Extracorporeal Life Support

What should Cardiologists know?

Samphant Ponvilawan

Bumrungrad International

ELSO

- Non profit organization, established in 1989
- Chapters
  - North America
  - Euro
  - Asia-Pacific
  - Latin America
  - South and West Asia
- Last Registry - July 2016 78,397 patients

ECLS Registry Report

International Summary

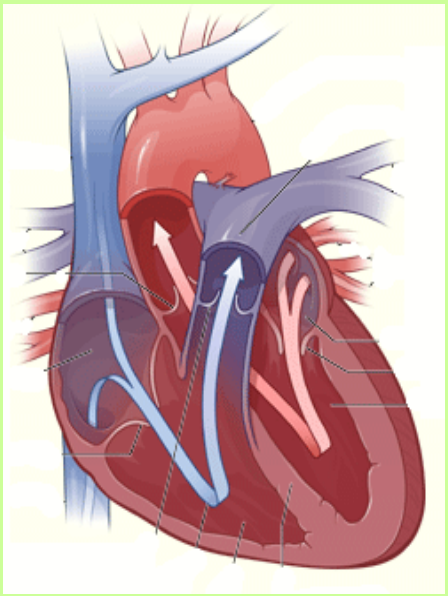
July, 2016

Extracorporeal Life Support Organization
2800 Plymouth Road
Building 300, Room 303
Ann Arbor, MI 48109

Overall Outcomes

	Total Patients	*Survived ECLS*		*Survived to DC or Transfer*	
Neonatal					
Respiratory	29,153	24,488	84%	21,545	74%
Cardiac	6,475	4,028	62%	2,695	42%
ECPR	1,336	859	64%	547	41%
Pediatric					
Respiratory	7,552	5,036	67%	4,371	58%
Cardiac	8,374	5,594	67%	4,265	51%
ECPR	2,996	1,645	55%	1,232	41%
Adult					
Respiratory	10,601	6,997	66%	6,121	58%
Cardiac	9,025	5,082	56%	3,721	41%
ECPR	2,885	1,137	39%	848	29%
Total	78,397	54,866	70%	45,345	58%

Typical ECMO circuit



Return

Vein or artery

Oxygenator

Pump

Access

vein

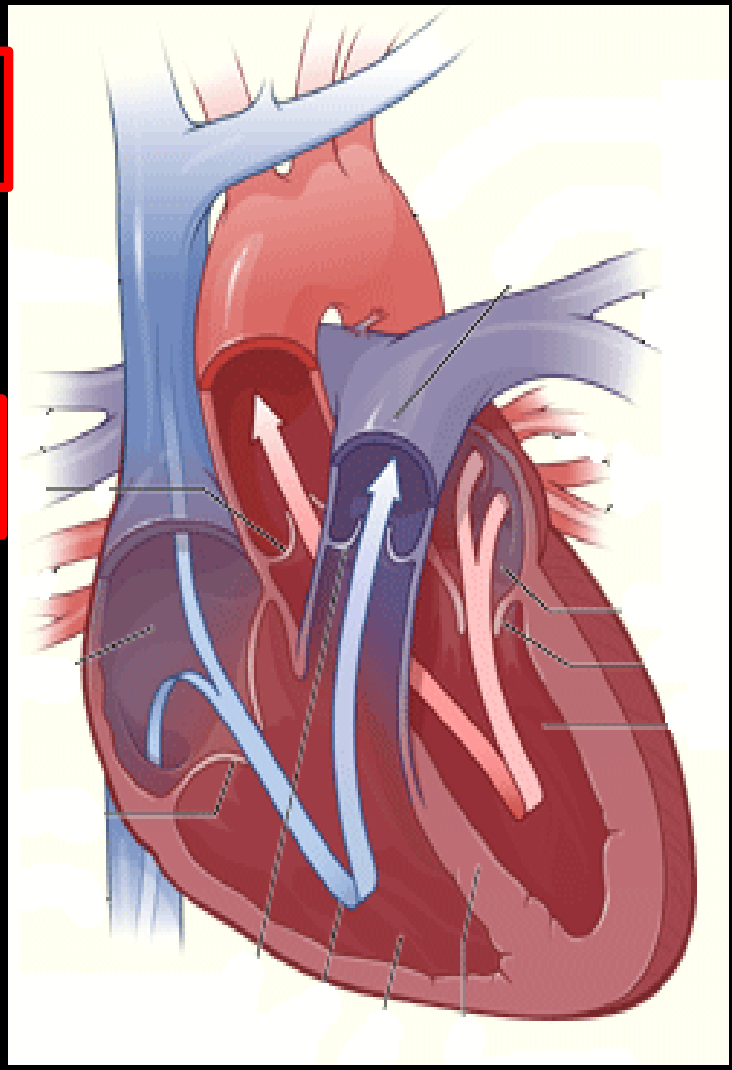
Mode of ECMO

V-V Veno-venous for Respiratory support

A-V Artero-venous Pumpless for selective CO_2 removal

V-A Veno-arterial for Cardiac support

V-PA Veno-pulmonary artery for RV function post LVAD insertion



VA ECMO
for Cardiac Failure

Configuration

Peripheral

- Femero-femoral
- Subclavian return

Central

- Via Sternotomy
- Specialised cannulae
- (tunneled)

Access (drainage)

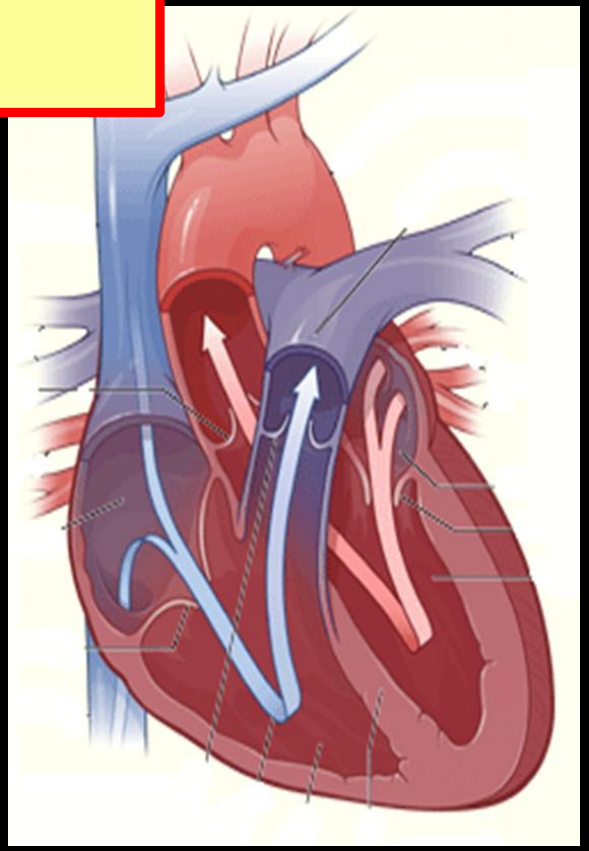
Right atrium

Return

Distal aorta

Subclavian artery

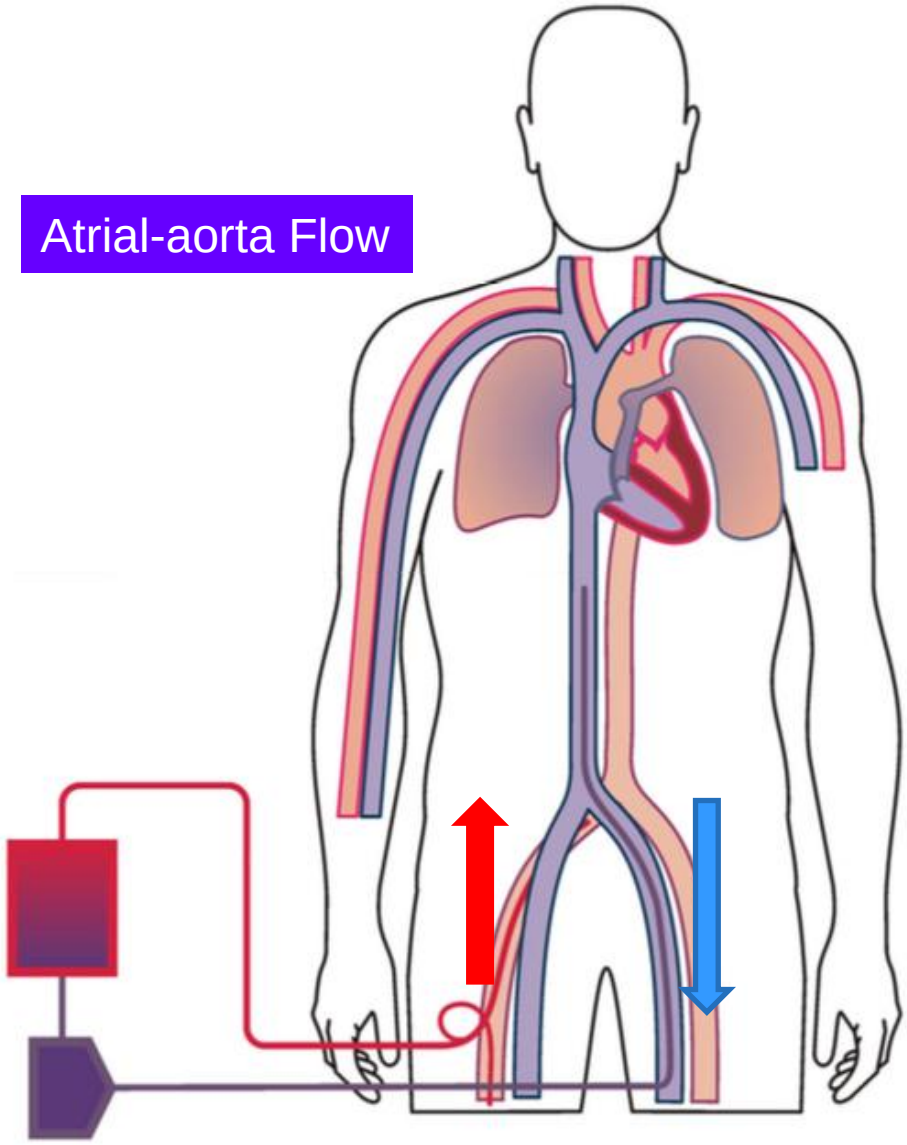
Proximal aorta

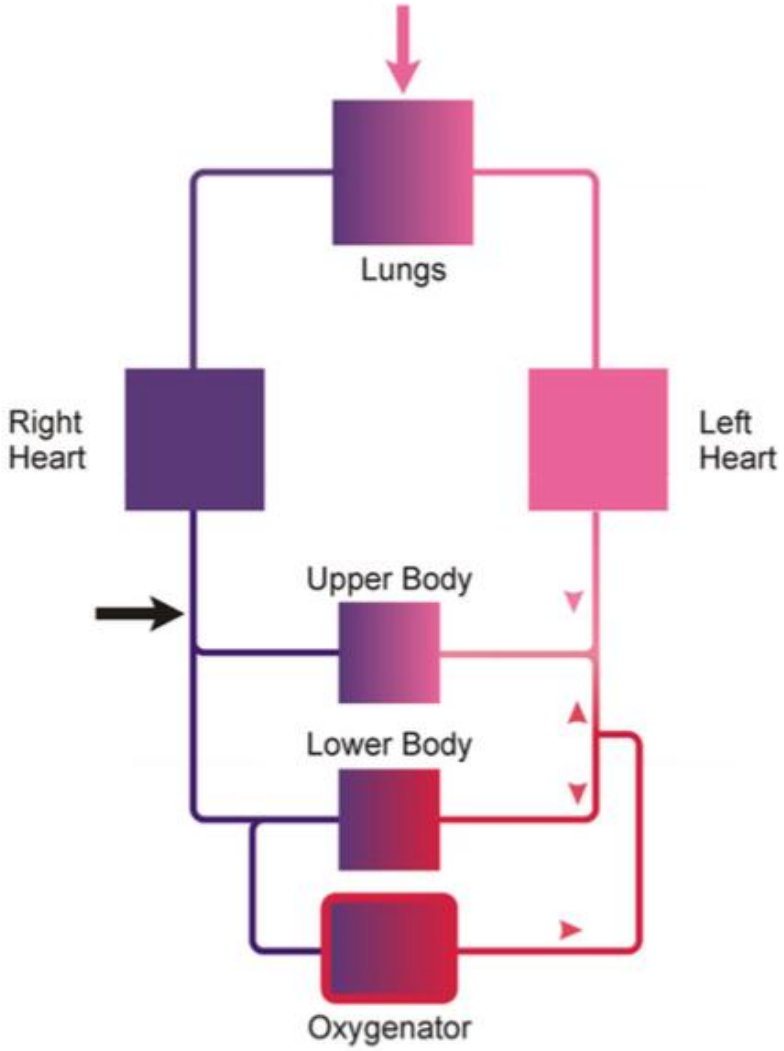


Veno-arterial ECMO

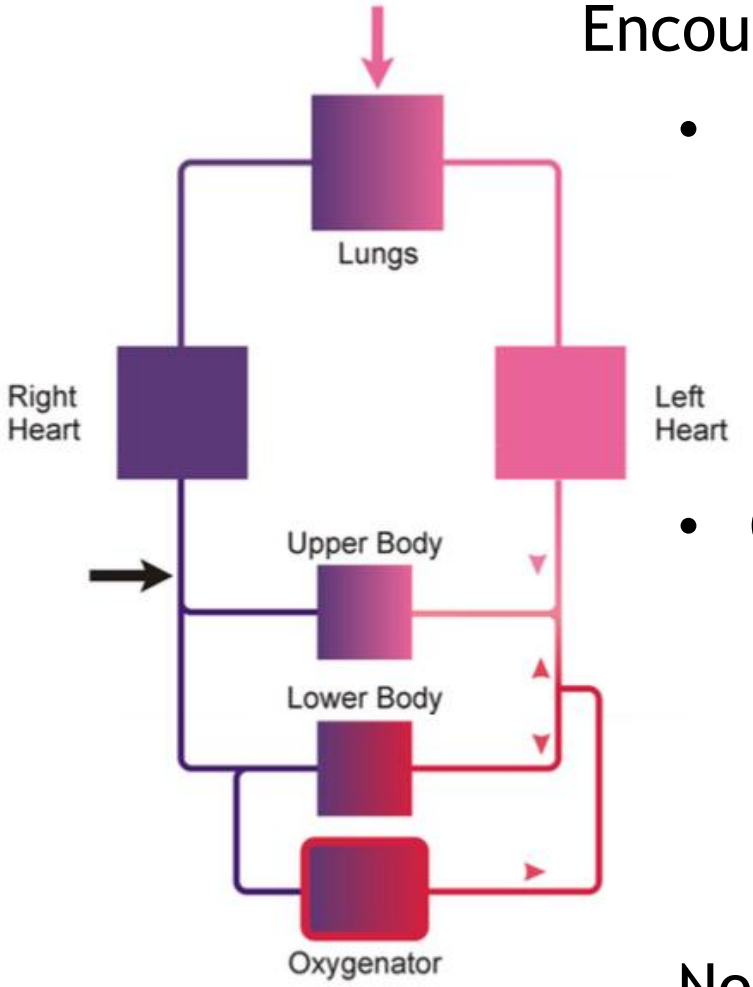
Standard Femoro-Femoral

Atrial-aorta Flow





VA ECMO physiology



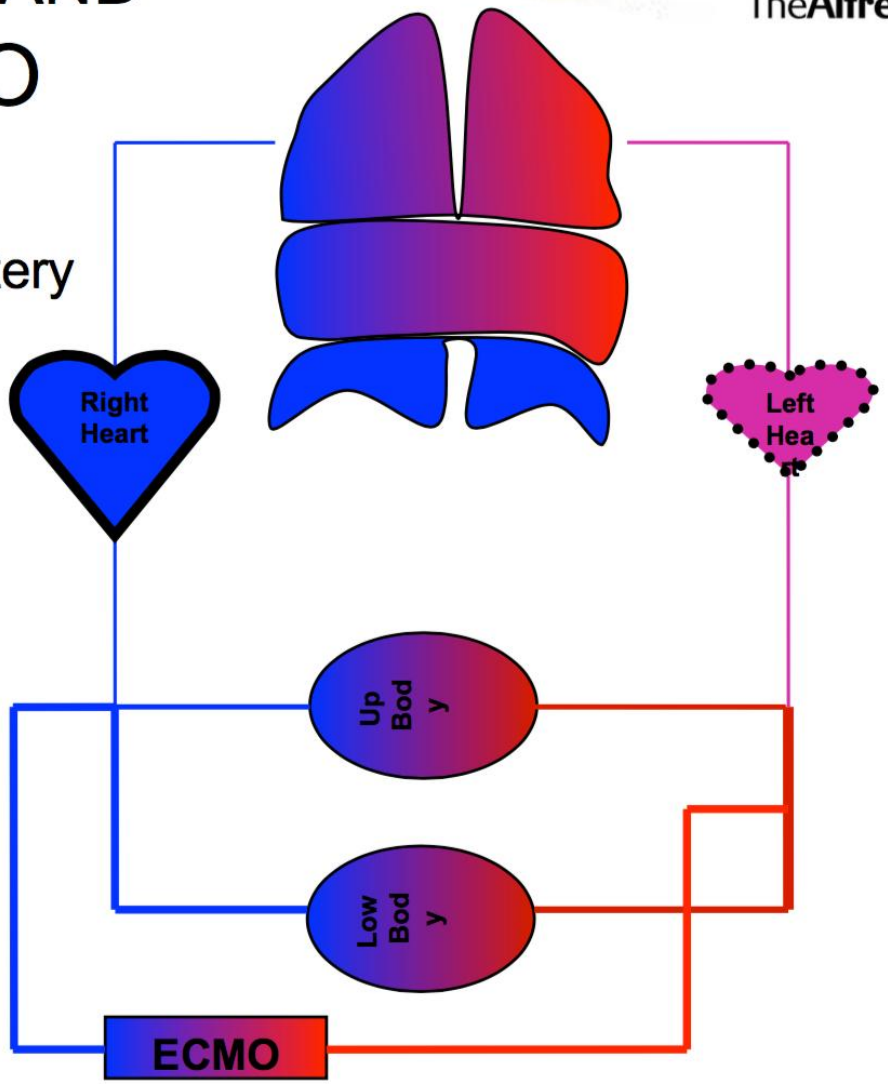
Encounter Two circulations

- Native (patient) = Cardiac function
  - provides pulsatility
  - provides blood and CO2 to lungs
  - Gas tensions depend on lung function and ventilation
- Circuit (ECMO)
  - Non pulsatile
  - Gas tensions determined by Oxygenator
  - High PaO2 (>200)
  - CO2 determined by sweep gas

No recirculation occurs
Differential hypoxia is possible

Assessment of Circuit and native flow in VA ECMO

- Can't measure with PAC
- Pulsatility of aortic and pulmonary artery wave forms
- $ETCO_2$
- Echo (TTE or TOE)



Respiratory management (Ventilator setting)

- Target paO2 70-90mmHg
  paCO2 40mmHg
  ETCO2 20-35mmHg
  PIP < 25mmHg
- Use TV 6ml/kg, RR 8/min initial setting

- ETCO2 <20 ; Lung ventilation should be reduced
- High arterial PCO2 ; Gas flow should be increased
- Low arterial PCO2 ; Gas flow should be reduced if V/Q >0.5
- Never turn off gas flow in VA ECMO for low PCO2, will cause hypoxic lower limbs and abdominal viscera

Management of intra-cardiac thrombosis (VA ECMO)

- When there is little pulsatility and native cardiac back flow, the risk of intra-cardiac thrombosis is high.
- Response
  - Correct diagnosis (don't miss: tamponade)
  - Higher anticoagulation levels
  - Low-moderate dose inotropes
  - Afterload reduction (left and right ventricles)
  - Consider reducing ECMO flow if > 4L/min (improve cardiac preload)

VA ECMO Maintenance

- Bleeding and Thrombosis
  - Left sided thrombus is the major concern
  - Circuit thrombosis (oxygenator and pump head) EXTREMELY rare
  - Arterial cannula bleeding is the major limitation to support beyond 15 days

Cardiac thrombosis with cerebral emboli

VA ECMO maintenance

- Respiratory setting : TV 6ml/kg, RR 8/min
- Cardiac setting : pulsatility, vasodilator
- Loss of Pulsatility
  - Cardiac Tamponade
  - Myocardial failure (w or w/o MR, AR)
    - LVF>RVF : acute pulmonary edema, hemorrhage
    - RVF>LVF : unable to wean ECMO
  - Access insufficiency
- Differential hypoxemia : Bad Lungs

Access Insufficiency
(Inadequate input to the ECMO circuit)

Findings

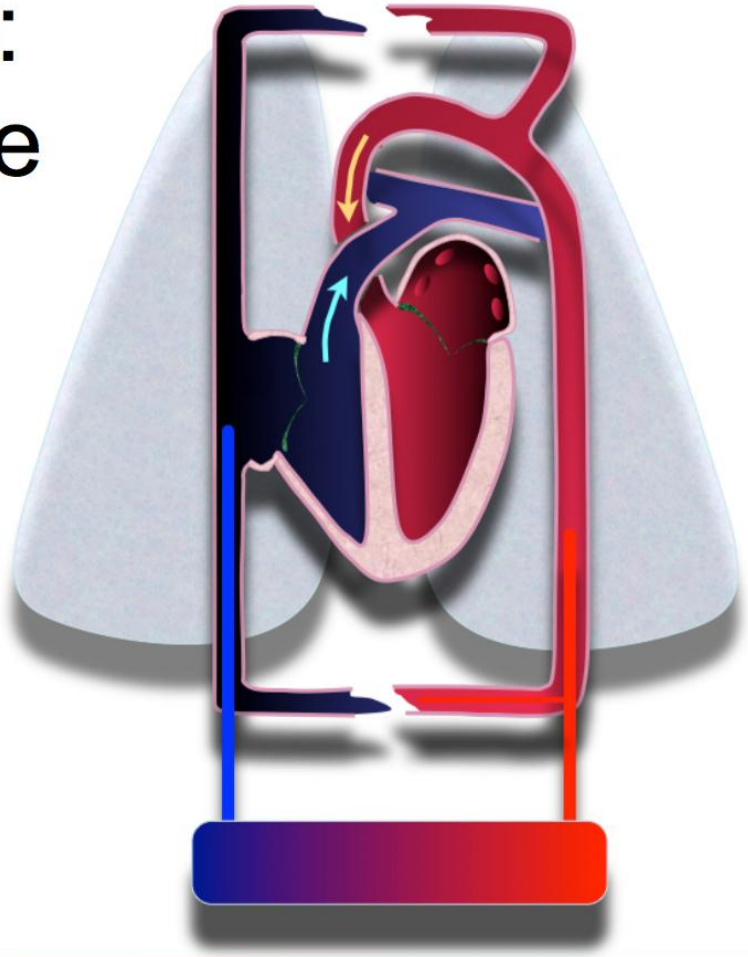
- Increase in Negative pressure (> -50mmHg)
- Beating of cannula
- Unstable or dropping flows

Cause

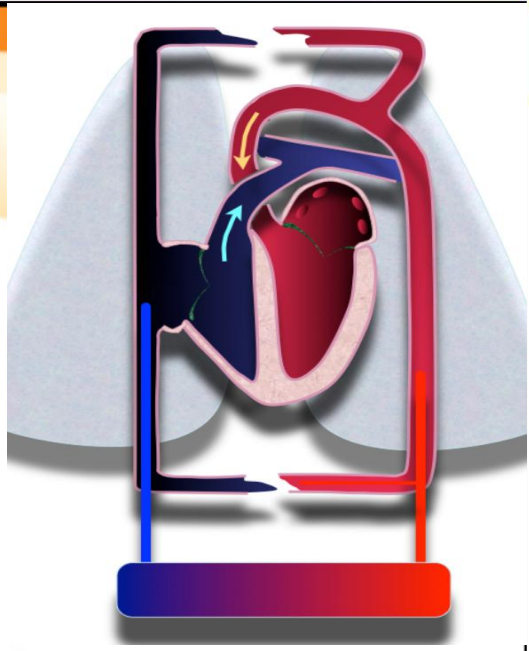
- Hypovolemia / Bleeding
- Poorly sited access cannula
- Pump speed too high
- LV failure
- Cardiac tamponade

VA ECMO Maintenance: Cardiac Management: Left Ventricular Failure

- Causes
  - Severe left ventricular failure with any AR or MR
    - Fatal pulmonary hemorrhage
  - Severe AR/MR
  - LVF > RVF
    - > Gradual, progressive infiltration



VA ECMO Maintenance: Cardiac Management: Left Ventricular Failure



- Treatment
  - Patient Selection
  - Decrease LV load
    - Increase PEEP
    - Decrease MAP
  - Increase circuit blood flow
  - Consider LVAD/BiVAD
  - Atrial Septostomy
  - (LA vent)

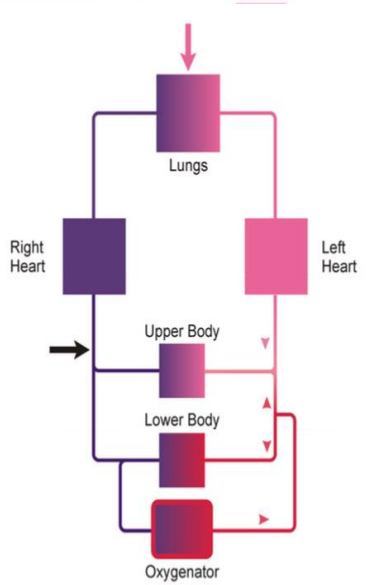
- The need to administer IV fluid boluses to the patient on VA ECMO is highly suggestive of LV failure

VA ECMO Maintenance: Cardiac Management: Right Ventricular Failure

- Causes: Right Ventricular Failure > LVF
  - > PE
  - > Primary graft failure (heart transplant)

Beautifully supported with VA ECMO

DIFFERENTIAL HYPOXIA AND VA ECMO



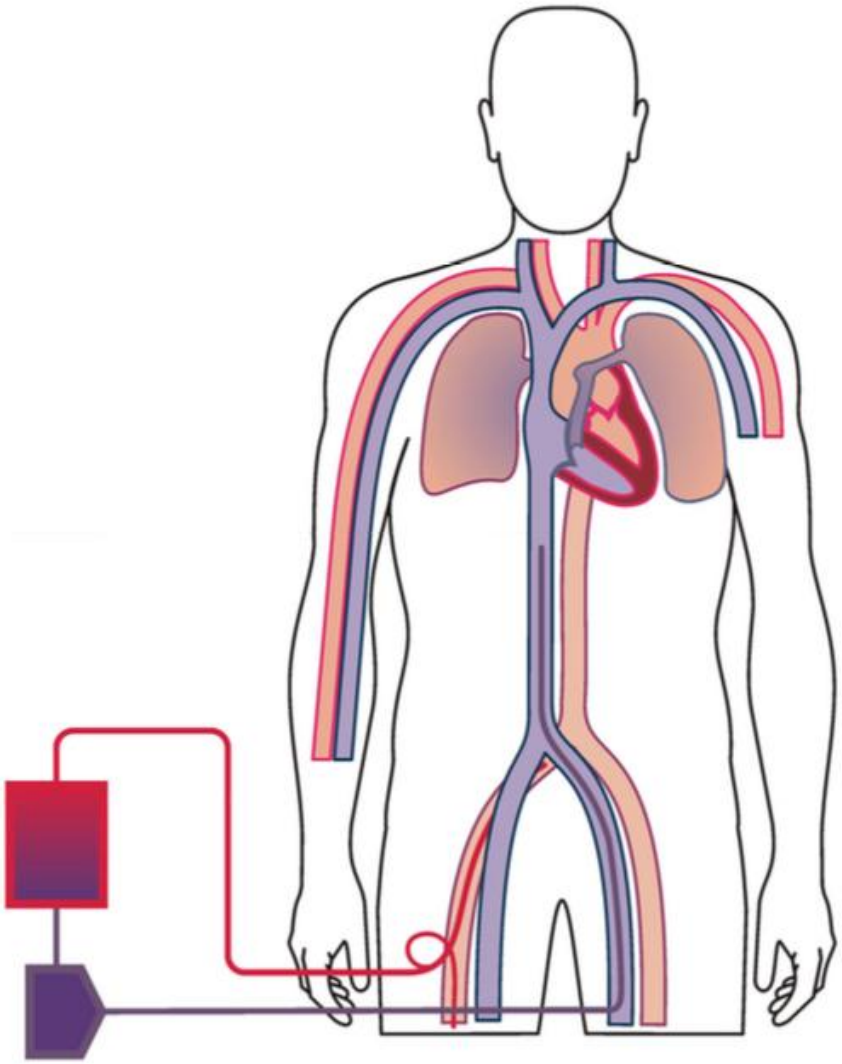
Due to mixing of ECMO blood (oxygenated) and deoxygenated blood from lungs ejected by heart (deoxygenated native circulation)

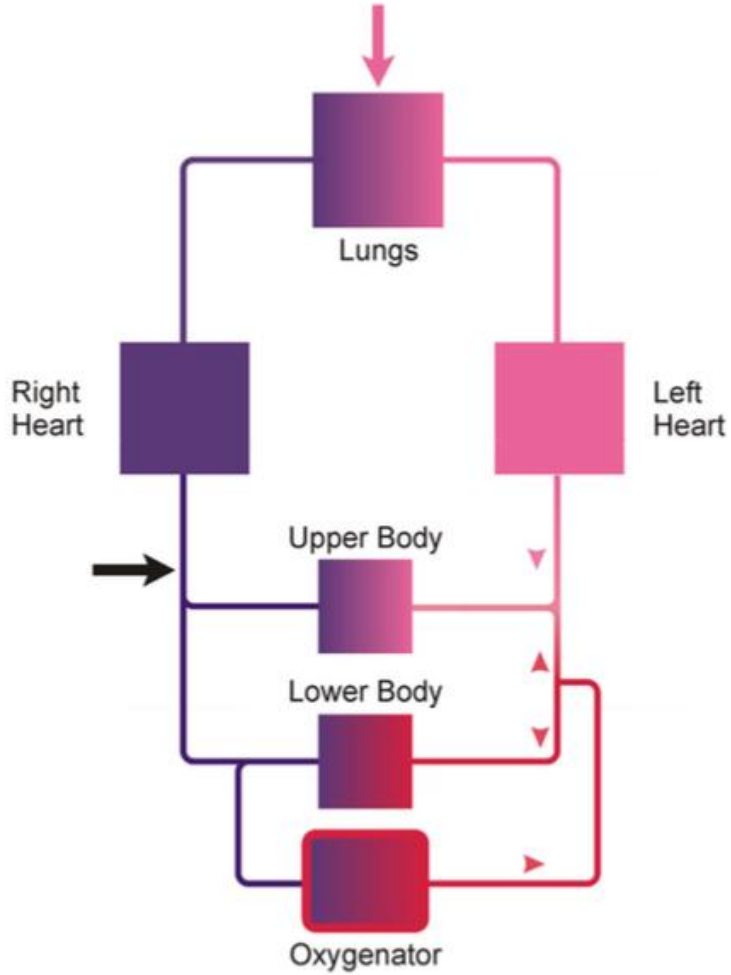
In order for it to happen you need

- VA ECMO
- Heart ejecting (e.g. pulsatility returning)
- **Bad Lungs (e.g. pulmonary oedema/ARDS)**

Differential Hypoxia = Bad Lung

(VA-peripheral configuration AND Beating heart)



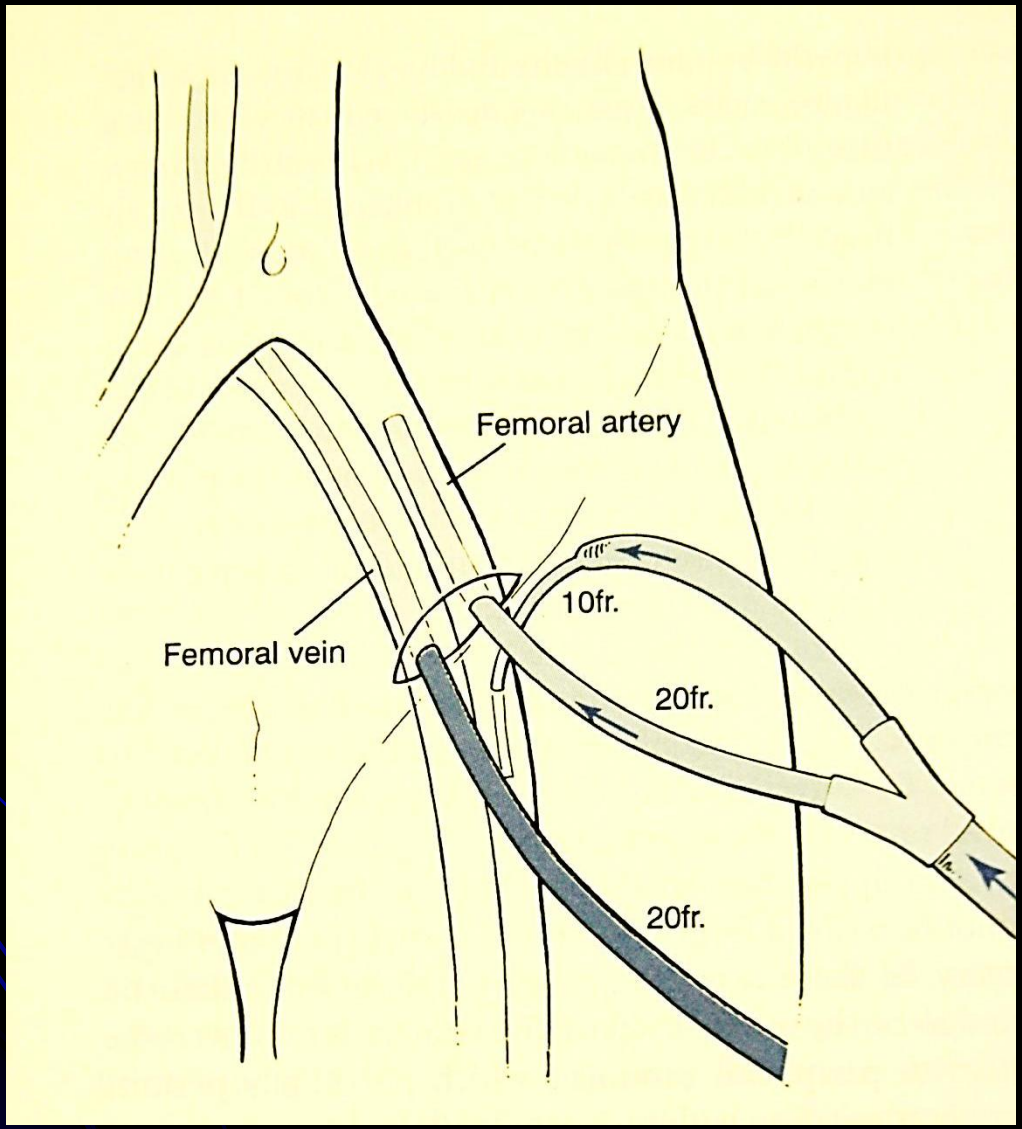


VA ECMO Maintenance: Respiratory Support: Differential Patient Hypoxia

- Peripheral ECMO only
- Measure SaO2 in right arm always
- Severe lung shunt with recovering cardiac function i.e. generally good news for cardiac recovery
- Seen typically with out of hospital cardiac arrest / aspiration

- Management
  - Treat cause of lung shunt
  - Increase lung support
  - Increase circuit blood flow (Hi-flow configuration)
  - Consider change of mode to VV ECMO support *(very severe respiratory process)*

Distal perfusion cannulation



Distal Perfusion Cannulation

Complication

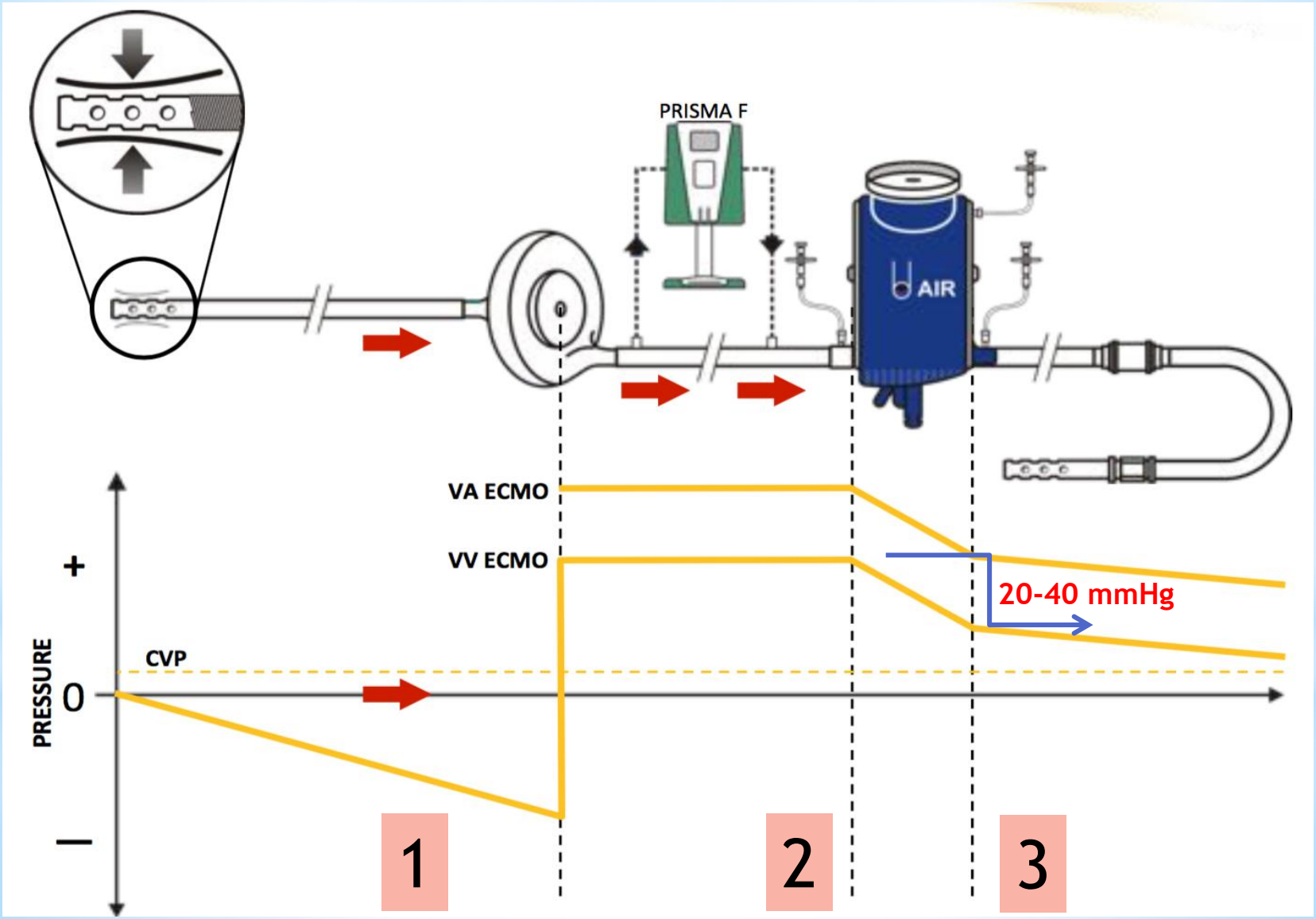
- Hyper-perfusion Syndrome
  - Pressurized flow into femoral arterial tree with obstructed venous return (usually from an ipsilateral femoral venous cannula)
  - Can result in leg swelling and infarction

Venous system must not be obstructed

Main target in VA-ECMO
(two circulations)

	Interpretation	Accessment
Pulsatile	no intra-cardiac thrombosis	echo
Adequate O2 delivery	good CO	SvO2>70%
No LVF	adequate LV-RV decompression	CXR, echo
No Differential hypoxia	good lung	SaO2 Rt. Arm
No Bleeding/Thrombosis	hematologic profiles	ACT 180-200
		APTT 50-70
		plt >80,000
No Limb ischemia	leg complication	doppler

ECMO circuit Pressure Monitoring



Increase Transoxygenator gradient
(normal 20-40 mmHg)

- Clot formation within oxygenator
- Return cannula size
- Excessive flow rate

ECMO Specific Routine Medical Care (1)

Routine Investigations

1. Daily CXR
2. Daily bloods : BS, BUN-Cr, K+, Mg++, PO4-, LFT, INR, Fibrinogen, D-dimers
3. APTT, plasma free Hb (<0.1g/dl) 6 hourly

Assess adequacy of ECMO support and target setting

1. **VV ECMO** target blood flow must provide **adequate SaO2** while allowing **non-injurious lung ventilation**
2. **VA ECMO** target and native blood flow must provide **adequate systemic O2 delivery**. Prevent clot formation within the heart. Adequate decompression of L and R heart

Prevention of lower limb ischemia (VA ECMO)

1. All patients with peripheral VA ECMO should have a backflow cannula inserted at the time of cannulation
2. Ultrasound lower limbs on day 1 and when significant arterial cannula site bleeding

ECMO Specific Routine Medical Care (2)

Anticoagulation and prevention of bleeding

1. **Non-Bleeding** Patients
   - Platelets > 50,000
   - Systemic heparin APTT target is 50-70
2. **Bleeding** and Post-op Patients
   - Hold heparin until bleeding stopped for 12-24 hr
   - Aggressively replace all clotting element deficiencies
   - Give cryoprecipitate to target fibrinogen > 1.5
   - Give platelets to target > 80,000
   - Give FFP to target INR <1.3
   - Bleeding >400ml/hr for two hr ; inform surgeon
   - Protamine use only in heparin overdose (pre primed circuit just in case)
   - Factor VIIa if indicated
   - Heparin induced thrombocytopenia (rare), stop heparin and give thrombin inhibitors, platelet counts should not be treated. Circuit bond heparin is OK.

Circuit thrombosis

- Increase D-Dimer
- Decrease fibrinogen (<2)
- Change circuit if post-oxygenator PaO2 <200mmHg

ECMO Specific Routine Medical Care (3)

Lung ventilation management

(Non-injurious lung ventilation is a primary goal)

1. VV ECMO keep sedation (midazolam if unstable BP)
    - TV < 3ml/kg
    - PEEP 10-15cmH2O
    - Pplat < 25cmH2O
    - FiO2 ≤ 0.4

    De-sedation if TV>3ml/kg for spontaneous breathing
2. VA ECMO ventilator setting to provide
    - Adequate lung aeration, normal FRC, adequate PEEP level
    - Prevent over lung ventilation. Target ETCO2 20-30mmHg
    - If RHF, minimising RV afterload

Tracheostomy

May be indicated In prolonged sedative VV ECMO

Uncommon in VA ECMO

Sedation

- During cannulation and first 24 hr
  to avoid spontaneous breathing, air embolism during cannulation
- After ECLS
  stop to allow neurological exam (daily). Then resumed
- Sedation should be minimal but sufficient to avoid increasing native metabolic rate
- Systemic paralysis and cooling may be necessary if venous drainage cannot be achieved

VV ECMO for Respiratory Failure

Configuration

- Femoro-femoral
- Femoro-jugular
- Hi-flow (3 catheter)
- Double lumen

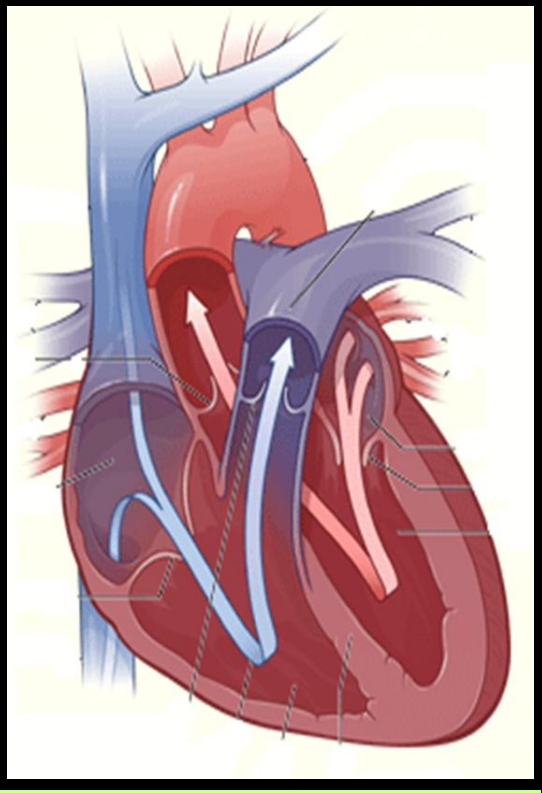
(Avalon / Novaport twin)

Access (drainage)

- IVC
- IVC and SVC

Return

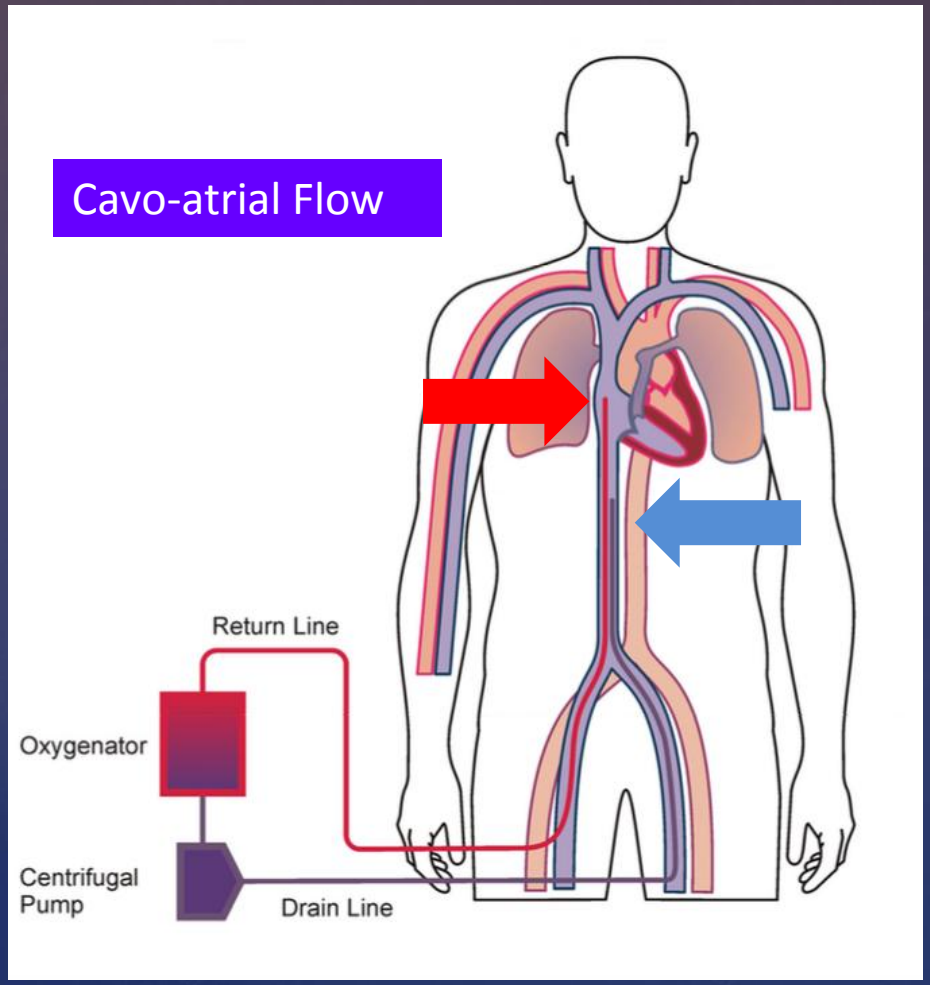
- Right Atrium



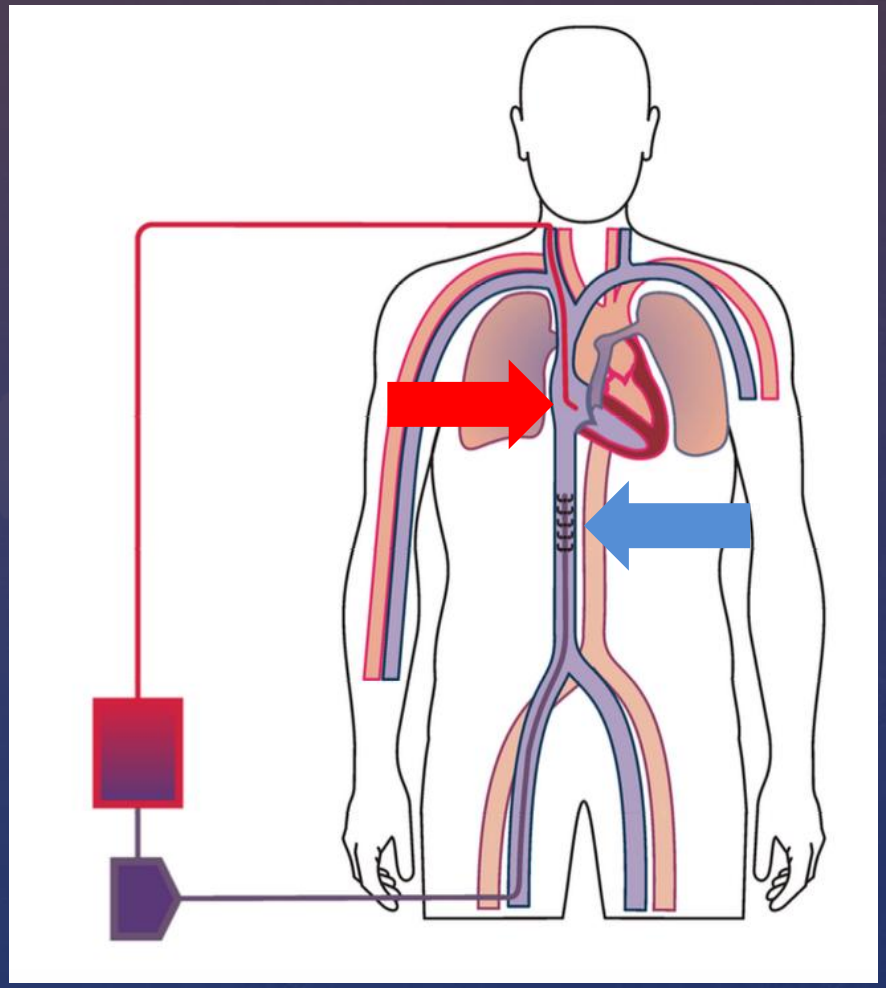
All provide cavo-atrial support to reduce re-circulation

Veno-venous ECMO

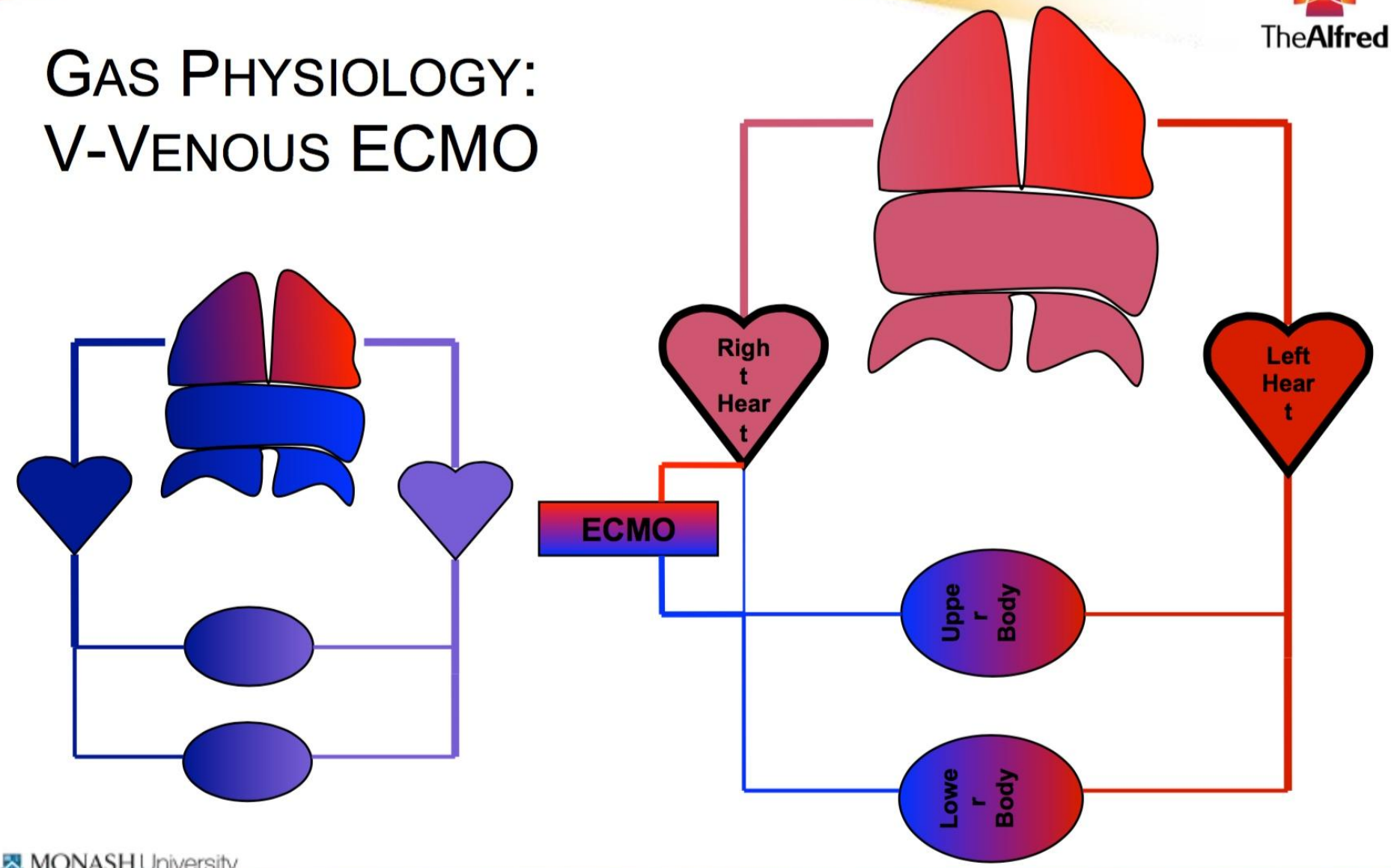
Standard Femoro-Femoral



Standard Femoro-Jugular



GAS PHYSIOLOGY: V-VENOUS ECMO



GAS PHYSIOLOGY: V-VENOUS ECMO

TheAlfred

To improve the patient's SaO_2 in the setting of a large lung shunt (on V-V ECMO):

Increase the ECMO flow

i.e. increase the proportion of venous return going to the oxygenator

Note: inflow of blood into the access cannula is limited by venous return to the vena cava

Or

Increase the Haemoglobin concentration

This is analogous to the native circulation

Gas Physiology : V-Venous ECMO

If the ECMO circuit is functioning correctly:

The ventilator settings are chosen to maximize lung recovery
(and minimize O_2 loss via the airway)

$FiO_2 <= 0.6$

Increasing the FiO_2 to the ventilator will NOT significantly change the SaO_2

Main target in VV-ECMO

1. Adequate Lung protection
2. Adequate SaO2
3. Adequate CO2 removal

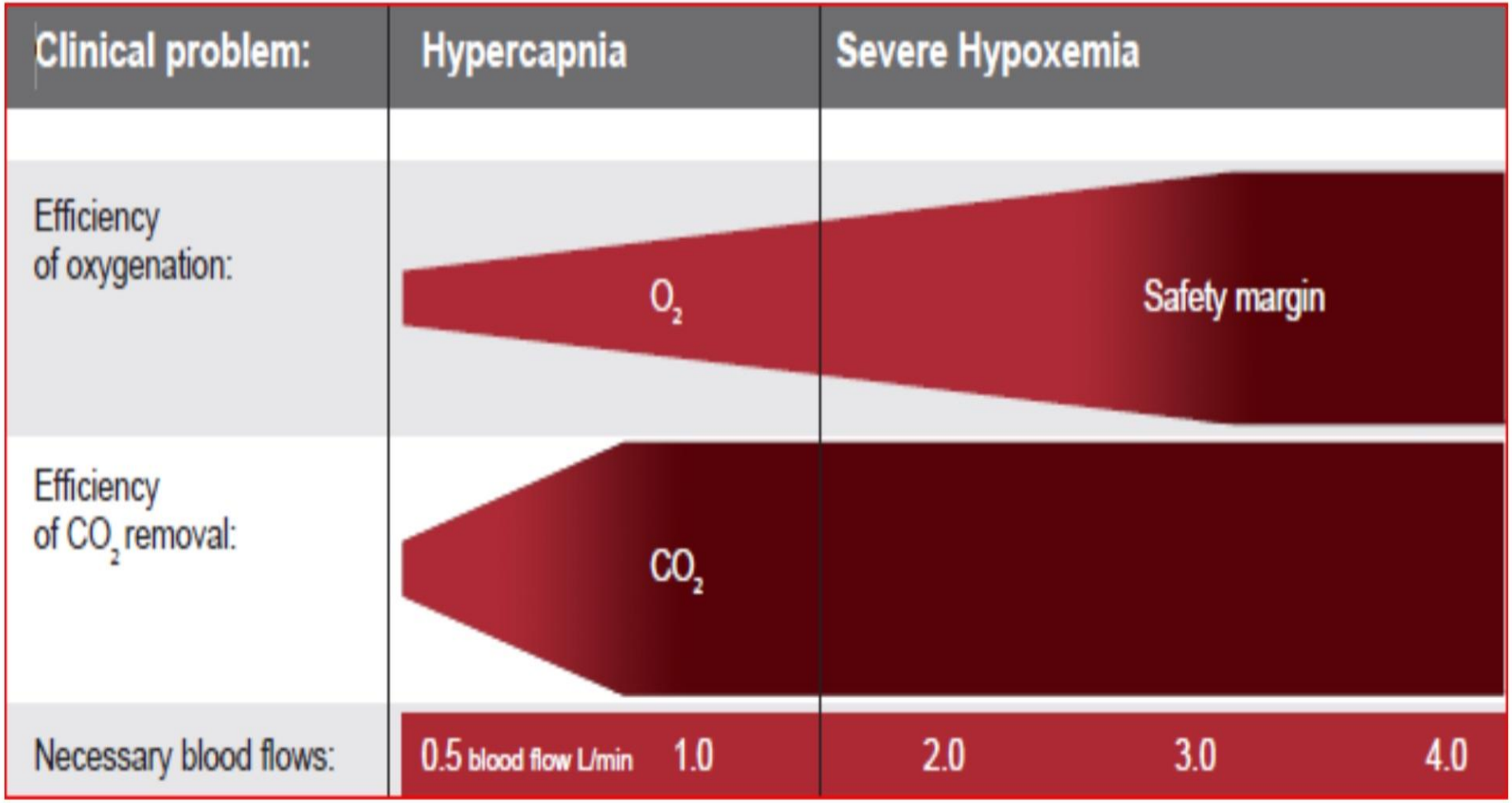
AVOID VENTILATORY DAMAGE

Spontaneous breathing, whenever possible ⇨ **support!!**

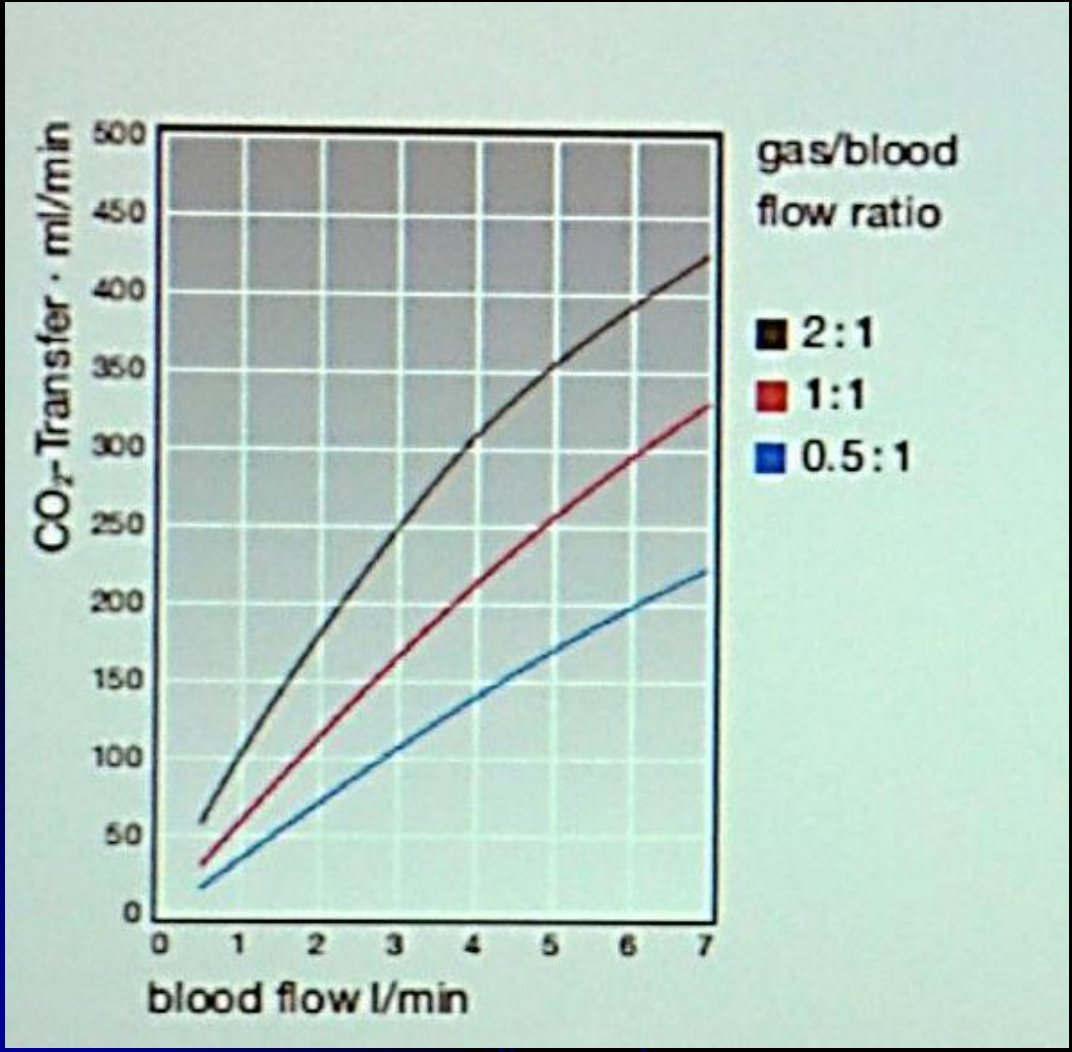
MINIMIZE VENTILATORY DAMAGE

Small tidal volumes	⇨	$V_T = 3 – 4$ ml/kg IBW
Low pressure amplitude	⇨	$\Delta P < 15$ cmH_2O
Low inspiratory pressure	⇨	PIP < 25 cmH_2O
High PEEP	⇨	Individual best level
Permissive hypercapnia	⇨	pH ≥ 7.2
Low respiratory rate	⇨	RR = 5 – 15 / min

BLOOD FLOW AND GAS EXCHANGE



CO_2 Transfer



Main determinant of CO2 removal is sweep gas flow

If gas/blood flow >2 or Gas flow >11L/min should consider oxygenator malfunction

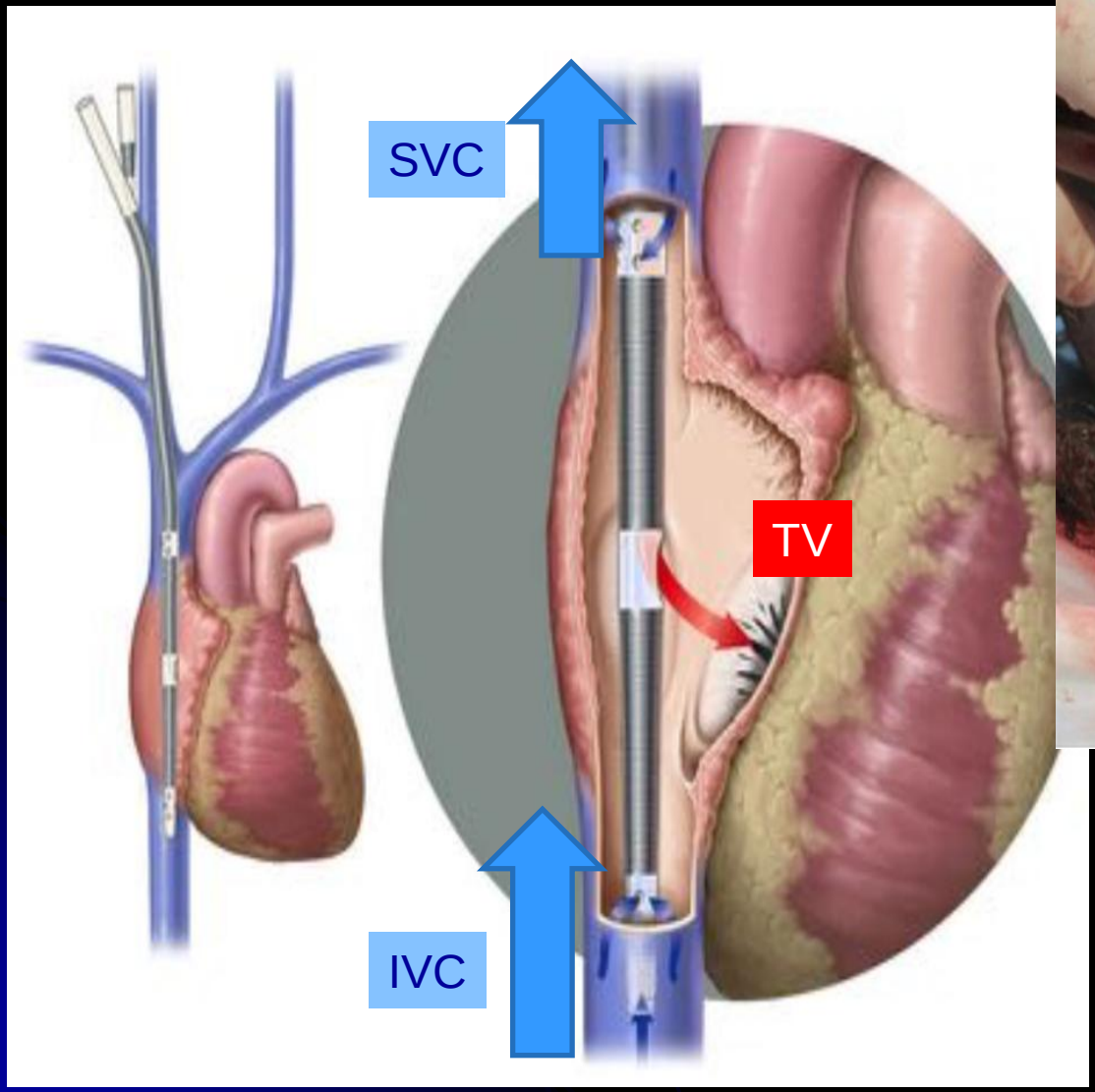
NovaPort twin double lumen

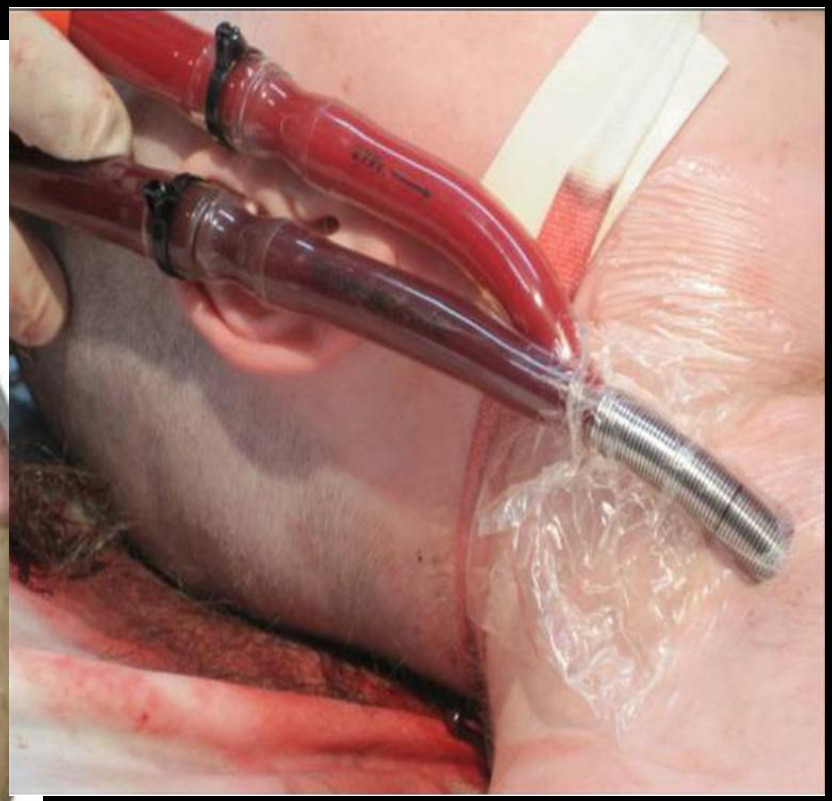
18 Fr	6 mm	170 mm
22 Fr	7.3 mm	170 mm
24 Fr	8 mm	270 mm

For Venovenous vascular access

Double Lumen Cannula for VV ECMO

(Avalon / NovaPort twin)





"SIMILAR BUT DIFFERENT"

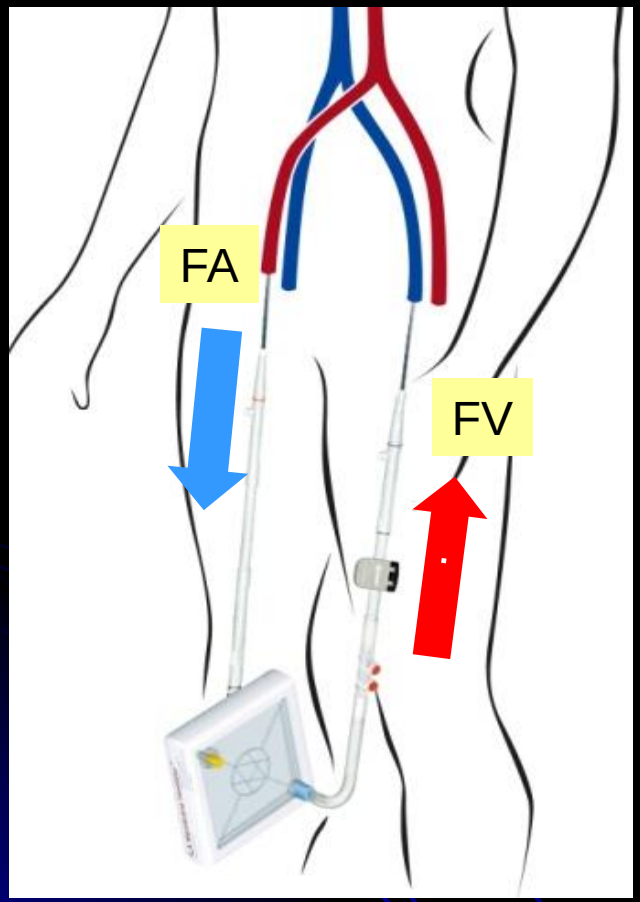
<u>$ECCO_2R$</u>

- Extracorporeal CO_2 removal
- Gattinoni (1980's)
- Low flow (small cannulae), peripheral cannulation, veno-venous support that provides good CO_2 removal but limited oxygenation.
  - Used as an adjunct for lung protective ventilation
- Seriously coming back into "vogue"

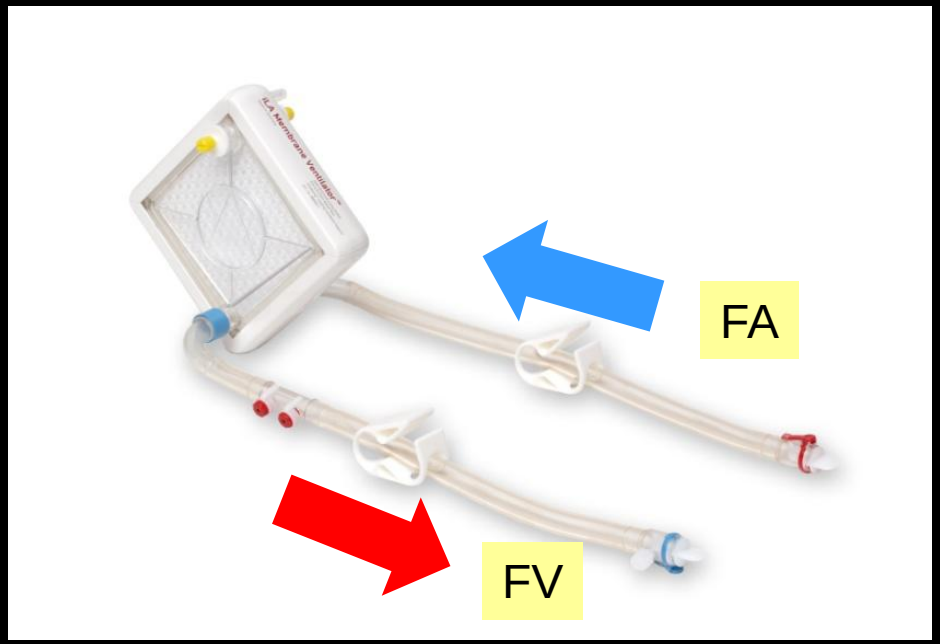
<u>A-V "pump-less" $ECCO_2R$:</u>
"Novalung"

- Arterio-venous pump-less extracorporeal CO_2 removal
- Arterial access cannula and venous return cannula
- Patient arterio-venous pressure gradient provides circuit flow to an oxygenator
- Good CO_2 removal but limited oxygenation
- Introduces the risks of arterial cannulation

iLA Membrane Ventilator
(pumpless ECCO2R)



- Pumpless Extrapulmonary Gas Exchange
- Lung Protection
- Extracorporeal CO2 Removal , Low Flow (25%)
- NovaPort one KI (single lumen cannulas)
- Longterm use (29 days)
- Combined CRRT



Clinical Usage : Pumpless(AV)

- Status asthmaticus
- Weaning ventilator
- ARDS
- H1N1
- Traumatic Brain Injury
- Bridge to Lung Transplant
- Transportation
- Thoracic Surgery

Weaning of ECMO

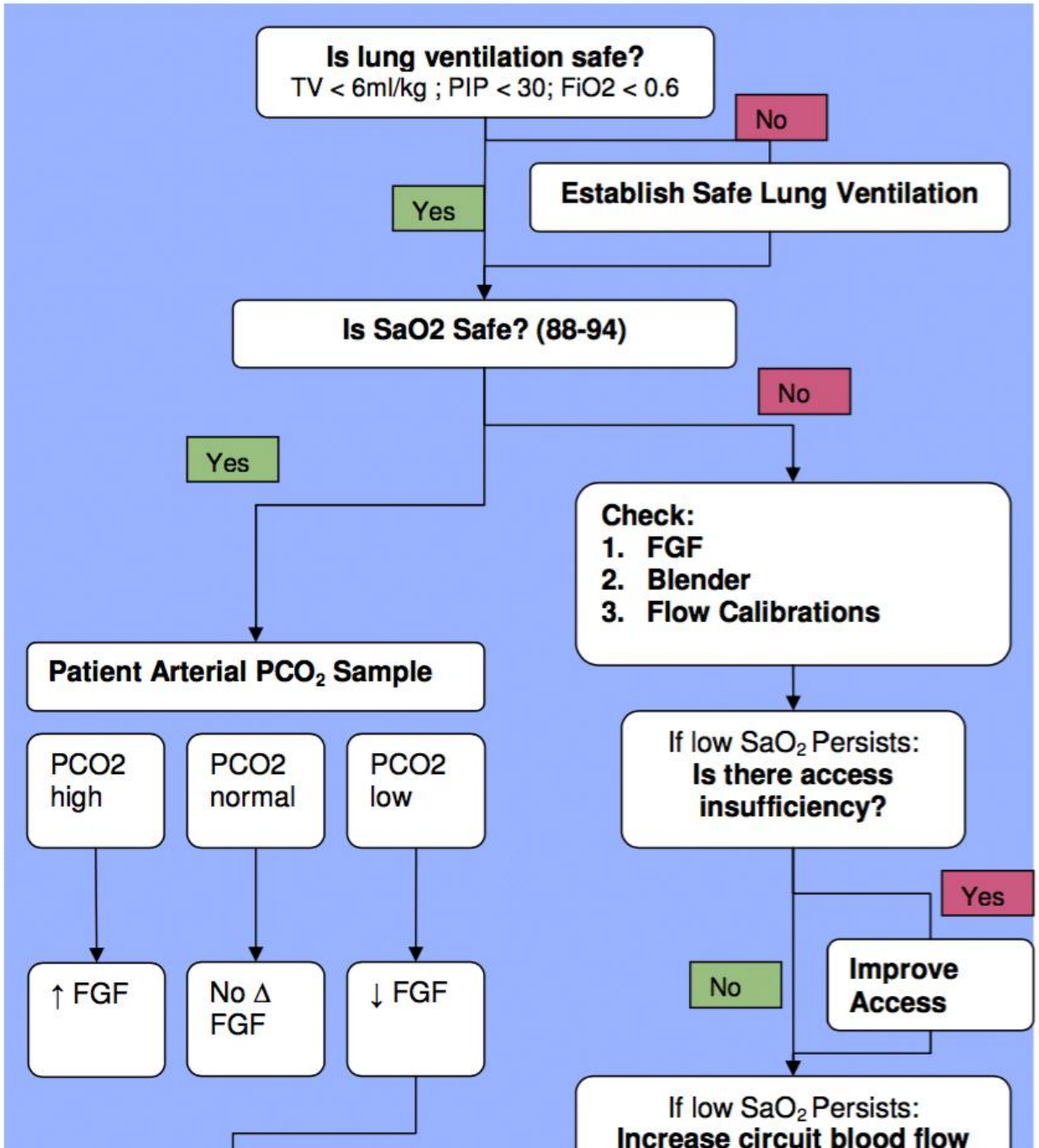
VV ECMO

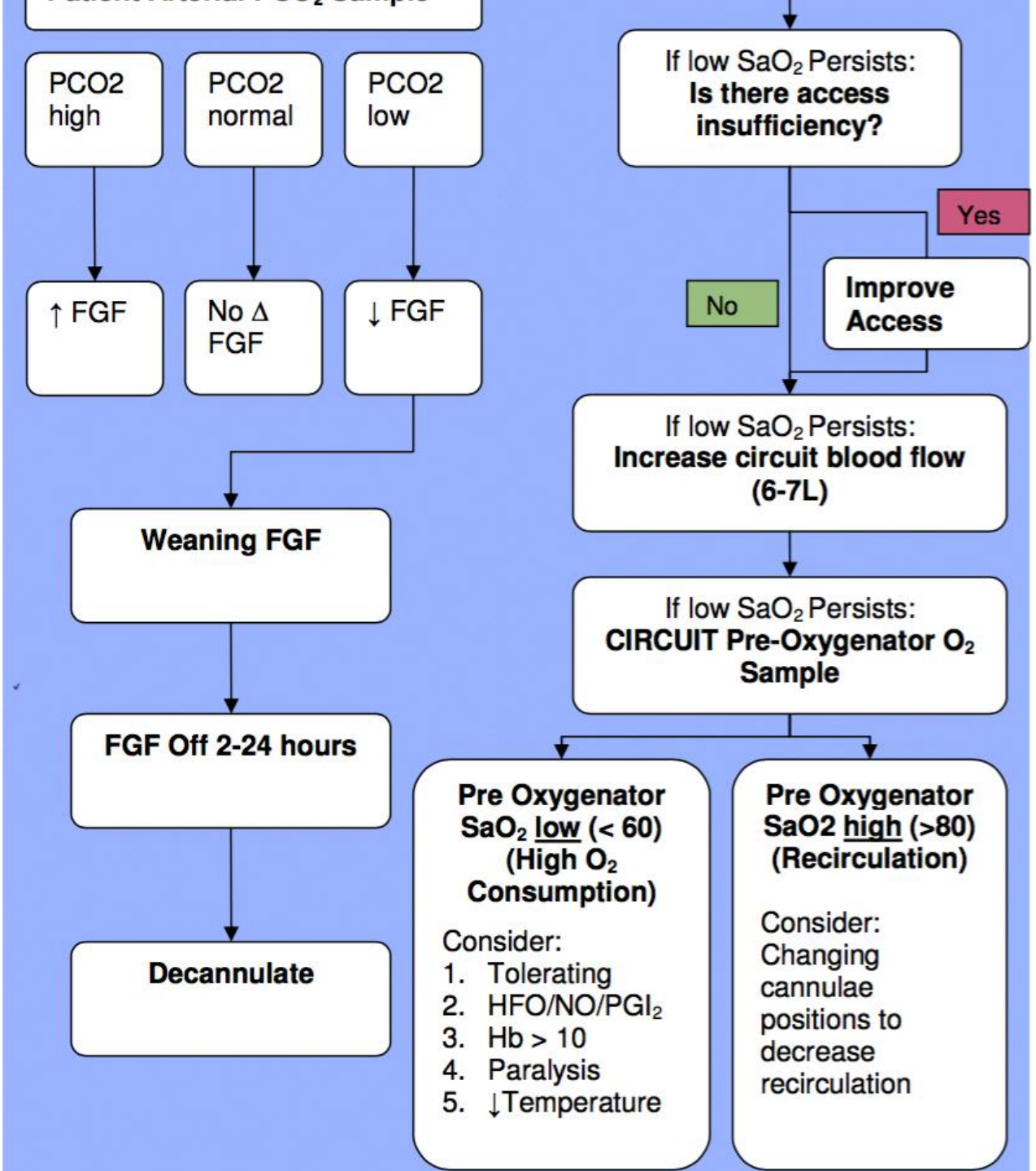
- Progressively **reducing gas flow**
- No need to reduce circuit flow
- No need to wean blender FiO_2
- Increase lung ventilation to ensure adequate CO_2 clearance
- Observe for 4-24hr with gas flow at 0 L/min
- Echo is not required

VA ECMO

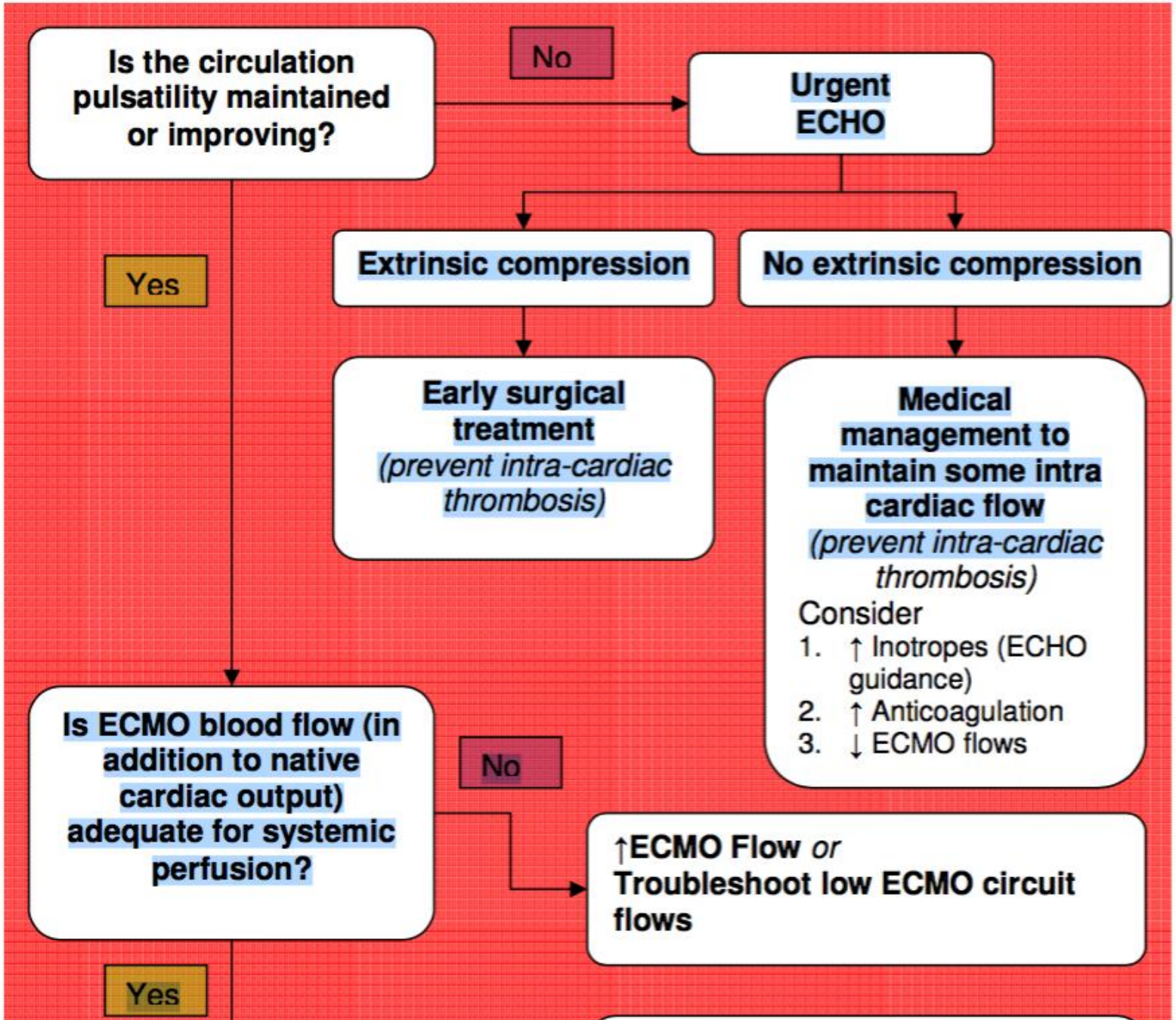
- Assess native heart function by reduce circuit flow, echo required
- Increase Lung ventilation, decrease gas flow

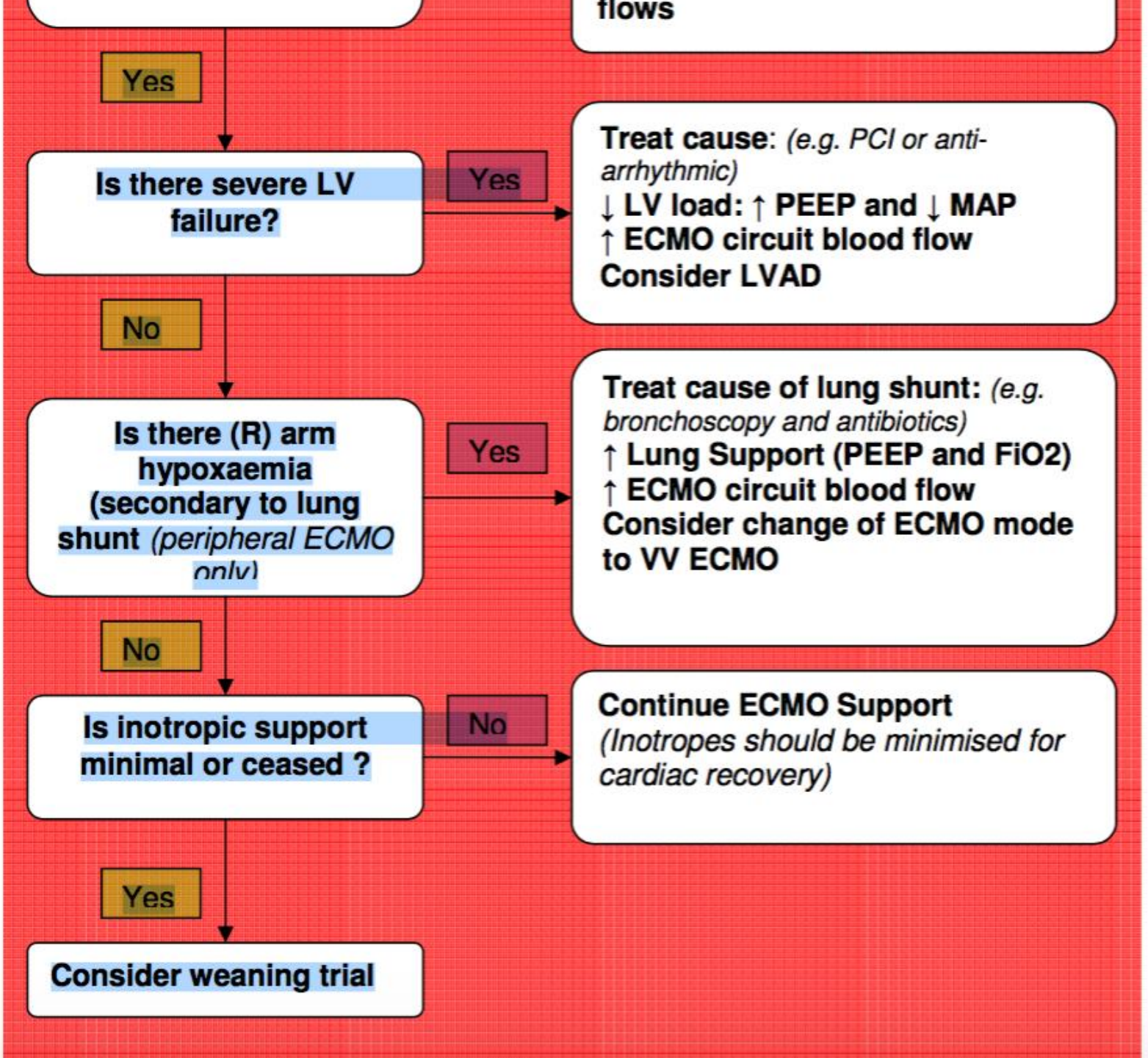
Veno-Venous ECMO Clinical Pathway




PCO2 high
PCO2 normal
PCO2 low
↑ FGF
No Δ FGF
↓ FGF
Weaning FGF
FGF Off 2-24 hours
Decannulate
If low SaO_2 Persists: Is there access insufficiency?
Yes
No
Improve Access
If low SaO_2 Persists: Increase circuit blood flow (6-7L)
If low SaO_2 Persists: CIRCUIT Pre-Oxygenator O_2 Sample
Pre Oxygenator SaO_2 low (< 60) (High O_2 Consumption)
Consider:
1. Tolerating
2. HFO/NO/PGI_2
3. Hb > 10
4. Paralysis
5. ↓Temperature
Pre Oxygenator SaO2 high (>80) (Recirculation)
Consider: Changing cannulae positions to decrease recirculation

Veno-Arterial ECMO Clinical Pathway




flows
Yes
Is there severe LV failure?
Yes
Treat cause: (e.g. PCI or anti-arrhythmic)
↓ LV load: ↑ PEEP and ↓ MAP
↑ ECMO circuit blood flow
Consider LVAD
No
Is there (R) arm hypoxaemia (secondary to lung shunt (peripheral ECMO only)
Yes
Treat cause of lung shunt: (e.g. bronchoscopy and antibiotics)
↑ Lung Support (PEEP and FiO2)
↑ ECMO circuit blood flow
Consider change of ECMO mode to VV ECMO
No
Is inotropic support minimal or ceased ?
No
Continue ECMO Support
(Inotropes should be minimised for cardiac recovery)
Yes
Consider weaning trial

ECMO- How to do it right?

1 Support what? Determine MODE
2 How much flow? Calculate adequate flow
3 Catheter size/type Size selection
4 Oxygenator size Size selection
5 What configuration? Access-Return sites
6 How/what to access? Set targets
7 Detection of complication
- Bleeding / Thrombosis
- Access insufficiency
- LV failure (LVF > RVF)
- Differential hypoxia
- Loss of pulsatility

8 How to wean?