knobs not in proper setting Wet connections Malfunction, inadequate seal	Check connections, use portable power supply, hand cranking Reset the system, check for air and switches Check connections Adjust occlusion/seal	Involve Perfusion STAT
Negative Pressure Monitor Failure at the bladder box (venous blood reservoir)	Cavitation (space free of fluid) as pump turns Pump not stopping when venous line clamped No alarms Blood on floor	Obstruction just after bladder (kicks or clots), malfunction of bladder or pressure transducer Equipment or wrong alarm threshold Leak in bladder	Inspect for obstruction prior to pump, change bladder, re-zero pressures, inspect pressure transducer lines, Change bladder	Ask nurse to inspect for clots close to the bladder. Call Perfusion to inspect bladder, lines and pressure settings