

WakeMed VV ECMO



Contents:

- VV ECMO Indications / Contraindications
- Deployment Algorithm
- Order set (Initial version)
- RT Protocol
- VV ECMO Pocket card
- VV ECMO Power point

VV ECMO INDICATIONS

Acute pulmonary disease process that is regarded as reversible!

- PF ratio < 150 (on FiO₂ > 90%)
- Refractory respiratory acidosis < 7.15 or PaCO₂ > 80
- Excessively elevated pPlat > 35 mm H₂O despite (lowVt, paralytics, proning)

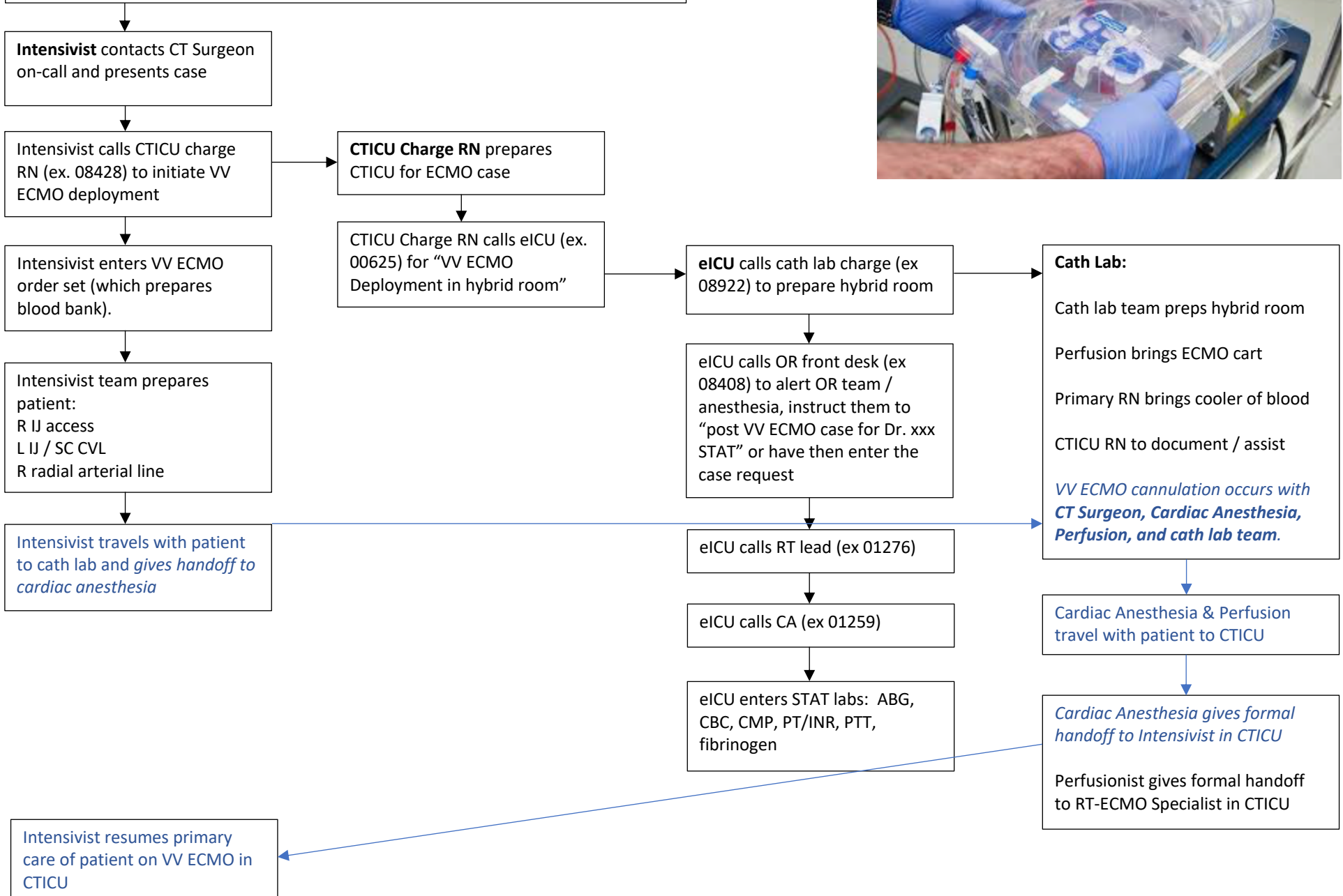
VV ECMO CONTRAINDICATIONS

CONTRAINDICATIONS	Age > 65
Outside hospital transfers	Contraindication to anticoagulation
CNS hemorrhage / tumor	Active malignancy
Prolonged mech vent > 7 days	Comorbidity (< 6 mo life expectancy)
Cardiac arrest w anoxia concern	End-stage lung disease
Major immunosuppression	BMI > 50
ESRD (relative contraindication)	Significant heart failure (consider VA)

*These are indications / contraindications for VV ECMO at WakeMed. Cases can still be reviewed with Duke for their consideration.

VV ECMO Deployment

Intensivist Internal Case Review (*Please include Dan Fox, Jason Wieland & David Kirk*)
If decision to proceed with VV ECMO initiate pathway below



▼ General

▼ Notify physician

- Notify physician regarding bruising, hemorrhage, bleeding or hematoma formation
Routine, Until discontinued, starting today at 1445, Until Specified
- Notify physician regarding ECMO MD of HCT < 21
Routine, Until discontinued, starting today at 1445, Until Specified

▼ Tubes/Lines/Drains

- Insert arterial line
Routine, Continuous, starting today at 1445, Until Specified
Rt radial artery preferred
- Foley Catheter Insert/Maintain
Routine, Continuous, starting today at 1445, Until Specified
Remove Foley Catheter: Do Not Remove
Indication: Other (see comment)
comment: ECMO
If difficulty placing Foley catheter, place consult for urology
- Do not remove foley
Routine, Until discontinued, starting today at 1445, Until Specified

► Consults

[Click for more](#)

- Consult ENT: Who: WPP ENT; How: Rapid Connect Message; Notification: Routine; Reason for Consult: bedside Tracheotomy
Routine, Once, First occurrence today at 1445
Who: WPP ENT
How: Rapid Connect Message
Notification: Routine
Reason for Consult: bedside Tracheotomy
- Pharmacy Consult; medication dosing; other; Adjust medication doses fo ECMO
Routine, Once, First occurrence today at 1445
- Physical Therapy Evaluate and Treat Reason for Request: Other. See Comment ECMO
Reason for Request: Other. See Comment
- Occupational Therapy Evaluate and Treat ECMO
Reason for Request: Other. See Comments
- Dietitian Consult and Protocols Reason for Consult: Other. See Comments ECMO
Reason for Consult: Other. See Comments
- Spiritual Care Consult Reason for Consult: Other. See Comments ECMO
Reason for Consult: Other. See Comments
- Consult Palliative Care: Who: Transitions LifeCare; How: Rapid Connect Message; Reason for Consult: ECMO
Routine, Once, First occurrence today at 1445
Who: Transitions LifeCare
How: Rapid Connect Message
Reason for Consult: ECMO

▼ Nursing Orders

- ECMO Cannula Care Per Policy
Routine, Until discontinued, starting today at 1445, Until Specified
- Dressing Changes on ECMO Catheters to be performed with ECMO Surgeon at Bedside. Timing of Dressing change to be assessed daily on rounds and will be performed at discretion of ECMO Specialist
Routine, Once, First occurrence today at 1445
- Evaluate for Bleeding/Hematoma q1hr
Routine, Until discontinued, starting today at 1445, Until Specified
- All patient turns to be performed with ECMO Specialist and RT at bedside
Routine, Until discontinued, starting today at 1445, Until Specified
- Initially target RASS of -5 until new RASS target ordered
Routine, Until discontinued, starting today at 1445, Until Specified
- Neuro checks q 2hr
Routine, Every 2 hours, First occurrence today at 1600, Until Specified
- Do not use routine SAT protocol
Routine, Until discontinued, starting today at 1445, Until Specified
- If desired temperature is not reached through ECMO water bath, apply external warming device
Routine, Until discontinued, starting today at 1445, Until Specified

▼ Laboratory

- ▶ STAT Labs [Click for more](#)
- ▶ AM Labs [Click for more](#)
- ▶ Serial Labs [Click for more](#)
- ▶ Blood Products [Click for more](#)
- CTICU RN to send blood products to cath lab in cooler for Adult ECMO Cannulation
Routine, Once, First occurrence today at 1445
- Target Hemoglobin > 7.0 g/dl, PLT > 50k (75k if bleeding complications), fibrinogen >100 (150 if bleeding noted), INR < 2.0
Routine, Until discontinued, starting today at 1445, Until Specified
- Order additional products as stat- RN to notify Transfusion Services they are coming to pick up cooler asap
Routine, Once, First occurrence today at 1445

▼ Radiology

- ▶ Chest [Click for more](#)
- ▶ Abdomen and Pelvis [Click for more](#)

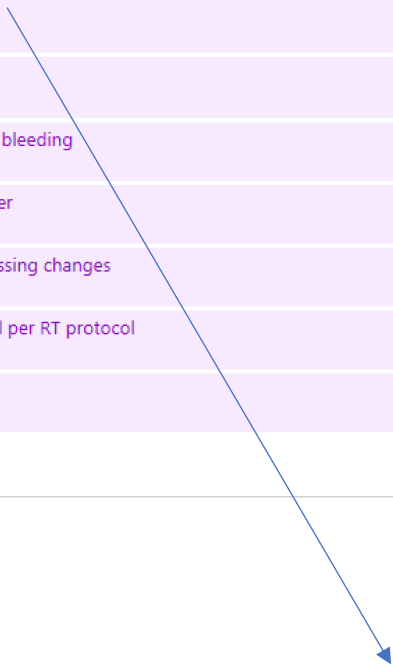
▶ Respiratory

- ECMO Monitoring
Routine, Continuous, starting today at 1445, Until Specified
! Type of ECMO: Veno-venous
Flow settings per ECMO protocol
- Vent Management
! Routine, Continuous, starting today at 1445, Until Specified
- RT Communication: minimize suctioning due to risk of airway bleeding
Routine, Once, First occurrence today at 1445
- RT Communication: enter ECMO flow rate and sweep gas order
Routine, Once, First occurrence today at 1445
- RT Communication: RT Present for all turns/repositioning/dressing changes
Routine, Once, First occurrence today at 1445
- RT Communication: Daily assessment for ECMO Weaning Trial per RT protocol
Routine, Once, First occurrence today at 1445
- RT Communication: do not use routine SBT protocol
Routine, Once, First occurrence today at 1445

▼ **!** Medications

▼ **!** Anticoagulant

- Heparin Anticoagulation Orders (ACS, ECMO Low)
- Heparin Anticoagulation Orders (VTE, AFib, ECMO High)
- Bivalirudin Anticoagulation Orders



Type of ECMO:	Veno-arterial	Veno-venous
Specify Flow Rate:		
! Titrate Sweep Gases To:	PaCO2 40-45mmHg	Normalize Patient pH 7.35 - 7.45
! Patient > or < 20kg?	<20 kg	>= 20 kg - 100% O2
Comments:	Flow settings per ECMO protocol	

✓ Heparin Anticoagulation Orders (ACS, ECMO Low)

✓ Heparin Indication: ACS, ECMO Low

Routine, Continuous, starting today at 1512, Until Specified

Protocol Document Link: \\epicfiles/misc/OrderDocs/Heparin%20ACS%20Dosing%20Nomogram.pdf

Initial dose is 12 units/kg/hour (unless initial dose exceeds 1000 units/hour)

✓ Loading Dose

heparin 60 units/kg loading dose (max 4000 units)

60 Units/kg, Intravenous, Once, Starting 1/14/20, For acute coronary syndrome. Load 60 units/kg (max 4000 units). Use vial for loading dose, do NOT bolus from IV pump.

No heparin loading dose

Routine, Once, First occurrence today at 1512

✓ heparin 25,000 units/500 mL D5W infusion (premix)

12 Units/kg/hr × 70 kg Dosing weight (16.8 mL/hr), Intravenous, Continuous, Starting today at 1530, For 6 hours

For ACS, ECMO Low indication. Refer to Heparin Dosing Nomogram at 6 hours for dose adjustments of maintenance infusion thereafter. Initial

Administration Checklist: * Confirm indication for heparin (ACS, ECMO Low vs. VTE/A-fib/ECMO High) * Is initial bolus ordered and/or given? *

Verify/Program Smart pump setting: -Verify pump library choice matches indication -Verify rounded dosing weight displayed in the Heparin order matches pump weight -Program the pump to match the MAR: dose (units/kg/hr) * Verify Anti-Xa lab ordered 6 hours after Heparin started

✓ heparin 25,000 units/500 mL D5W infusion (premix)

0-40 Units/kg/hr × 70 kg Dosing weight (0-56 mL/hr), Intravenous, Titrated, Starting today at 2115

For ACS, ECMO Low indication. Refer to Heparin Dosing Nomogram for dose adjustments of maintenance infusion following initial infusion. Anti-Xa

follow up Checklist: * Verify Anti-Xa level * Use Heparin Dose Action flowsheet row to determine and document action -Is subsequent bolus

needed? -Is maintenance dose change needed? (units/kg/hr increase or decrease) -Is Heparin being held? * Verify pump setting are correct for action (units/kg/hr) * Order next Anti-Xa lab

ⓘ heparin (porcine)

↑ Single dose of **0-2,800 Units/hr exceeds** recommended maximum of **1,680 Units/hr (24 Units/kg/hr)**, over by **67%**

↑ Daily dose of **0-67,200 Units (0-40 Units/kg/hr Titrated) exceeds** recommended maximum of **40,320 Units (24 Units/kg/hr)**, over by **67%**

✓ heparin (porcine) 1,000 unit/mL injection 4,000 Units

4,000 Units, Intravenous, As needed, Subsequent bolus per nomogram, Starting today at 2111

Use vial for bolus doses, do NOT bolus from IV pump.

✓ Heparin: adjust infusion rate per Heparin Anti-Xa and Heparin Dosing Nomogram

Routine, Continuous, starting today at 1512, Until Specified

✓ Heparin: order Heparin Anti-Xa daily once therapeutic and after any dose change; DC daily Heparin Anti-Xa when off heparin

Routine, Continuous, starting today at 1512, Until Specified

✓ Notify physician regarding any other anticoagulant given within 12hr of starting heparin including Lovenox, Arixtra, Fragmin, Pradaxa, Xarelto, Eliquis, t-PA

Routine, Once, First occurrence today at 1512

✓ Notify physician regarding bleeding, widely fluctuating Heparin Anti-Xa (e.g. > 1.0 then < 0.2), consecutive changes in rate of 200 units/hr or more, new back pain or altered mentation while on heparin

Routine, Continuous, starting today at 1512, Until Specified

✓ Heparin Anti-Xa

in 6 hours, First occurrence today at 2112

✓ CBC

Daily, First occurrence tomorrow at 0605, Last occurrence on Tue 1/21 at 0605, for 7 occurrences

✔ Heparin Anticoagulation Orders (VTE, AFib, ECMO High)

✔ Heparin Indication: VTE, AFib, ECMO High Other

Routine, Continuous, starting today at 1514, Until Specified

Protocol Document Link: \\epicfiles/misc/OrderDocs/Heparin%20VTE-AFib-Other%20Dosing%20Nomogram.pdf

Initial dose is 18 units/kg/hour (unless initial dose exceeds 1500 units/hour)

✔ Loading Dose

heparin (porcine) 1,000 unit/mL injection 5,600 Units

5,600 Units (80 Units/kg × 70 kg Dosing weight), Intravenous, Once, today at 1530, For 1 dose

For VTE/AFib/ECMO High indication. Load 80 units/kg (max 9000 units). Use vial for loading dose, do NOT bolus from IV pump.

No heparin loading dose

Routine, Once for 1 occurrence

✔ heparin 25,000 units/500 mL D5W infusion (premix)

18 Units/kg/hr × 70 kg Dosing weight (25.2 mL/hr), Intravenous, Continuous, Starting today at 1530, For 6 hours

For VTE/AFib/ECMO High indication. Refer to Heparin Dosing Nomogram at 6 hours for dose adjustments of maintenance infusion thereafter. Initial

Administration Checklist: * Confirm indication for heparin (ACS vs. VTE/A-fib/ECMO High) * Is initial bolus ordered and/or given? * Verify/Program Smart

pump setting: -Verify pump library choice matches indication -Verify rounded dosing weight displayed in the Heparin order matches pump

weight -Program the pump to match the MAR: dose (units/kg/hr) * Verify Anti-Xa lab ordered 6 hours after Heparin started

✔ heparin 25,000 units/500 mL D5W infusion (premix)

0-40 Units/kg/hr × 70 kg Dosing weight (0-56 mL/hr), Intravenous, Titrated, Starting today at 2115

For VTE/AFib/ECMO High indication. Refer to Heparin Dosing Nomogram for dose adjustments of maintenance infusion following initial infusion. Anti-Xa

follow up Checklist: * Verify Anti-Xa level * Use Heparin Dose Action flowsheet row to determine and document action -Is subsequent bolus

needed? -Is maintenance dose change needed? (units/kg/hr increase or decrease) -Is Heparin being held? * Verify pump setting are correct

for action (units/kg/hr) * Order next Anti-Xa lab

ⓘ heparin (porcine)

↑ Single dose of **0-2,800 Units/hr** exceeds recommended maximum of **1,680 Units/hr (24 Units/kg/hr)**, over by **67%**

↑ Daily dose of **0-67,200 Units (0-40 Units/kg/hr Titrated)** exceeds recommended maximum of **40,320 Units (24 Units/kg/hr)**, over by **67%**

✔ heparin (porcine) 1,000 unit/mL injection 4,000 Units

4,000 Units, Intravenous, As needed, subsequent bolus per nomogram, Starting today at 2113

Use vial for bolus doses, do NOT bolus from IV pump.

✔ Heparin: adjust infusion rate per Heparin Anti-Xa and Heparin Dosing Nomogram

Routine, Continuous, starting today at 1514, Until Specified

✔ Heparin: order Heparin Anti-Xa daily once therapeutic and after any dose change; DC daily Heparin Anti-Xa when off heparin

Routine, Continuous, starting today at 1514, Until Specified

✔ Notify physician regarding any other anticoagulant given within 12hr of starting heparin including Lovenox, Arixtra, fragmin, Pradaxa, Xarelto, Eliquis, t-PA

Routine, Once, First occurrence today at 1514

✔ Notify physician regarding bleeding, widely fluctuating Heparin Anti-Xa (e.g. >1.0 then <0.2), consecutive changes in rate of 200 units/hr or more, new back pain or altered mentation while on heparin

Routine, Continuous, starting today at 1514, Until Specified


✔ Heparin Anti-Xa

in 6 hours, First occurrence today at 2114

✔ CBC

Daily, First occurrence tomorrow at 0605, Last occurrence on Tue 1/21 at 0605, for 7 occurrences

Bivalirudin Anticoagulation Orders

 Bivalirudin ****dosing for HIT/ECMO****

- bivalirudin (Angiomax) IV infusion at 0.15 mg/kg/hr ****Clcr >30 mL/min****
- bivalirudin (Angiomax) IV infusion at 0.06 mg/kg/hr ****Clcr <30 mL/min or dialysis****

BMP

Every third day, First occurrence tomorrow at 0605, Last occurrence on Tue 1/21 at 0605, for 3 occurrences

CBC

Every third day, First occurrence tomorrow at 0605, Last occurrence on Tue 1/21 at 0605, for 3 occurrences

PTT daily

Daily, First occurrence tomorrow at 0605, Last occurrence on Tue 1/21 at 0605, for 7 days

Bivalirudin: obtain timed PTT 2hr after initiating bivalirudin and after any dose change

Routine, Continuous, starting today at 1515, Until Specified

Bivalirudin: document infusion rate and all PTTs on Bivalirudin Monitoring Nursing Flowsheet

Routine, Continuous, starting today at 1515, Until Specified

Bivalirudin: adjust infusion rate per PTT and Bivalirudin Dosing Nomogram

Routine, Continuous, starting today at 1515, Until Specified

Bivalirudin: notify provider if two consecutive PTTs <42 or >70

Routine, Continuous, starting today at 1515, Until Specified

Adult ECMO RT Management Protocol

Ventilator Settings: "ECMO Rest Settings"

- Fio2 = .40
- RR = 10 breaths per minute
- Set Vt = 4-6 cc/kg IBW keeping plateau pressures <30 cmH2O
- Driving pressures = 15-16 cmh2o

Sweep Gas: Sweep Gas rate equal to blood flow (0.5:1 ratio) when ECMO is initiated

Sweep Gas should be titrated to maintain:

- Primary Goal: pH > 7.30
- Secondary Goal: Co2 40-45

ECMO specialist will assess each morning and initiate sweep trial if patient meets following

Weaning criteria include:

- Pplat: <30 cmH2O
- Hemodynamic stability
- pH: >7.30
- paO2 > 65 with Sao2 > 90 on fiO2 < .60

Sweep trial:

- increase fio2 to .60
- turn sweep gas off 0 l/min
- perform ABG after 20 mins, then Q1 hour x 3 during trial

Weaning is successful if patient remains stable after 4 hours

Sweep Trial termination

- Spo2: <85%
- Hemodynamic compromise
- paO2: <55

if termination criteria met, then place back on sweep gas at prior settings

VV ECMO POCKETCARD

INDICATION: acute pulmonary disease process that is regarded as reversible!

- PF ratio < 150 (on FiO2 > 90%)
- Refractory respiratory acidosis < 7.15 or PaCO2 > 80
- Excessively elevated pPlat > 35 mm H2O despite (lowVt, paralytics, proning)

CONTRAINDICATIONS	
Outside hospital transfers	Age > 65
CNS hemorrhage / tumor	Contraindication to anticoagulation
Prolonged mech vent > 7 days	Active malignancy
Cardiac arrest w anoxia concern	Comorbidity (< 6 mo life expectancy)
Major immunosuppression	End-stage lung disease
ESRD (relative contraindication)	BMI > 50
	Significant heart failure (consider VA)

ECMO Blood Flow (V) L/min - rate of blood flow thru ECMO circuit, measured by flow probe (bubble detector)

Venous Pressure (P_{ven}) pressure inside venous drainage tubing, reflects degree of suction the pump need to drain central venous blood.

Internal Pressure (P_{int}) pressure the pump must generate to push blood through the oxygenator.

Arterial Pressure (P_{art}) pressure the pump must generate to push blood through the "arterial" return tubing.

ΔP (mmHg) = (P_{int} - P_{art}) a calculated value representing the pressure drop across the oxygenator. As fibrin and clots build up resistance and pressure increase.

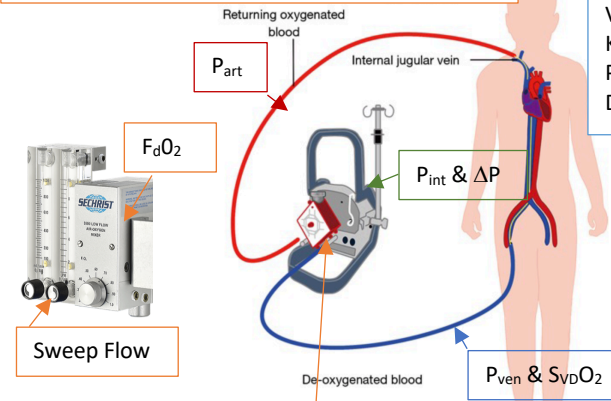
Pump speed rpm – maintain > 2000 rpm to reduce stasis / clot

\dot{V}	4.37 lpm	rpm	3620
P _{ven}	-73 mmHg	P _{art}	275 mmHg
P _{int}	300 mmHg	T _{art}	37.3 °C
Δp	25 mmHg	S _v O ₂	78.2 %

S_vO₂ (%) oxygen saturation of blood in the venous drainage tubing

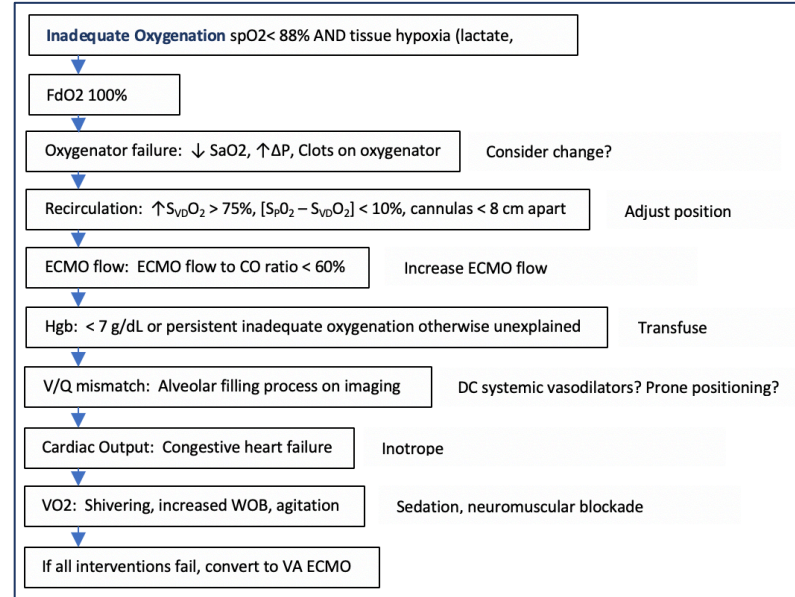
$$\frac{(\text{Current pCO}_2 \times \text{Current Sweep})}{\text{Desired pCO}_2}$$

New Sweep Flow Rate



Vent Rest:
FiO2 0.40
RR 10
Vt 4-6 cc/kg IBW
Keep Pplat < 30
PEEP 10
Driving P 15-16

Oxygenator – where blood is oxygenated F_dO₂ set on blender and CO2 removed by sweep gas flow (initial sweep 0.5:1 ECMO flow). Sweep is then adjusted for ABG (primary goal pH > 7.3, secondary goal pCO2 40-50)





WAKEMED CRITICAL CARE DIVISION

**VENO-VENOUS ECMO
EDUCATIONAL SERIES**
JASON WIELAND PA-C

3 RULES OF ECMO!

1. ECMO is a team sport!

- ▶ ECMO requires a true coordinated multidisciplinary team effort to manage these patients (Critical Care, Cardiac Surgery, RN's, ECMO specialists, Perfusionists, Pharmacy, Physical Therapy)

2. ECMO = Time

- ▶ ECMO only provides an extended time window for disease management. ECMO itself directly has **ZERO** effect on the disease process. This needs to be reiterated to patient families in detail upon initiation and throughout therapy.

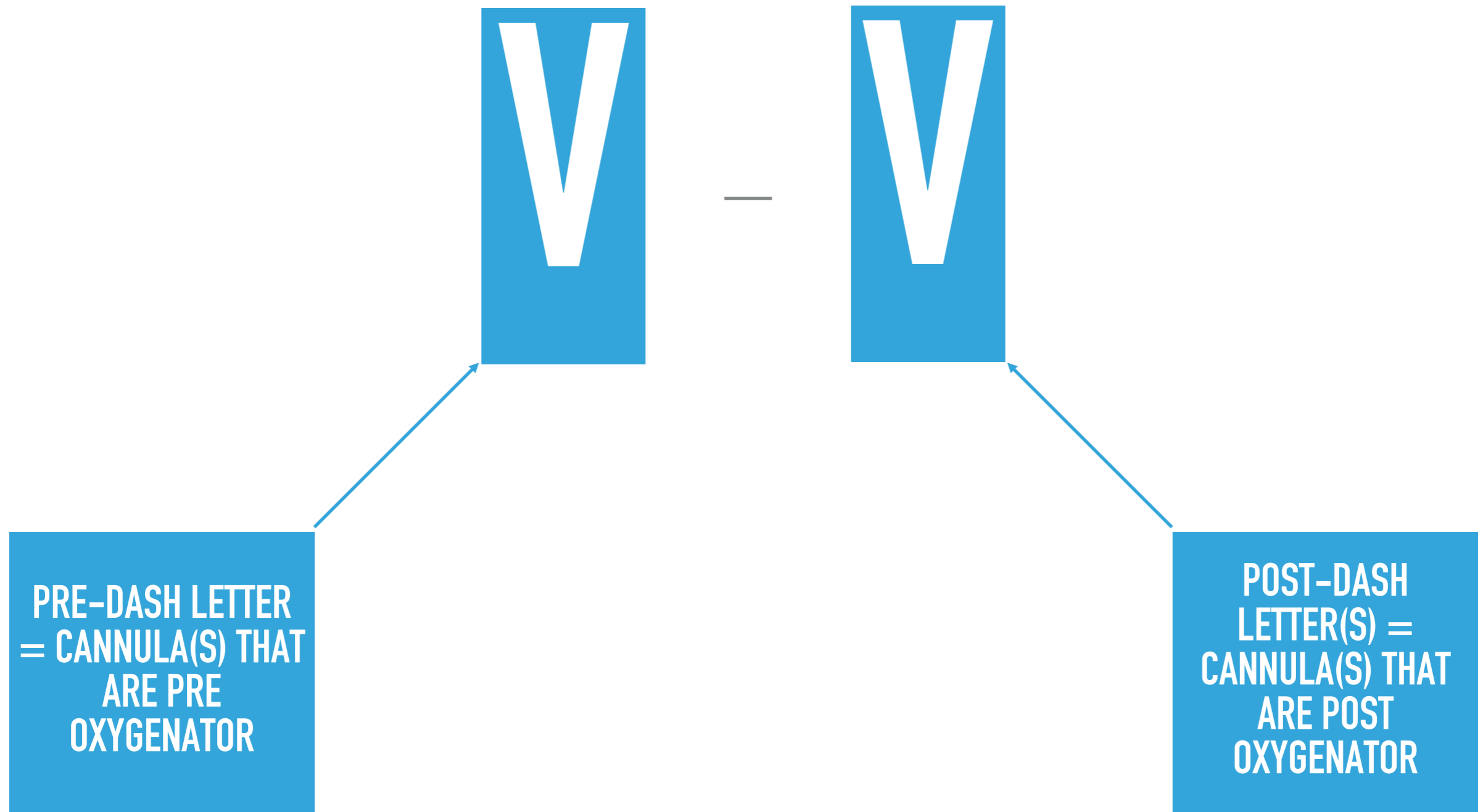
3. Hands off!

- ▶ Tampering with the circuit without proper knowledge can be lethal. Please do not touch the circuit!

OBJECTIVES

- ▶ Review Indications/Contraindications of patient candidacy
- ▶ Review anatomy/nomenclature of ECMO circuit
- ▶ Review Cannulation types/locations
- ▶ Review role of “ECMO specialist”
- ▶ ECMO 101
- ▶ Troubleshooting
- ▶ ECMO standards
- ▶ Review weaning candidacy and protocol

ECMO NOMENCLATURE



INDICATIONS

- ▶ Any underlying acute pulmonary disease process that is regarded as reversible!
 - ▶ PaO₂/FIO₂ Ratio <150 on FIO₂ >90%
 - ▶ Refractory Respiratory Acidosis: <7.15 or PaCo₂ >80
 - ▶ Excessive elevated pPlat >35mm H₂O despite optimal ventilator settings/strategies (paralytics/proning)

CONTRAINDICATIONS

- ▶ Age >65
- ▶ Outside hospital transfers
- ▶ Irreversible Brain Damage/CNS hemorrhage (h/o ICH, Recent CVA, Brain tumor)
- ▶ Prolonged Mechanical Ventilation > 7 days (despite optimal settings and ARDS pathway)
- ▶ Cardiac Arrest with concern for anoxic brain injury
- ▶ Major immunosuppression/neutropenia
- ▶ Contraindication to anticoagulation or ongoing coagulopathy
- ▶ Active Malignancy
- ▶ Non recoverable comorbidity (<6 months life expectancy)
- ▶ End stage lung disease (not transplant candidate)
- ▶ ESLD
- ▶ Relative Contraindication: ESRD
- ▶ Significant Heart failure (These patients need VA ECMO)
- ▶ BMI >50

CARDIOHELP ECMO CIRCUIT

- ▶ HLS 7.0
- ▶ Bioline coating (heparin/albumin)
- ▶ Monitor displays continuous:
 - ▶ Venous pressure
 - ▶ Internal Pressure (pInternal) = Premembrane pressure
 - ▶ Arterial Pressure (pArterial) = Postmembrane pressure
 - ▶ Delta P (pArterial - pInternal = Delta P)
 - ▶ RPM
 - ▶ Pump flow (l/min)
- ▶ Capable of dynamic blood monitoring:
 - ▶ Hematocrit
 - ▶ Venous Blood Temperature
 - ▶ SVo2 (not true mixed venous)
- ▶ Centrifugal pump
 - ▶ 0.5-7.0 l/min
- ▶ VA or VV configuration



Front View



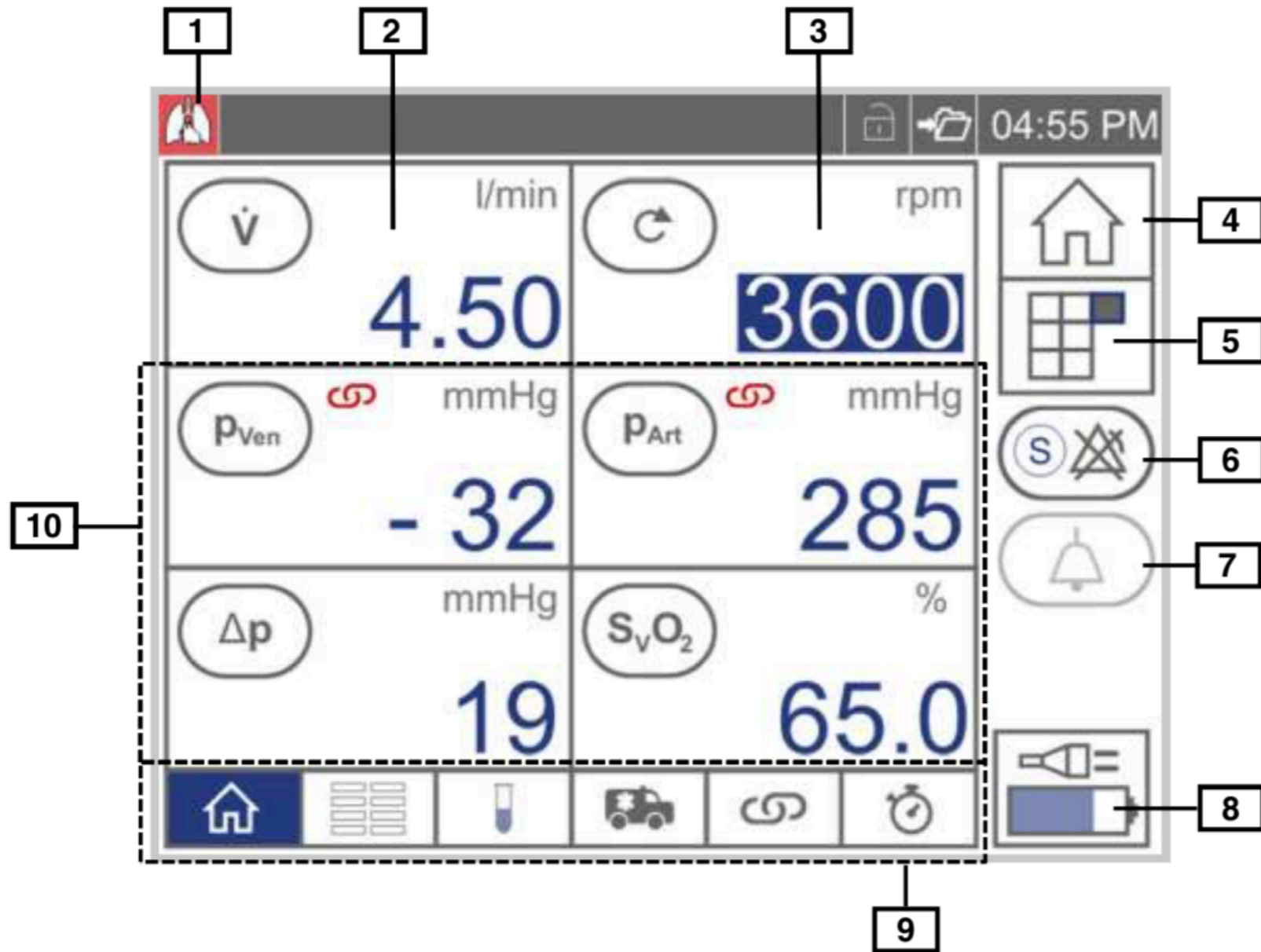
Display

Rear View



Pump inserts here

CARDIOHELP DISPLAY

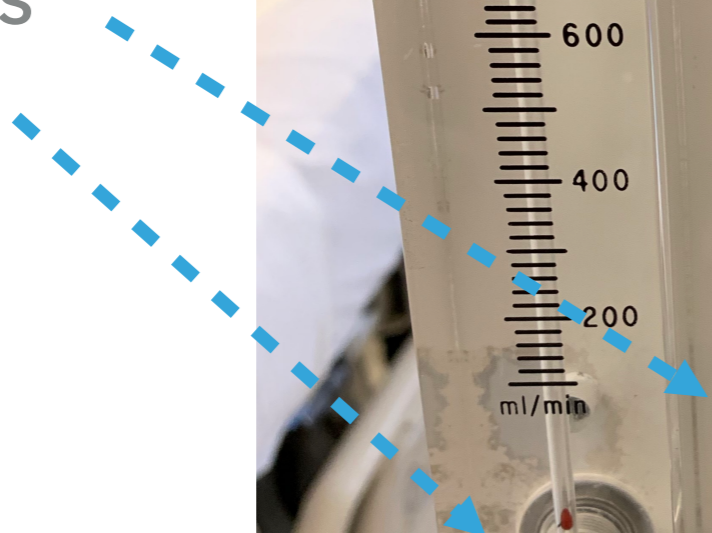


- [1] thApp
- [2] LPM data
- [3] RPM data
- [4] Startup screen
- [5] Menu screen
- [6] Global override
- [7] Alarm pause
- [8] Power supply status
- [9] Tab bar
- [10] Parameter display

BLENDER/SWEEP GAS INTERFACE



Sweep Gas



FiO2



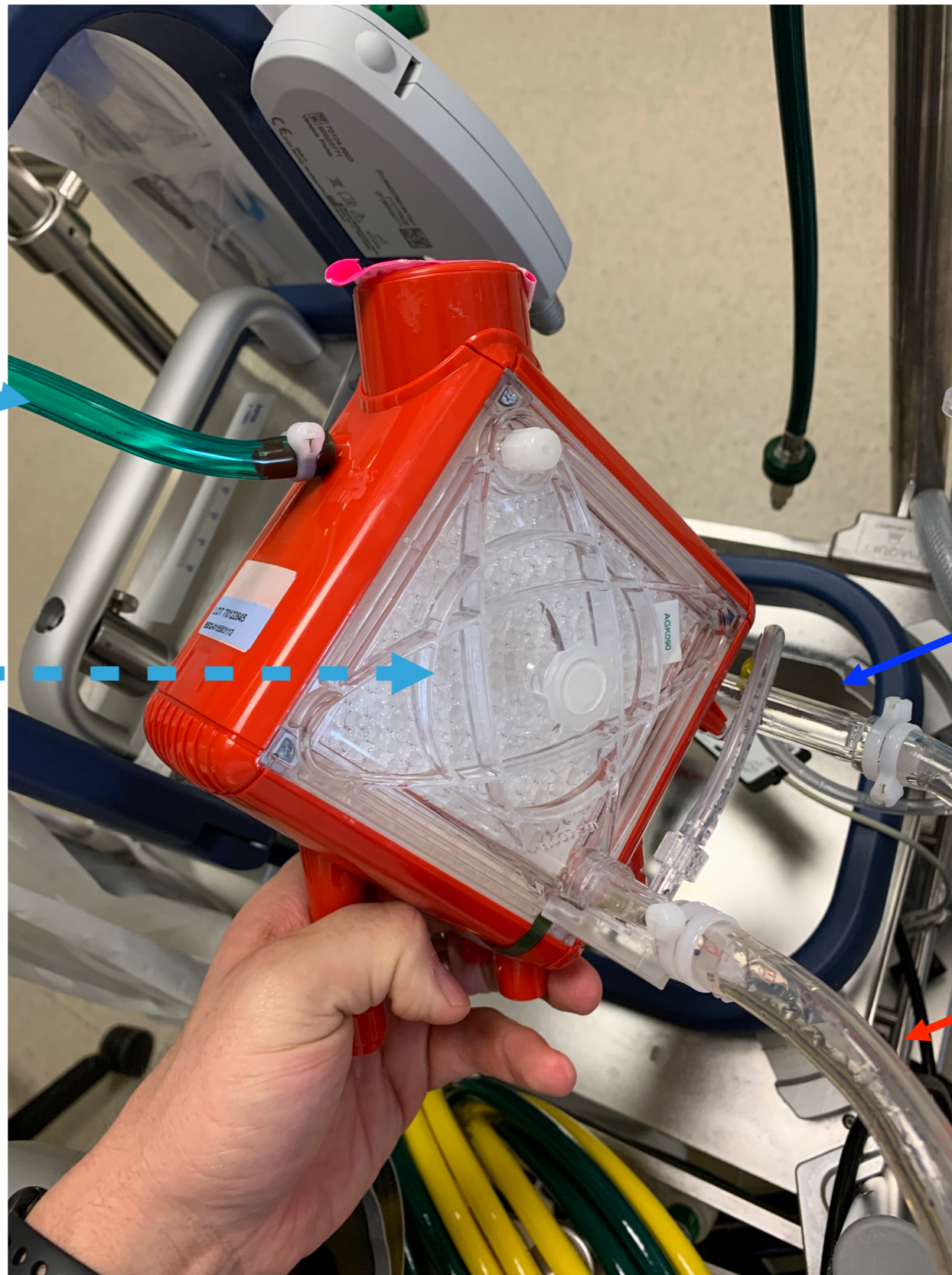
OXYGENATOR/CENTRIFUGAL PUMP: FRONT VIEW

Wall Oxygen inserts here

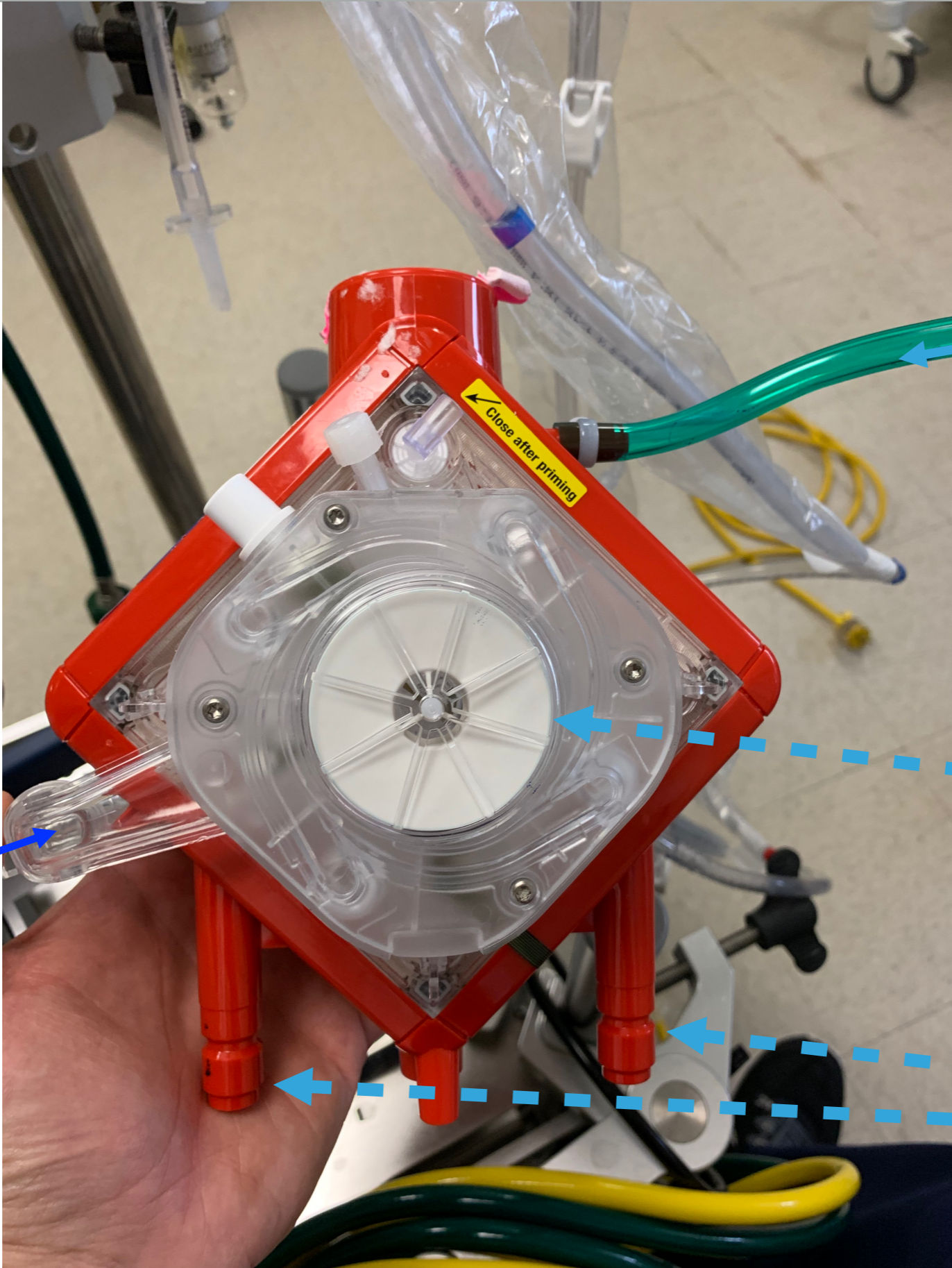
Membrane Oxygenator

Venous drainage line

Arterial return line



OXYGENATOR/PUMP: BACKVIEW



Wall Oxygen inserts here

Centrifugal pump

Heater/Cooler Access

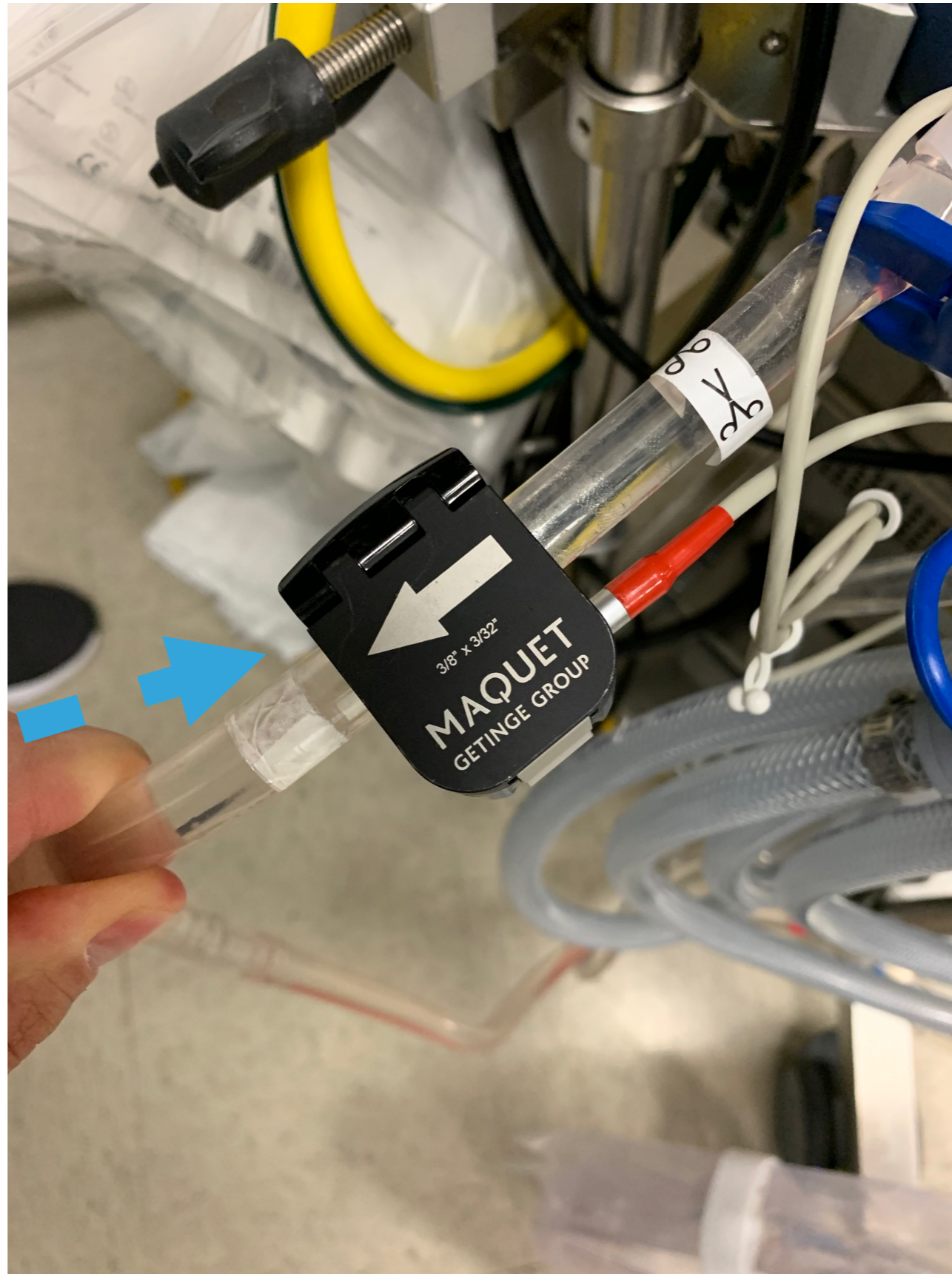
Venous drainage line

VENOUS TEMP/SVO2 MONITOR

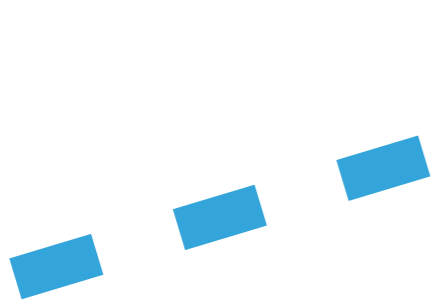
Attaches to top of venous drainage line proximal to the pump



VV ECMO BUBBLE DETECTOR



BUBBLE DETECTOR



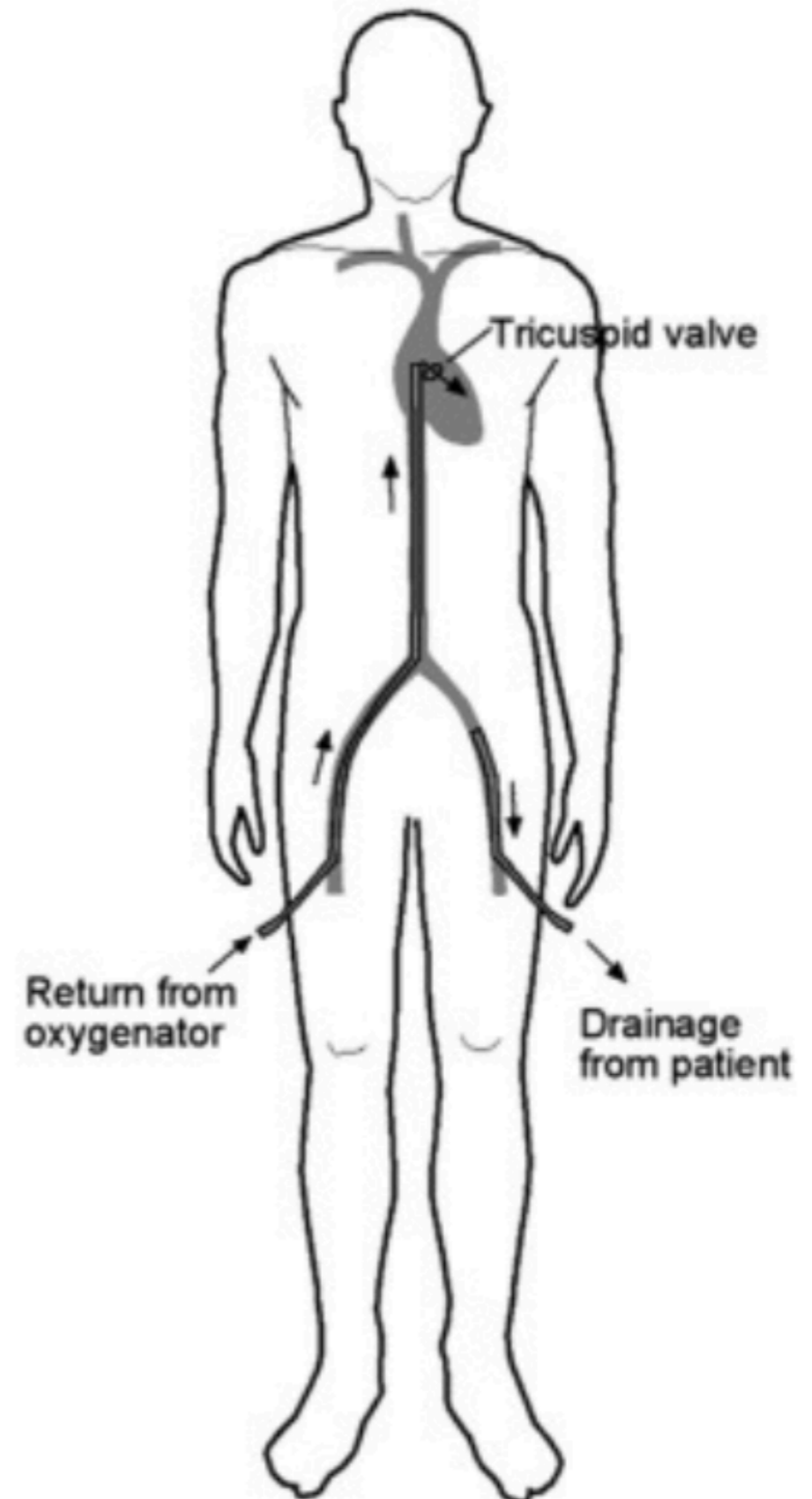
BACKUP HAND PUMP



Emergency hand crank

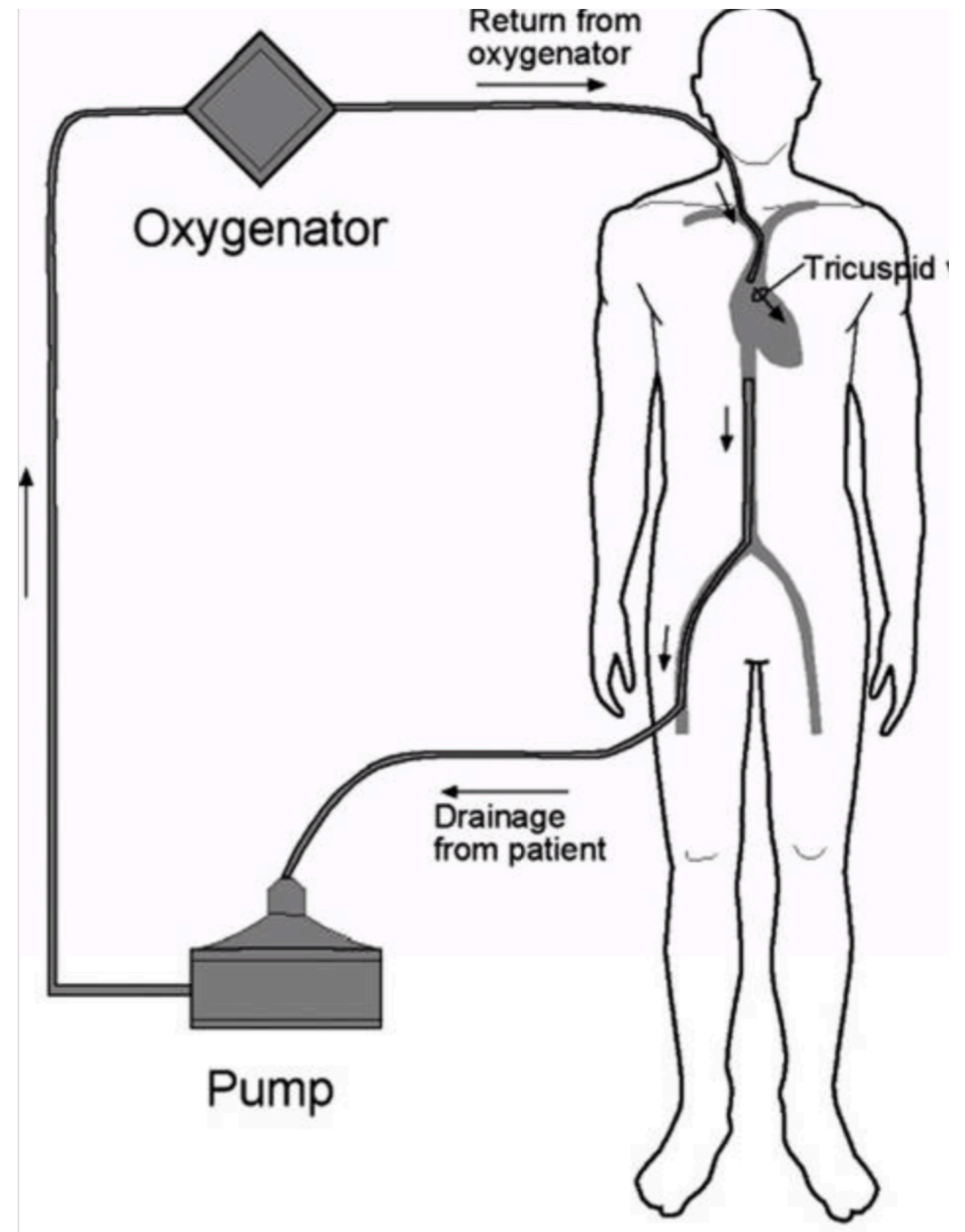
FEMORAL-FEMORAL

- ▶ Venous drainage from femoral access site with cannula (21F-29F) terminating in IVC-Iliac junction
- ▶ Arterial return in opposite femoral vein with cannula (15-19F) terminating in RA
- ▶ Advantages:
 - ▶ Can be inserted quickly at bedside.
- ▶ Disadvantages:
 - ▶ Venous return is limited to IVC blood.
 - ▶ Limited patient mobility.



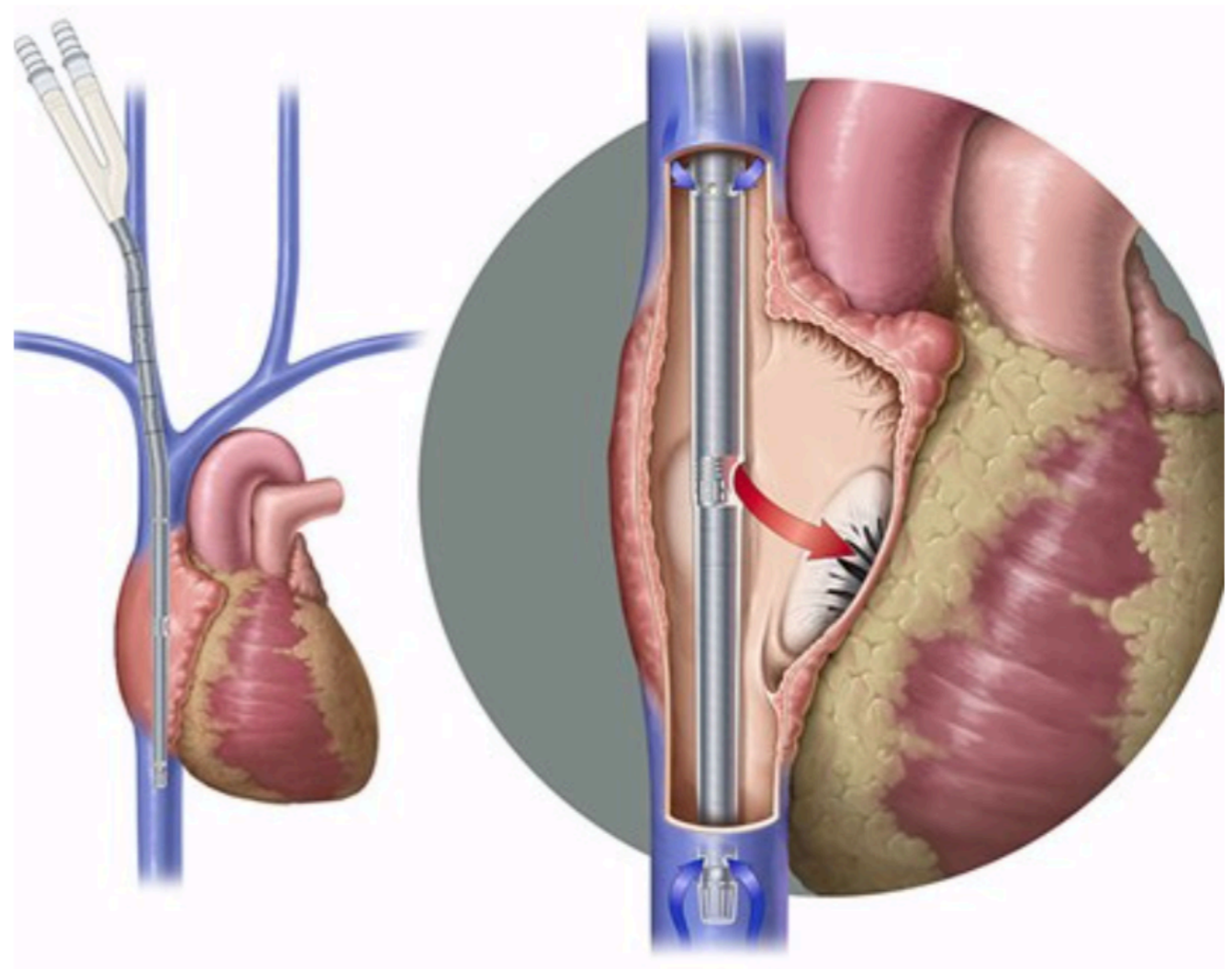
FEMORAL-INTERNAL JUGULAR

- ▶ Venous drainage accessed via femoral vein (21-29F) terminating in IVC just above renal vein or just below RA (latter increased risk of recirculation).
- ▶ Arterial return access via right internal jugular (15-19F) with cannula terminating in RA.
- ▶ Advantages:
 - ▶ Can be inserted at bedside.
- ▶ Disadvantages:
 - ▶ Venous return blood is limited to IVC blood.
 - ▶ Limited patient mobility.
 - ▶ Recirculation.



DUAL LUMEN CANNULATION (AVALON CANNULA)

- ▶ Single site cannulation via right internal jugular vein.
- ▶ Cannula has drainage line and return line built into one.
- ▶ Advantages:
 - ▶ Allows patient to mobilize.
 - ▶ Access site away from the groin.
 - ▶ Allows for IVC & SVC drainage.
 - ▶ Recirculation rates are lower.
- ▶ Disadvantages:
 - ▶ Difficult placement, requires fluoroscopy or echocardiography guidance.
 - ▶ Any unintended movement either superior, inferior and/or rotational of cannula can cause malposition and ECMO failure.



ECMO SPECIALIST

- ▶ Selected group of respiratory therapists who are going through extensive training in coordination with Duke's ECMO program.
- ▶ Requires extensive 4 day didactic course, wet lab, written examination and yearly CME mandates.
- ▶ Along with perfusion team, they will be first line providers in regards to managing the ECMO circuit, making adjustments and troubleshooting.

PHYSIOLOGY OF THE CIRCUIT

- ▶ Flow is generated by a centrifugal pump.
- ▶ The pump creates a negative pressure or vacuum effect on the venous drainage line generating inflow of blood into the pump.
 - ▶ This force is displayed on the monitor as **pVenous** and is a **negative!**
- ▶ Forward flow is then generated from the pump through the oxygenator where ventilation/oxygenation take place. This is then delivered to the patient.
 - ▶ $p_{Internal}$ = Pressure between pump and Oxygenator
 - ▶ $p_{Arterial}$ = Pressure after Oxygenator
 - ▶ $p_I - p_A = \Delta P$

WHAT CAN I ADJUST ON THE ECMO CIRCUIT?

- ▶ RPMs → Flow
- ▶ Sweep
- ▶ Flo₂

ITS ALL ABOUT THE FLOW!

- ▶ $DO_2 = CO \times CaO_2$
- ▶ Increasing flow, HgB concentration or FIO_2 will increase DO_2 .
- ▶ ECMO flow is directly proportional to venous drainage.
 - ▶ Larger the better.
 - ▶ More return lines the better (although we rarely need two drainage lines it is a possibility)

HOW DO WE SELECT OUR OPTIMAL FLOW?

- ▶ Our flow should match patients native cardiac output as best as possible (at least 75%).
- ▶ Rough Estimate: RPMs can be increased until we have a flow that achieves SpO₂ >88% (PaO₂ 55-80).
- ▶ Exact Calculation: CO can be measured via FloTrac, TTE (full ECHO reports generally will give patients stroke volume, we can then calculate native CO ourselves)

SWEEP GAS = VENTILATION

- ▶ Increasing sweep will lower pCO₂
- ▶ Decreasing sweep will increase pCO₂
- ▶ When ECMO is first initiated, the sweep will be set to 0.5:1 ratio to the flow.
 - ▶ Example: ECMO is set to 5L/min, sweep will be set to 2.5
- ▶ After we are on ECMO, Sweep will be adjusted for ABG values:
 - ▶ Primary Goal : pH >7.3
 - ▶ Secondary Goal : pCo₂ 40-50

MY PCO₂ IS NOT IN RANGE, HOW DO I CALCULATE MY NEW SWEEP GAS?

(Current pCO₂ x Current Sweep)/Desired pCO₂



New Sweep Flow rate

Example: (pCO₂ 60 X 3LPM) / pCO₂ 40



New sweep Rate of 4.5LMP

OXYGENATION

- ▶ Oxygen blender is routinely set to 1.0 (100% F_{IO2})
- ▶ Titrated down PRN

THE SVO₂ DISPLAYED ON ECMO MONITOR, IS THIS A TRUE SVO₂?

- ▶ This is not a “true” mixed venous due the reintroduction of oxygenated blood onto the venous side of circulation.
- ▶ It is measured on the venous drainage line and can be artificially high due to recirculation!
- ▶ Trend this value only.

WHERE SHOULD THE PULSE OXIMETRY BE PLACED WHILE ON VV?

- ▶ Oxygenation should be equal throughout systemic circulation, given native LV ejection is providing oxygenated blood flow.
- ▶ Anywhere possible!

WHERE SHOULD OUR ARTERIAL MONITORING LINE BE PLACED WHILE ON VV?

- ▶ As described on previous slide, oxygenation should be equal throughout systemic circulation, given native LV ejection is providing oxygenated blood flow.
- ▶ Any site is possible. However we should stay away from the groins, as we do not want to disturb our ECMO cannulas.
- ▶ We should get into habit of placing RUE arterial access, as this is **NEEDED** while on VA ECMO.

COMPLICATIONS

- ▶ Bleeding
- ▶ Hemolysis
- ▶ Vascular Injury
- ▶ Thromboembolic
- ▶ Cerebrovascular

ECMO PHARMACOLOGY

- ▶ Growing evidence that ECMO can effect pharmacokinetics/pharmacodynamics of certain commonly used ICU medications.
- ▶ For example Propofol, Versed, Fentanyl and Ceftriaxone can become sequestered in oxygenator and do not reach adequate plasma concentrations.
- ▶ We need to keep this in the back of our minds, especially when it comes to sedation.

Review Article

Optimising drug dosing in patients receiving extracorporeal membrane oxygenation

Vesa Cheng¹, Mohd-Hafiz Abdul-Aziz^{1,2}, Jason A. Roberts^{1,3,4,5}, Kiran Shekar^{6,7}

¹Faculty of Medicine, The University of Queensland, UQ Centre for Clinical Research, Brisbane, Australia; ²School of Pharmacy, International Islamic University Malaysia, Kuantan, Malaysia; ³Department of Intensive Care Medicine, ⁴Department of Pharmacy, Royal Brisbane and Women's Hospital, Brisbane, Australia; ⁵Centre for Translational Anti-infective Pharmacodynamics, School of Pharmacy, The University of Queensland, Brisbane, Australia; ⁶Adult Intensive Care Services, the Prince Charles Hospital, Chermside, Australia; ⁷Critical Care Research Group, Centre of Research Excellence for Advanced Cardio-respiratory Therapies Improving OrgaN Support (ACTIONS) and the University of Queensland, Brisbane, Australia

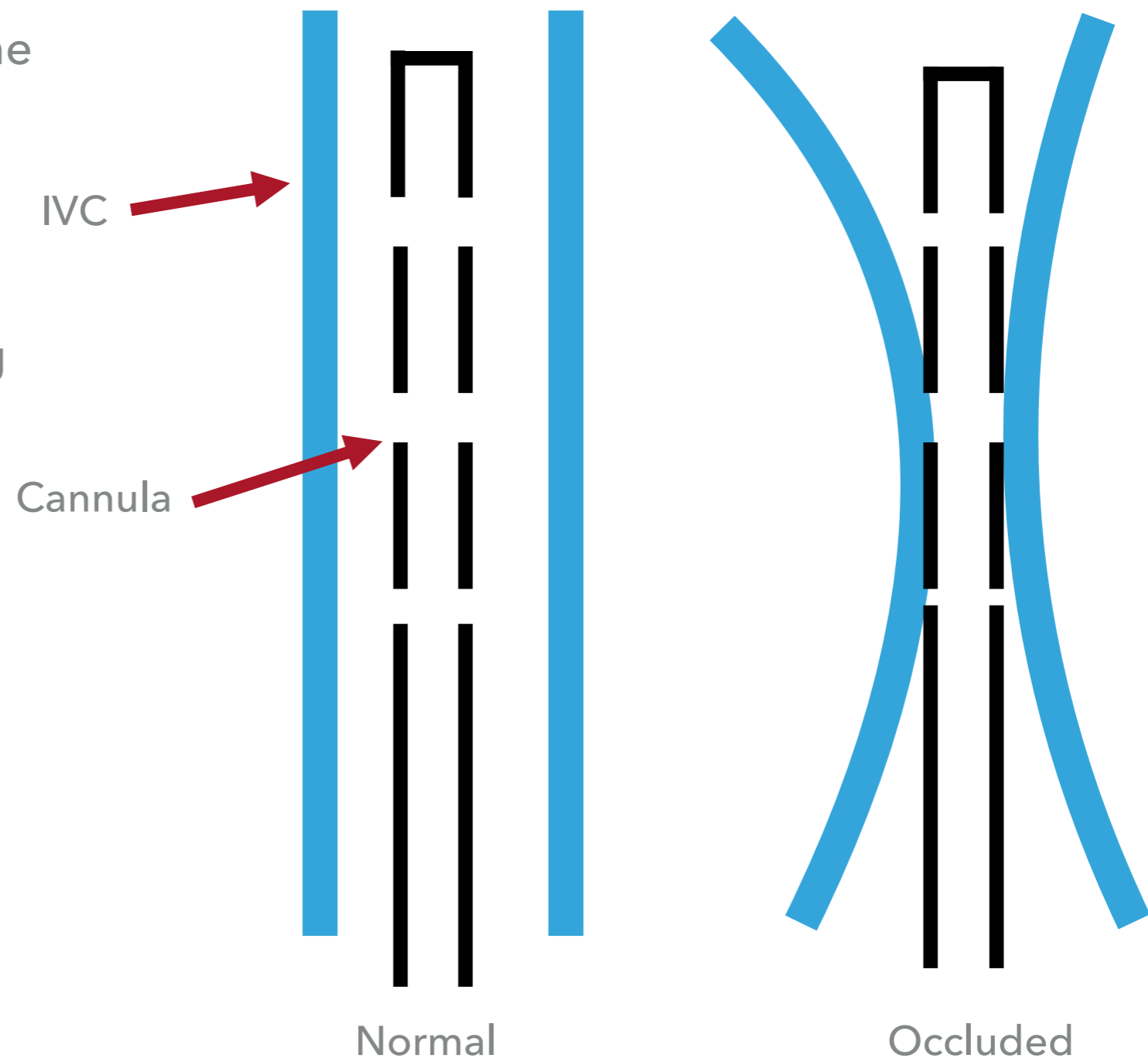
Contributions: (I) Conception and design: K Shekar, JA Roberts; (II) Administrative support: K Shekar, JA Roberts; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Kiran Shekar. The Prince Charles Hospital, Rode Road, Chermside, Brisbane 4032, Australia. Email: kiran.shekar@health.qld.gov.au.

Abstract: Optimal pharmacological management during extracorporeal membrane oxygenation (ECMO) involves more than administering drugs to reverse underlying disease. ECMO is a complex therapy that should be administered in a goal-directed manner to achieve therapeutic endpoints that allow reversal of disease and ECMO wean, minimisation of complications (treatment of complications when they do occur), early interruption of sedation and rehabilitation, maximising patient comfort and minimising risks of delirium. ECMO can alter both the pharmacokinetics (PK) and pharmacodynamics (PD) of administered drugs and our understanding of these alterations is still evolving. Based on available data it appears that modern ECMO circuitry probably has a less significant impact on PK when compared with critical illness itself. However, these findings need further confirmation in clinical population PK studies and such studies are underway. The altered PD associated with ECMO is less understood and more research is indicated. Until robust dosing guidelines become available, clinicians will have to rely on the principles of drug dosing in critically ill and known PK alterations induced by ECMO itself. This article summarises the PK alterations and makes preliminary recommendations on possible dosing approaches.

THE VENOUS RETURN LINE IS SHAKING, WHATS GOING ON?

- ▶ “Chattering” or “Chugging” is the description of when the venous line shakes.
- ▶ This is due to access insufficiency!
- ▶ The venous cannula is being occluded by the vessel wall, causing acute occlusion of inlet holes, therefore inhibiting venous return.
- ▶ **ONLY A PROBLEM IF VENOUS LINE IS CHUGGING!**



ACCESS INSUFFICIENCY

- ▶ What we will see:
 - ▶ Line chugging, variable drop in flows on monitor, increasing negative venous line pressure and possible systemic hypoxia.
- ▶ What causes this?
 - ▶ **Hypovolemia/Anemia (M/C)**, elevated flows, kink/compression of line (ie thrombus/clot burden), malposition, patient valsalva/agitation, intraabdominal compartment syndrome.
- ▶ Troubleshooting:
 - ▶ 500cc NS/LR bolus immediately, check HgB. If this does not correct, have ECMO specialist lower RPMs if SPO₂ can tolerate. We can sedate the patient deeper. If this does not fix, then we need to check for cannulation abnormalities (ie kinks, malposition). Order CXR/Abd Xray.
 - ▶ Ramp Testing: Increasing RPM should **increase** flow. If increasing the RPM **decreases** flow and/or worsens “chugging” then this confirms access insufficiency.

CHUGGING




Intensive. (2018, April 14). An ECMO Earthquake? Retrieved December 5, 2019, from <https://intensiveblog.com/an-ecmo-earthquake/>.

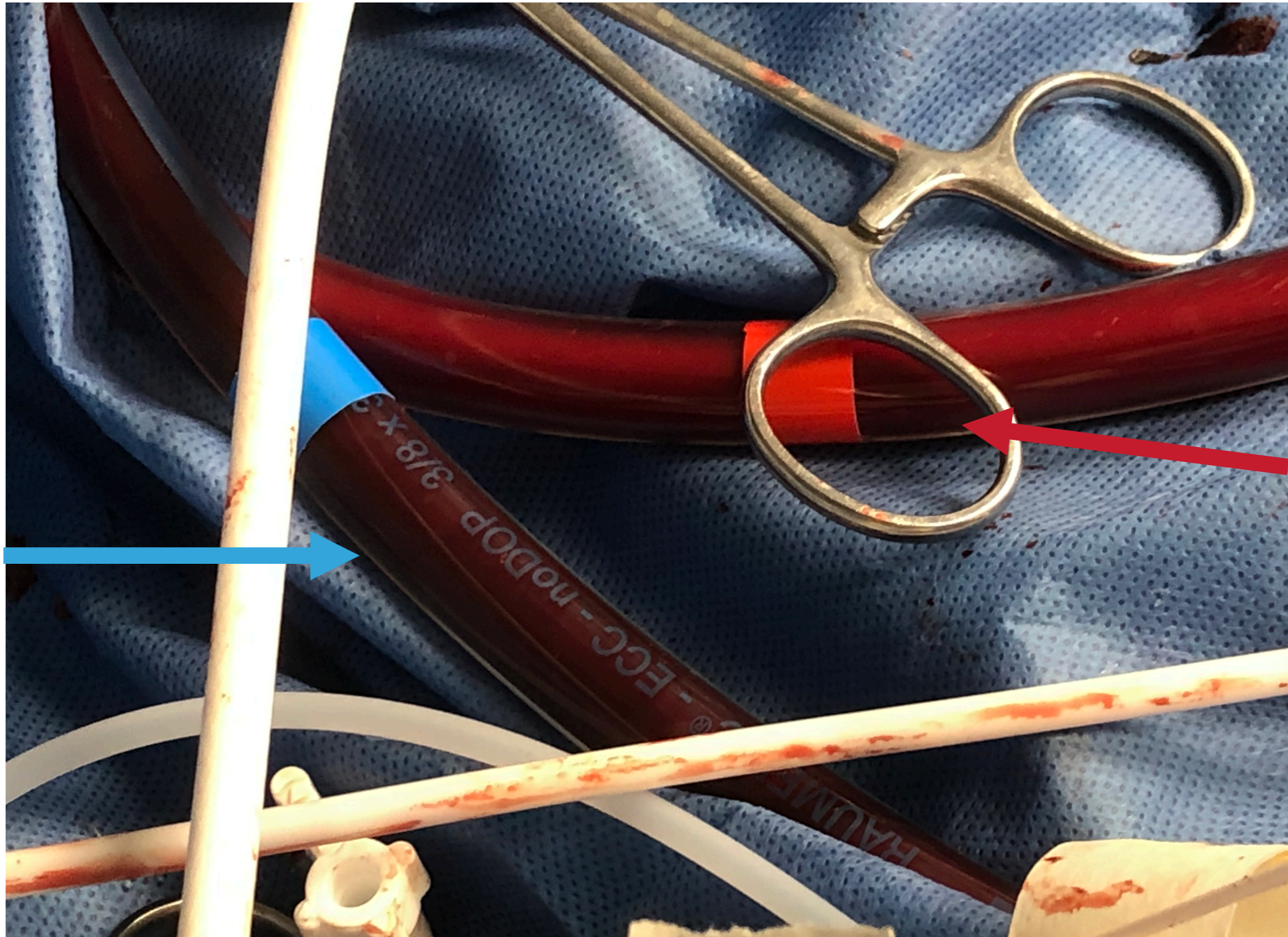
RECIRCULATION

- ▶ Recirculation is when the drainage line drains oxygenated (arterial) returned blood back into the circuit.
- ▶ This is due to the geographic proximity of single lumen cannulas in respect to each other.
- ▶ This will cause systemic hypoxia/hypercarbia, if the native lungs are not able to maintain adequate gas exchange.

RECIRCULATION

- ▶ What will we see?
 - ▶ Hypoxia
 - ▶ Venous Drainage line and Arterial return line blood will be same color!
 - ▶ PreOxygenator PO₂  PostOxygenator PO₂
 - ▶ S_{Vo}2 >/= SPO₂
- ▶ Troubleshooting if causing hypoxia:
 - ▶ Turn RPMS down
 - ▶ CXR/Abd film to check cannula location (may need to reposition cannulas if becomes ongoing issue)

NORMAL COLOR DIFFERENTIATION ON VV ECMO



Venous

Arterial

PATIENT IS HYPOXIC DESPITE VV ECMO...

- ▶ Are flows stable and adequate?
- ▶ Rule out Recirculation.
- ▶ Rule out Access Insufficiency.
- ▶ Consult ECMO specialist to check circuit.
- ▶ Check Hgb.
- ▶ Has the patients cardiac output increased?
 - ▶ If so, need to increase flow to reflect change in CO.
- ▶ Increase FIO₂ on ventilator.
- ▶ Sedate/paralyze patient to decreased O₂ demand.

MY DELTA P VALUE IS INCREASING, IS THIS WORRISOME?

- ▶ Increasing delta P means there is increased resistance within the oxygenator.
 - ▶ Fibrin clots can develop within the oxygenator. ECMO specialist will inspect the oxygenator daily to check for thrombus formation.
- ▶ This value is relative (~80 is considered elevated)
- ▶ If delta P is increasing and there is no issues with our flow or our SPO₂, then this is OK.
- ▶ If Delta P is increasing and we are having trouble flowing or the patient is hypoxic then there needs to be conversation about changing out the oxygenator.

MY POST MEMBRANE PO₂ IS 480, HOWEVER MY PATIENTS PO₂ IS 86. HOW IS THIS POSSIBLE?

- ▶ In a perfect world, we would be able to drain 100% of the patients cardiac output and run it through the circuit. However this is not fully plausible while on peripheral ECMO, especially with multi-site single lumen cannulation.
- ▶ Given we are only able to drain a fraction of the patients cardiac output at any given time, there is native blood exchange through the patients diseased lungs.
- ▶ This will create an admixture of oxygenated blood and poorly oxygenated blood.
- ▶ For example...

Patients CO is 8 L/min, we are flowing 4 L/min. This means 50% of the patients CO is theoretically shunting passed the ECMO circuit and oxygenated through the injured lungs.

- ▶ Do we need to address this? And if so, how do we fix it?
 - ▶ This is generally not an issue unless we are hypoxic.
 - ▶ We can add an extra venous drainage line in the SVC and change circuit to VV-V. This will increase our drainage volume and allow for higher flow rates. We can also theoretically lower the patients native CO.

THERE ARE BUBBLES IN THE RETURN LINE, WHAT DO I DO?

- ▶ Call ECMO specialist ASAP!

WHAT IS OUR STANDARD SEDATION REGIMEN?

- ▶ Patients will be sedated/paralyzed for first 24-48hrs.
- ▶ Thereafter patient will be allowed trial off paralytics depending on patients condition.

WHAT IS OUR TARGET HEMOGLOBIN CONCENTRATION AND PLATELET COUNT?

- ▶ Target HgB: >7.0 g/dl
- ▶ Target PLT: >50k (75K if bleeding complications)

DO PATIENTS NEED TO BE ON ANTICOAGULATION?

- ▶ Drug of choice is heparin.
- ▶ We will utilize lower ACS target goal measuring anti-Xa.
- ▶ We need to keep in mind these patients are at risk for HIT, however are also at risk for ongoing hemolysis and megakaryoblast/platelet destruction resulting in thrombocytopenia.

WHAT LABS/MODALITIES NEED TO BE MONITORED?

- ▶ CBC q12h
- ▶ BMP q12h
- ▶ Mag q12h
- ▶ Phosphorus q12h
- ▶ Ionized Calcium q12
- ▶ ABG q6h
- ▶ PT/INR QD
- ▶ Fibrinogen QD
- ▶ Hepatic Function QD
- ▶ LA QD
- ▶ T/S Q3D
- ▶ Haptoglobin QD
- ▶ CXR QAM
- ▶ ABD Xray QAM

WHAT WILL BE OUR STANDARD VENT SETTINGS WHILE ON ECMO?

- ▶ Static Ventilation Strategy
 - ▶ Resting the lungs without causing extensive atelectasis
- ▶ PRVC
- ▶ Fio₂ 40%
- ▶ RR = 10 bpm
- ▶ Tidal Volume = 5cc/kg IBW keeping pPlat <30ccmH₂O
- ▶ Driving Pressures = 15-16 cmH₂O

WHEN WILL I KNOW IT'S TIME TO START WEANING ECMO?

- ▶ ECMO specialist will assess patient each morning starting at 4am and will initiate a "sweep trial" if patient meets the following criteria:
 - ▶ pPlat: $<30\text{cmH}_2\text{O}$
 - ▶ Hemodynamic stability
 - ▶ pH: >7.30
 - ▶ PaO₂ >65 with SaO₂ $>90\%$ on FIO₂ $< 60\%$

WHAT IS A “SWEEP TRIAL”?

- ▶ Standardized technique to “test run” the patient off ECMO support without removing the cannulas.
 - ▶ This is performed and monitored by ECMO specialist. Providers permission is not required. DO NOT TOUCH THE CIRCUIT and perform yourself!
- ▶ Ventilator FIO₂ is increased to 60%, RR is increased to maintain adequate M_{Ve}.
- ▶ Sweep gas is turned completely off = 0L/min.
 - ▶ ECMO will still flow, however there is ZERO gas exchange provided (ventilation or oxygenation)
 - ▶ THIS IS ONLY FOR VV ECMO. WE CAN NEVER TURN SWEEP GAS OFF ON VA ECMO!
- ▶ ABG is run after 20 minutes, then q1HR x 3 hrs.
- ▶ Weaning is successful if patient remains stable after 4 hours with sweep off.
- ▶ Weaning is TERMINATED if SP_O₂: <85%, hemodynamic compromise, PaO₂: <55
 - ▶ Sweep gas will be placed back on previous settings and ventilator will be returned to rest settings.

**“PLACE A SHEET OVER THE
ECMO CIRCUIT AND PRETEND
ITS NOT THERE”**

Enlightened Cardiac Surgeon

REFERENCES

Cardiohelp System. (2018). *Cardiohelp System*. Retrieved from https://www.getinge.com/dam/hospital/documents/sales/sales---brochures/english/cardiohelp_system_brochure-en-non_us_japan.pdf

Intensive. (2018, April 14). An ECMO Earthquake? Retrieved December 5, 2019, from <https://intensiveblog.com/an-ecmo-earthquake/>.

Sidebotham, D. (2011, March). Troubleshooting adult ECMO. Retrieved December 5, 2019, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4680094/>.