Macau Society of Emergency and Critical Care Medicine

Extracorporeal Membrane Oxygenation
An update

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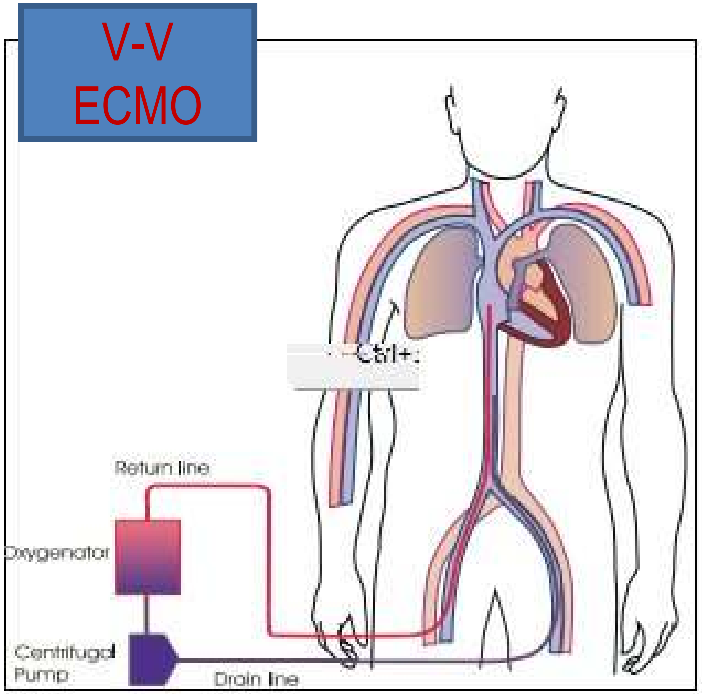
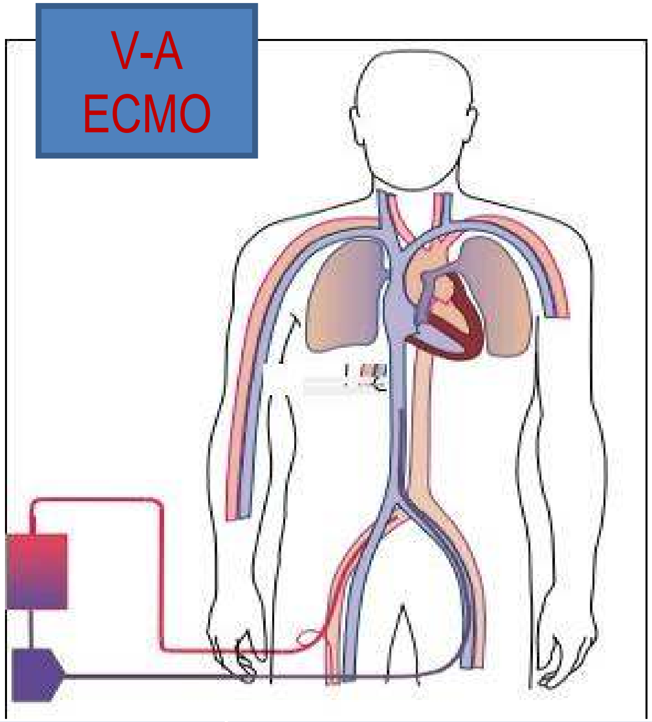
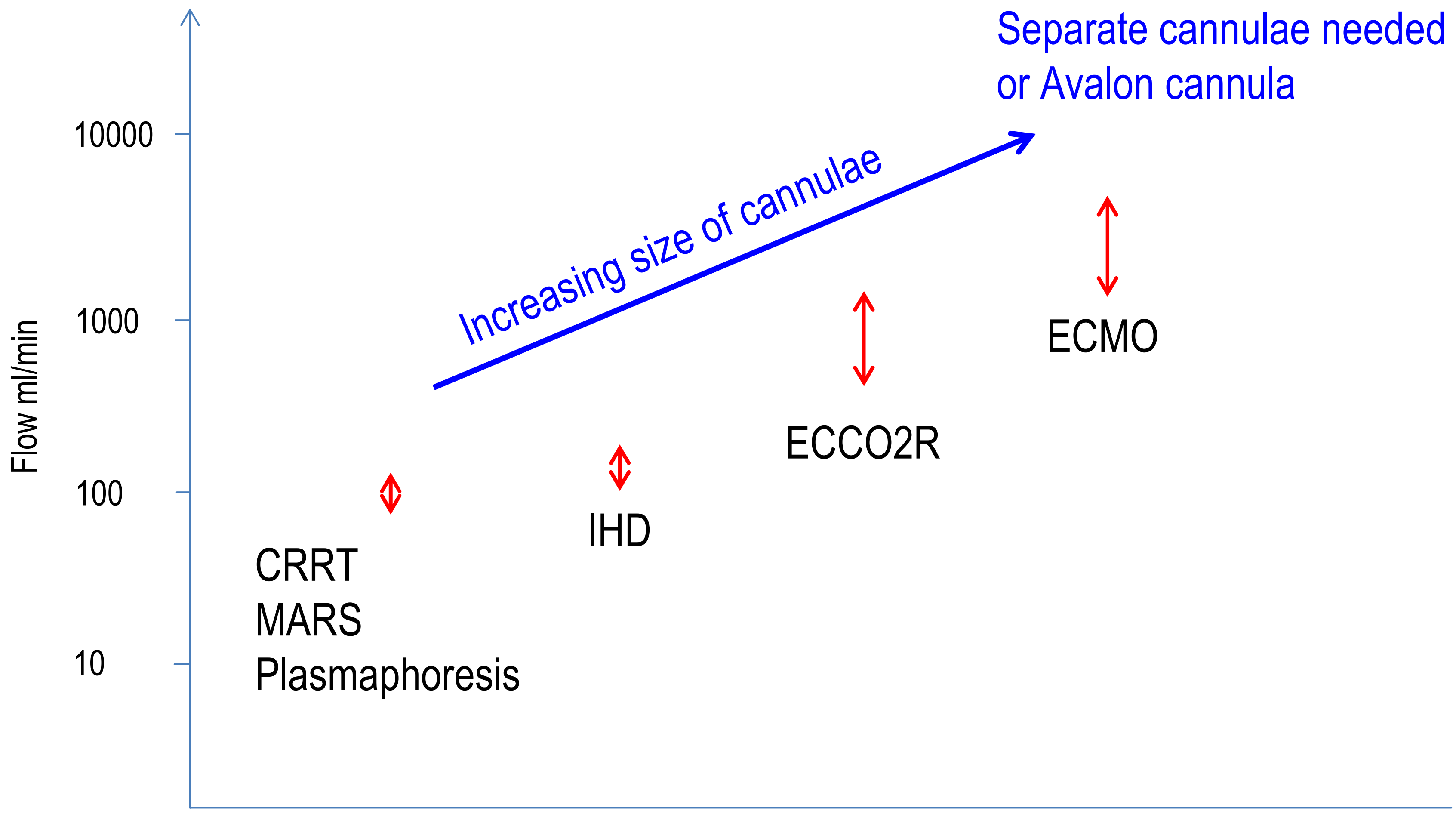
Types of ECMO





	Bad lung good Heart	Good lung Bad heart	Bad lung Bad heart
V-V	√	X	X
V-A peripheral	X	√	√
V-A Central	√ (not required)	√	√

Extracorporeal flow needed



Regional citrate
anticoagulation possible

Principles of ECMO

- Temporary support the failed lung
  - Not suitable for irreversible lung failure
  - Less suitable for the lung condition required long time to heal (complication risk > benefit)
- Buy time for the lung to recover
  - Keep patient alive
  - Create an optimal condition for the lung to heal
- Avoid complications related to ECMO

Complications of ECMO

- Vessel damage during insertion
- Unidentified heart failure
- Bleeding
- Circuit thrombosis
- Oxygenator failure
- Haemolysis
- Air embolism
- Circuit rupture
- Infection
- Access recirculation

Vessel damage

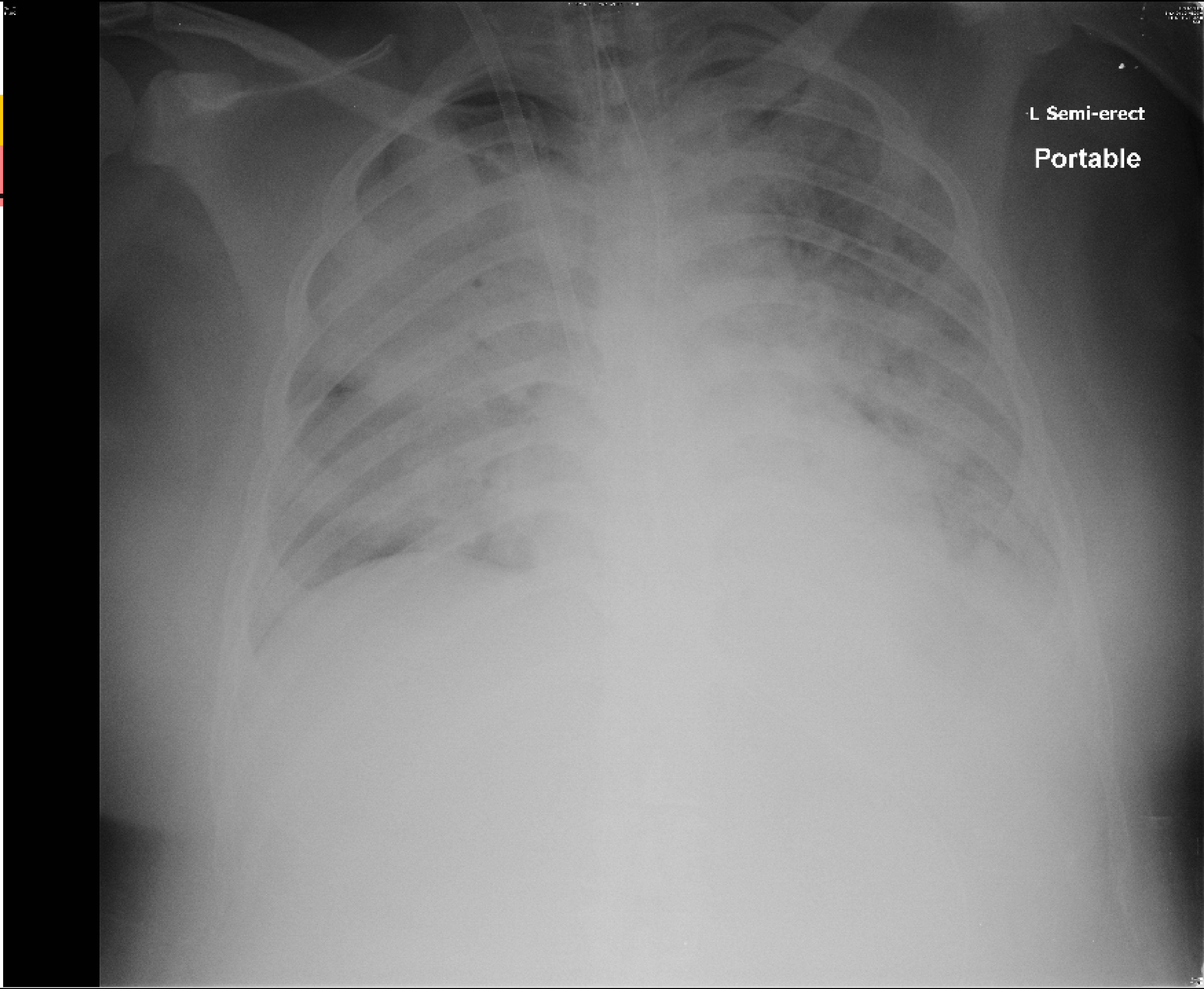
- Appropriate size
- Too large
  - More damage to vessel
  - Increase insertion failure
  - More chance of chattering (cf. size of IVC)
- Too small
  - Not enough flow$_e$
  - Haemolysis
  - May need to insert one more access cannula

Vessel damage

- Arterial damage
  - May be fatal
  - Or limb loss
  - Need surgical repair
- Better having ultrasound guidance
  - Don't trust pre-existing central lines (re-wiring)
  - Especially in obese patients
- Difficult if ECMO is running, especially VA-ECMO
- Need expertise

Risk of unidentified heart failure

- Desaturation
  - No longer a sign of heart failure even with severe pulmonary oedema
  - CXR - can't differentiate LVF with underlying lung problem
- Esp. with line chattering or hypotension
  - Need repeated fluid challenge
  - Very common especially in the first few days
- Monitor
  - Clinical examination
  - Daily I & O   Input >> Output
  - Echocardiography
- Treatment
  - Diuretics
  - CRRT


L Semi-erect
Portable

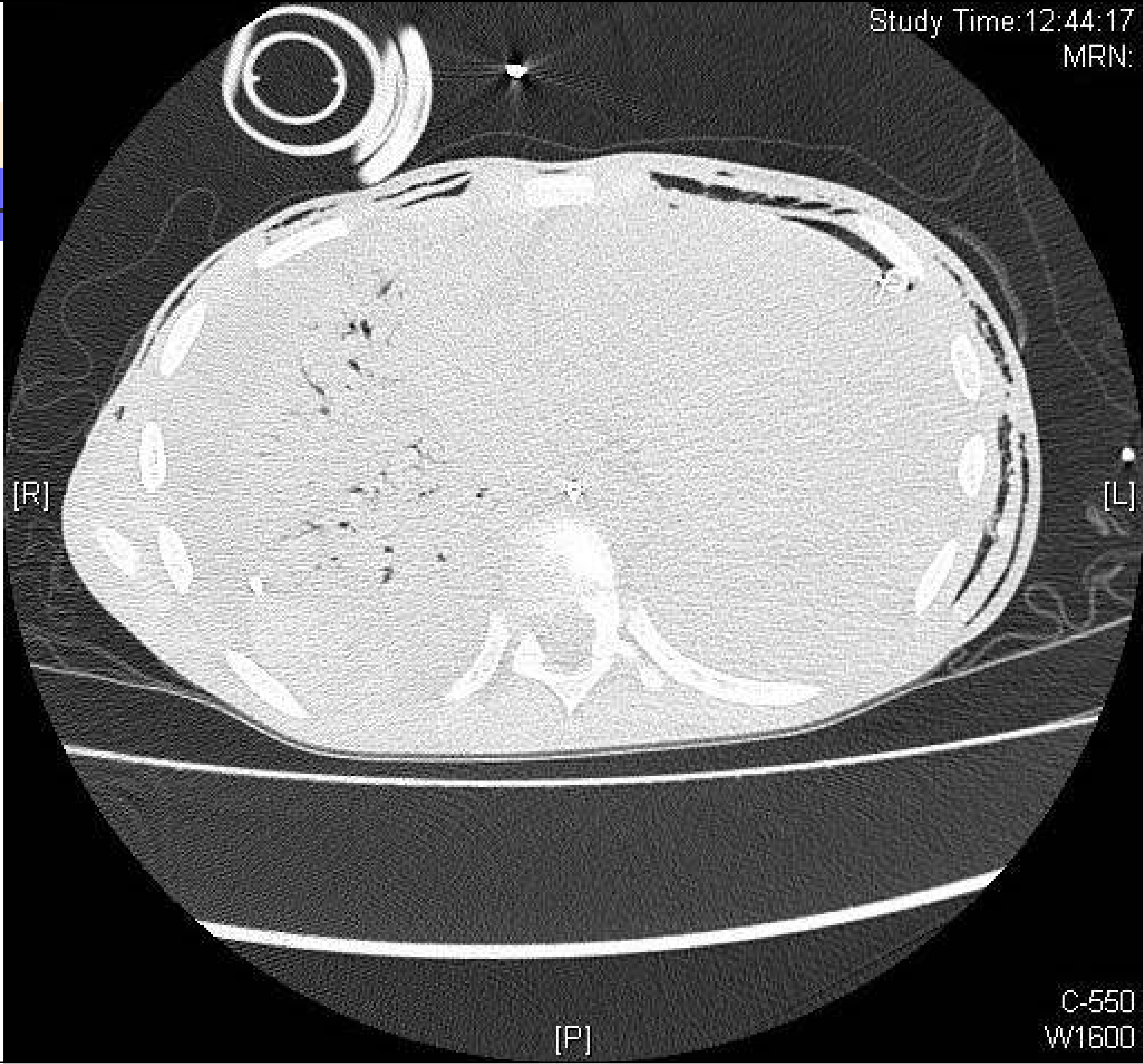
Risk of haemorrhage

- Systemic anticoagulation
  - Regional citrate anticoagulation is not possible
- Major cause of mortality of the past ECMO series
  - 43% of deaths in ANZ ECMO series were related to ICH, JAMA 2009;302:1888-95
  - Zapol study JAMA 1979;242:2193-6
  - Gattinoni study JAMA 1986;256:881-6
- ICH, GIB, pulmonary haemorrhage or cannulation sites
- Too low anticoagulation
  - Risk of thrombosis
  - Keep $flow_e$ >1 L/min
  - Chinese less thrombosis, more haemorrhage
  - Target 40-50s APTT (more accurate than ACT for low level anticoagulation)

Risk of haemorrhage

- Tracheostomy
  - Prolonged intubation and ventilation
- Chest drain insertion or removal
- Pleural aspiration
  - Pneumothorax
  - Pleural effusion

- Don’t do unless you have no choice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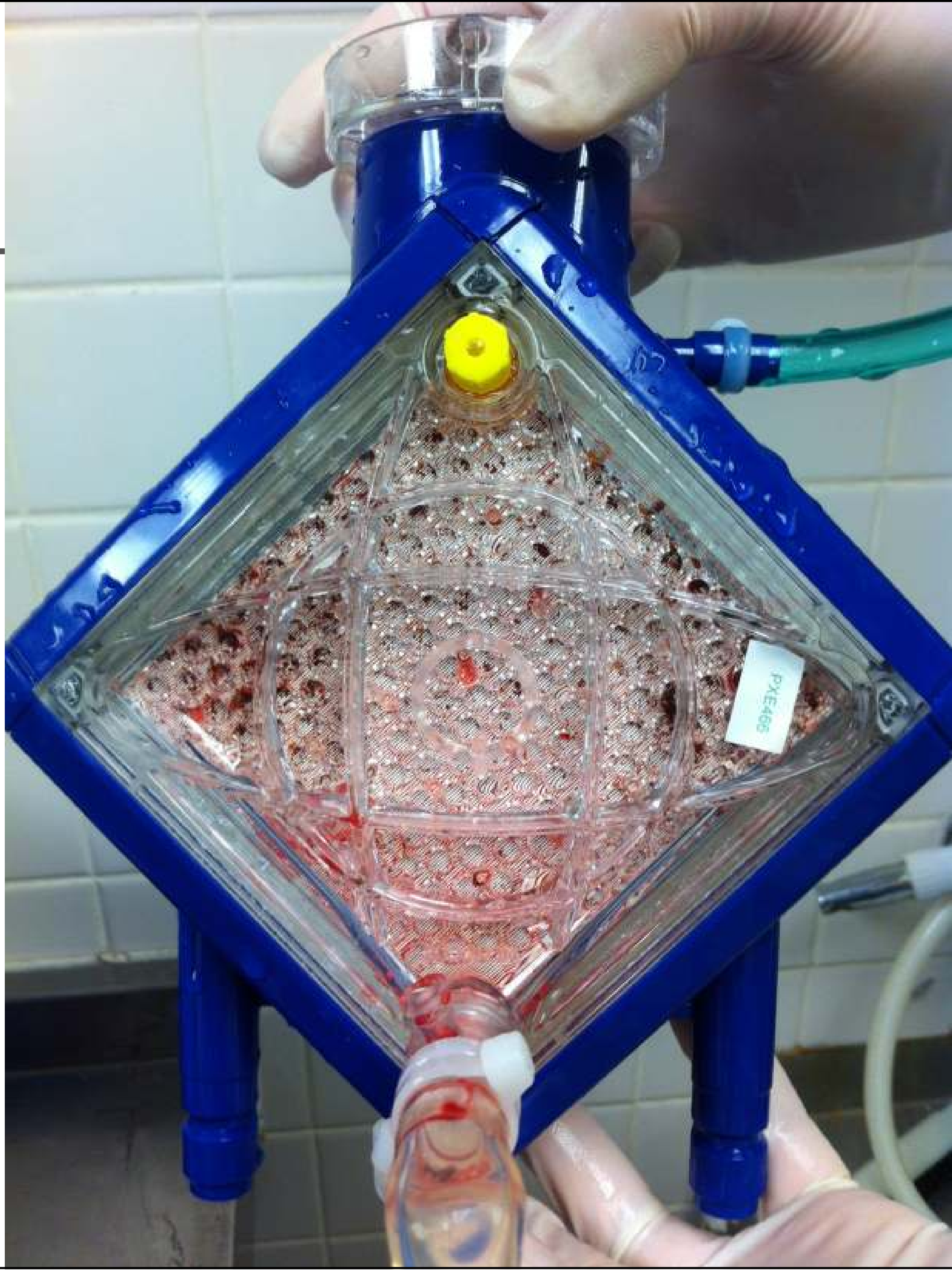
Circuit thrombosis → Oxygenator failure

- Oxygenator failure
- Colour of return blood, should be 100% saturated
- Monitor clot formation on oxygenator surfaces
  - Especially when no systemic anticoagulation
  - Difficult to detect sometimes
  - The process is accelerating
    - Very quick decision
    - Reserve set should be available at all time


PXE466

Oxygenator failure

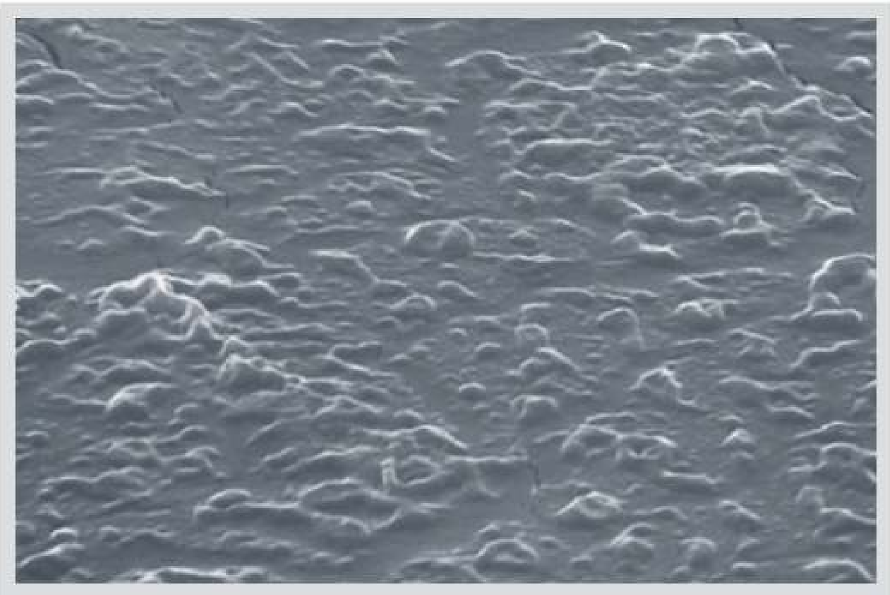
- Days of ECMO therapy
- Any evidence of DIC
- Systemic anticoagulation
- Post-oxygenator blood gases
  - PO2 >40-80kPa
  - PCO2 should not increased
- Pre & post oxygenator pressures (pressure drop)
  - Estimated by CRRT machines
  - Noted the pressure changes during blood flow or
  - Stopped the CVVH blood flow and record the pressures

Pressure Monitors

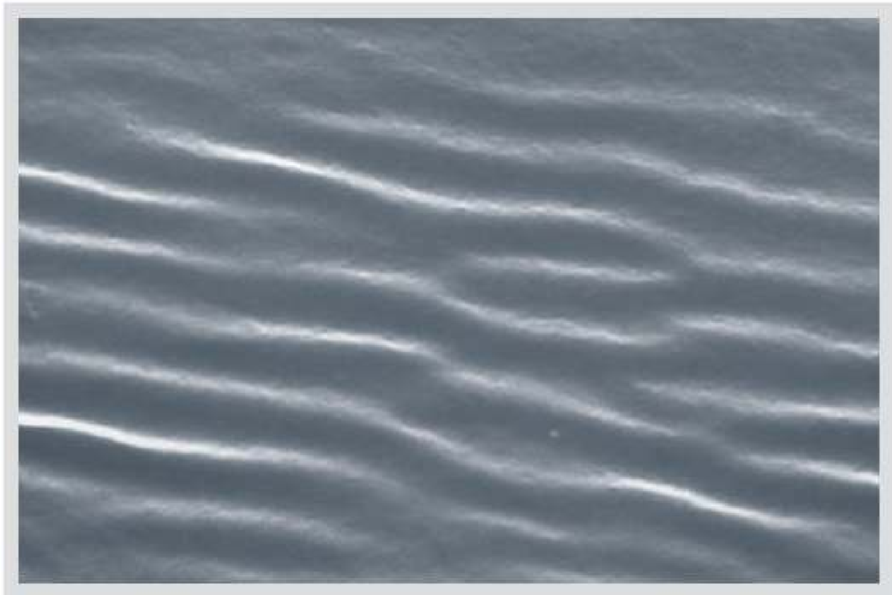
- Venous pressure
  - Detect insucking
- Arterial pressure
  - Detect obstruction to outflow
- Pressure drop across oxygenator
  - Detect oxygenator clotting
- Risk of thrombosis / infection as a segment of stagnant blood is introduced
  - Integrated senor in the Cardiohelp system (cannot recalibrate)

Bioline coating form Maquet

- Covalently bonded heparin to an albumin layer on PVC surface
  - Reduced clotting activity
  - Reduction of platelet adhesion and of thrombi creation
  - Less complement activation & neutrophil activation



Uncoated inner surface of PVC tubing (5000 x magnified)



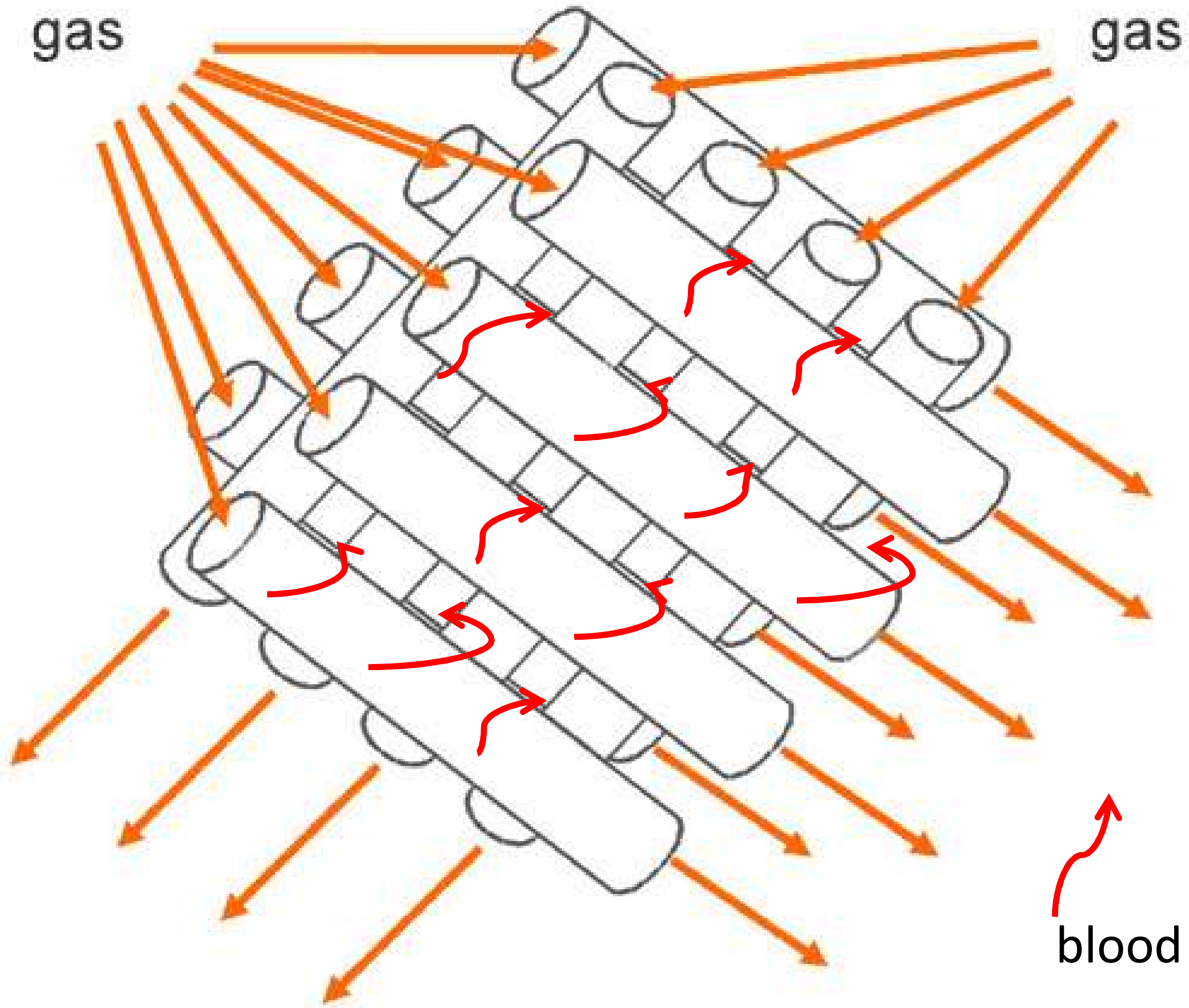
BIOLINE coated inner surface of PVC tubing (5000 x magnified)

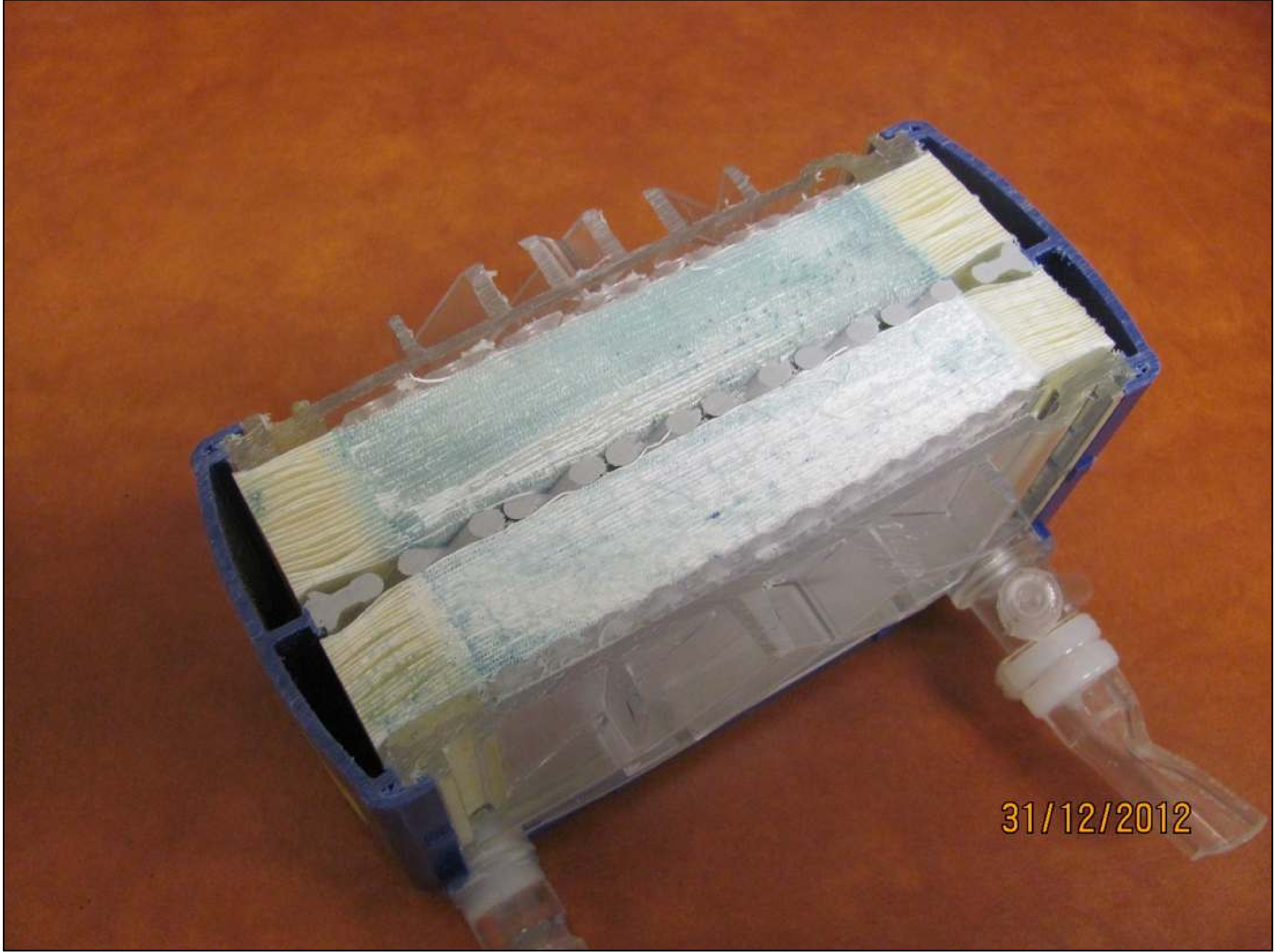
Risk of haemolysis

- Minimize
  - Larger cannulae size
  - Lower flow$_e$
    - Lowest possible to maintain adequate oxygenation
    - Still >1.5L/min to prevent circuit thrombosis
- May need to insert one more access cannula; high-flow ECMO
- Change oxygenator if lots of clots exist
- Monitor
  - Dec. Hb
  - Inc. plasma free Hb
  - Inc. bilirubin
  - Urine colour
  - Renal function test

Haemoglobinuria

Membrane Lung

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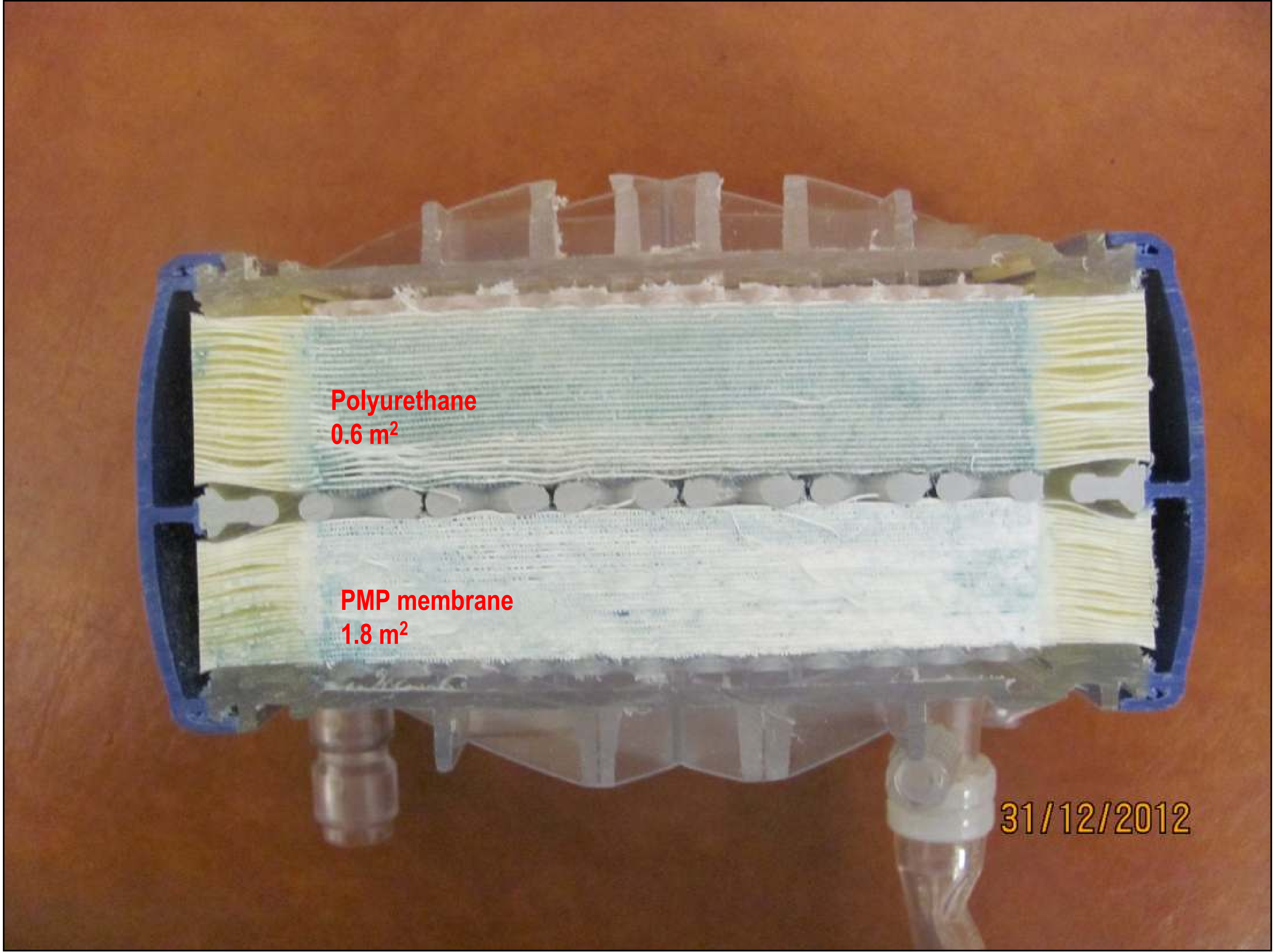

Polyurethane
0.6 m2
PMP membrane
1.8 m2
31/12/2012

Risk of air embolism

- Life threatening
- Disconnection before the centrifugal pump
  - Negative pressure
  - Virgin area
  - No connection over these sites
  - Plastic binders to reinforce tightness
- After pump
  - Positive pressure
  - Bleeding
  - Connection to CRRT circuit

Air embolism

- Total disconnection before pump
  - Circuit embolism and pump failure
- Partial disconnection
  - Circuit embolism and patient gas embolism
- Air embolism during CVC insertion while ECMO is running especially VA-ECMO
- Clamping of circuit in drainage line (pre-pump area) with pump running at high speed

Three fatal scenarios with ECMO gas flow

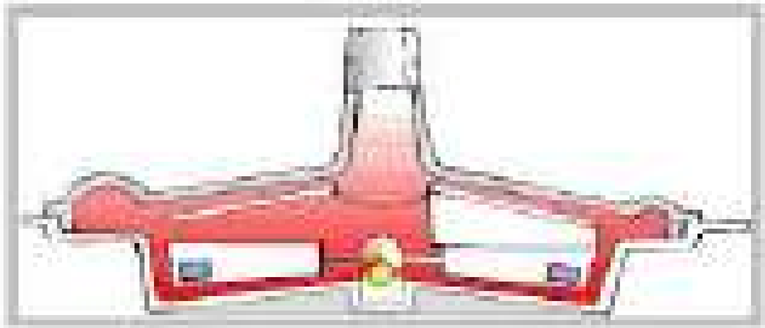
- Failure to connect O_2 tubing
  - Staff teaching
  - To & after transport
- Obstructed gas outlet
  - During transport (putting oxygenator on bed upright)
  - Water collection cup too close to gas outlet
- Gas flow too high
  - As in resuscitation to >15L/min
  - Normally Gas flow < 2x ECMO blood flow

Risk of bleeding from circuit rupture

- Much less with centrifugal pump
  - Compared with roller pump
  - Important advancement in ECMO design
- If it really happens, what would you do?
  - Clamp the line with two line clamps ?
    - not practical
  - Basic PPE and then grab the line

Centrifugal Pump

- Jostra RotaFlow impeller pump
- 32ml priming volume
- The RotaFlow had no stagnant blood zones, no shaft and no seals



Roller vs. Centrifugal Pump

	Roller Pump	Centrifugal Pump
Advantages	Reusable pump with inexpensive disposable parts	No possibility of disruption from excessive line pressure buildup
	Ease of sterilization	Decreased blood trauma
	Simple flow rate determination	Less risk of massive air emboli
	Variable SV for different-sized patients	Less cavitation
Disadvantages	Blood trauma	More expensive non-reusable pump
	Possibility of circuit disruption and termination from excessive line pressure	Retrograde flow when pump slows or stops
	Particulate microemboli from tubing spallation	Flowmeter is necessary (poor performance at low flow)
	Possibility of massive air emboli	
	Occlusion variability affecting flow rate and blood trauma	

Infection

- Risk increases with increasing handling
  - Connection disconnection (CRRT circuit)
  - Blood taking
  - Not adopting aseptic technique
    - Connecting up the circuit
    - Priming
    - Insertion of cannulae
    - Blood taking
  - Patient immunocompromised
  - Multiple foreign materials in body

Hypothermia

- Failure of blood warmer
  - After transport

Temperature Control

- Thermo-controlled water bath necessary
- Avoid a high water bath temperature if possible
  - Bubble formation with heating of blood
  - Not more than 4C compared with blood

ACCESSORIES – HEATER UNIT HU 35

Pharmacokinetics

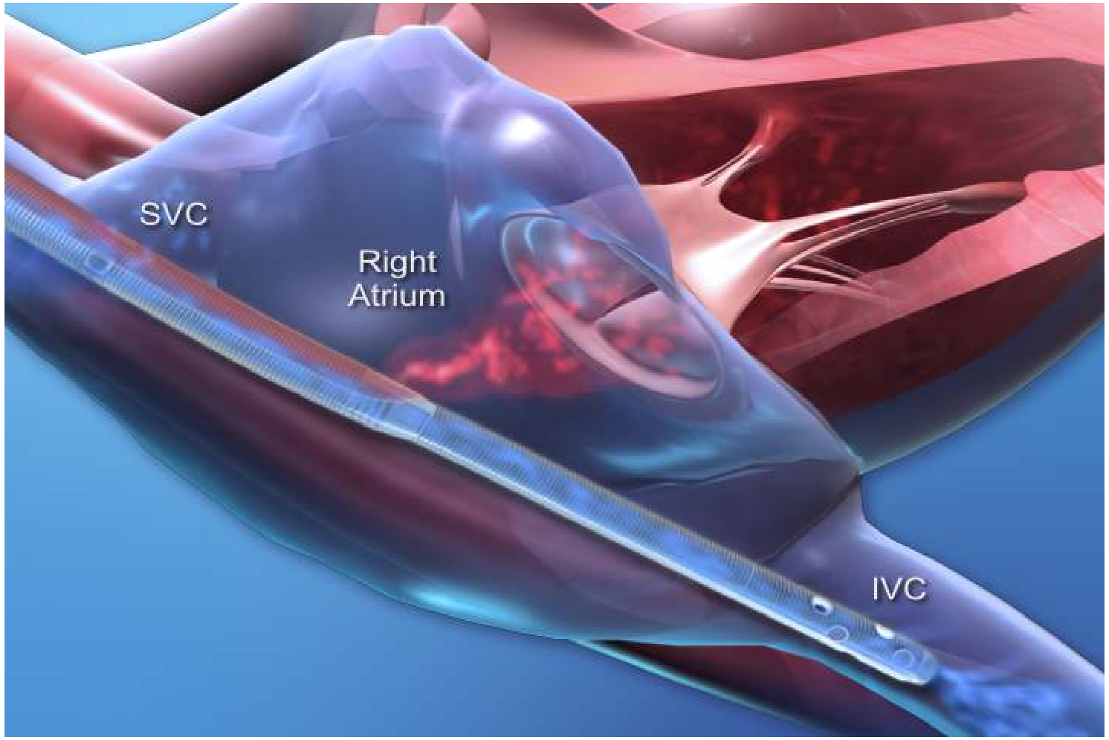
- If NS for priming
  - Initial hypotension may be related to hypocalcaemia, iCa
- Increase drug sequestration → lower drug levels
  - Esp. benzodiazepine, propofol, opioids, frusemide, phenytoin, phenobarbital
- Increase in vol. of distribution
  - Adjust drug dose, e.g. gentamicin, tobramycin

Risk of Access recirculation

- During insertion
  - Estimate the depth of insertion before cannulation
  - No need to adjust according to X-ray position, but the degree of access recirculation
- Oxygen saturation of drained blood
  - Rotaflow: colour of blood in access cannula
  - Cardiohelp: colour of blood in access cannula + SvO_2
- Note the change in blood colour without and with O_2

Risk of Access recirculation (2)

- Ways to reduce AR
  - Separation of the access and return cannulae
  - Return cannula to RV
  - Insertion of one more access cannula, high-flow ECMO
  - Avalon bi-caval cannula



Risk of further lung damage

- Aims
  - Decrease tidal volume
  - Decrease FiO_2 to an acceptable level (0.3-0.5)
    - Beware of reverse diffusion; $FeO_2 > FiO_2$
  - PEEP to keep alveoli open, 10-15cmH_2O
- Need to be decreased if pneumothorax; BPF
- If not able to do this
  - ECMO is futile
    - (UCH 1st case)

… On commencement of VV-ECMO, the patient had no other vital organ failure and her oxygenation improved initially. Nonetheless, we failed to wean down the ventilatory support to reduce the risk of VILI….

Hong Kong Med J 2009;15:381-4

In patient with lots of ventilator associated complications

- Pneumonthorax – bronchopulmonary fistula
- Ventilator associated pneumonia
- Agitated with sedation AND
- ECMO running is smooth

- Consider wake and extubate with ECMO running

Decreasing/inadequate SpO_2/SaO_2

- Increase flow$_e$
  - (inc. cannulae size)
  - More access recirculation
  - More chattering
  - More haemolysis
  - Need more fluid
    - Make lung condition worse
  - One more access cannula
    - Risk of line complication
    - If insertion failure, difficult to control bleeding

Decreasing/inadequate SpO_2/SaO_2 (2)

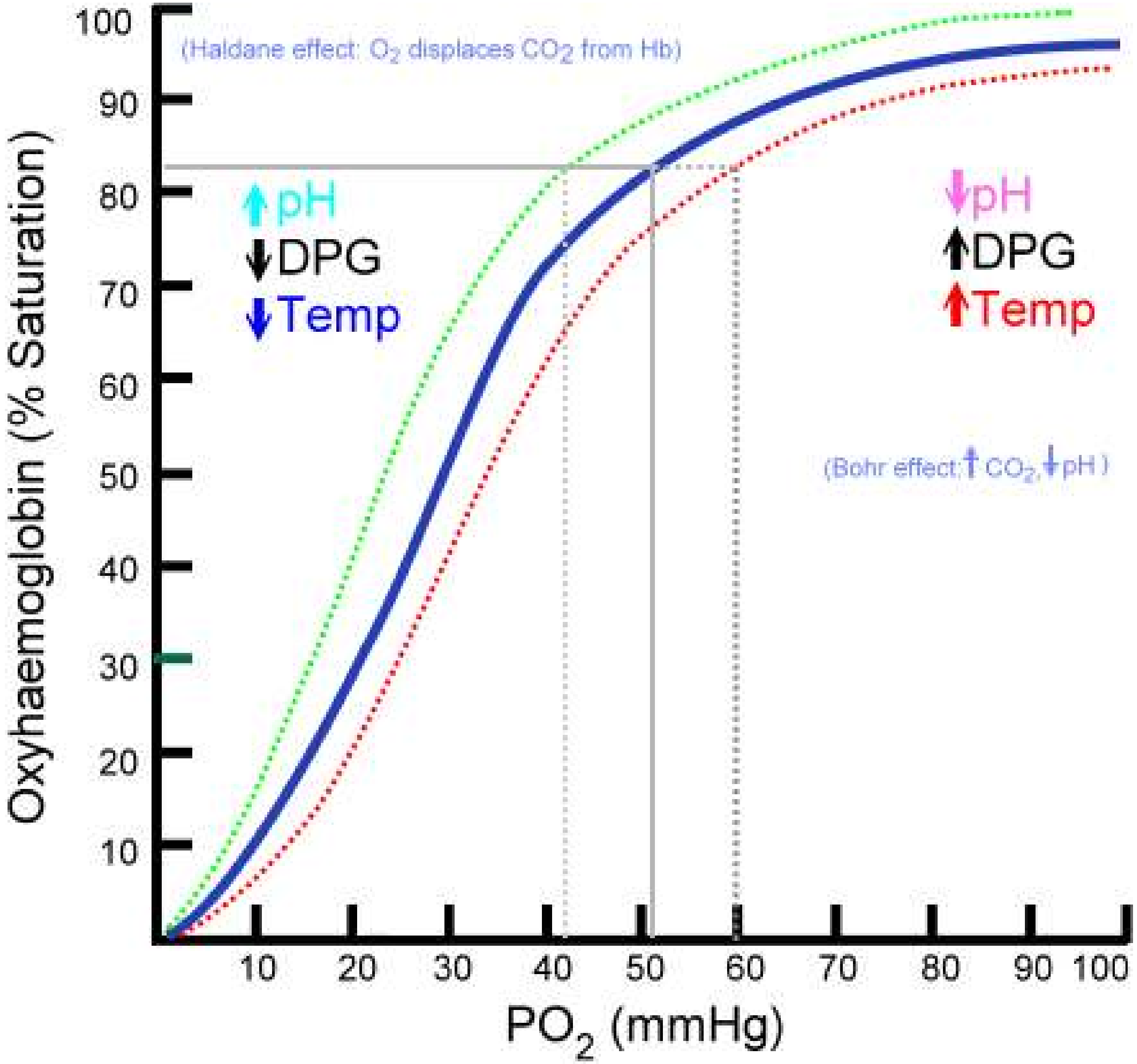
- Decrease O_2 consumption
  - If shivering, increase temperature$_e$
    - May help in viral clearance
- Increase Hct to 0.4 or Hb to >10g/dl

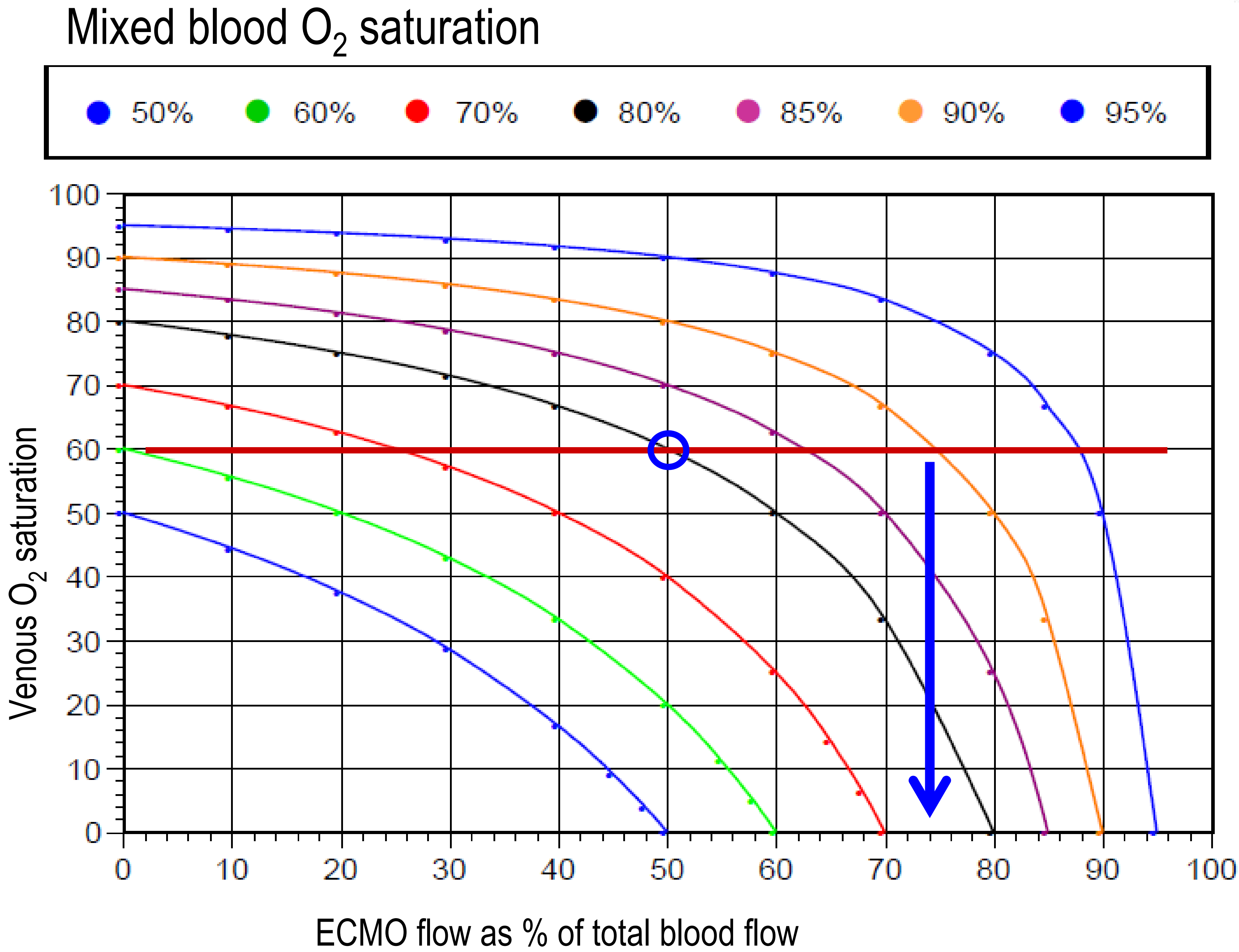
ECMO

- ECMO
  - Add oxygen to blood AND
  - Remove CO_2 from blood

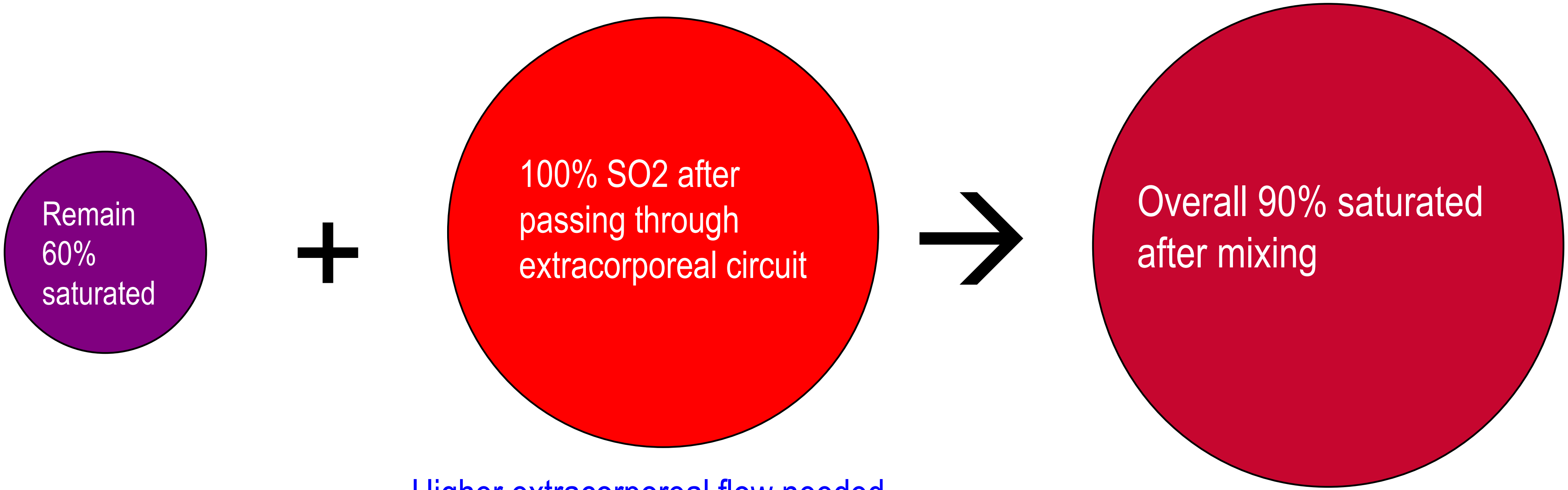
  - Higher flow needed
    - O_2 is carried mainly through Hb, not plasma
    - $1.36 \times Hb \times (SaO_2\text{-}SvO_2) = O_2$ ml /l blood
      $1.36 \times 120 \times (1.00 \text{ to } 0.72) = 46$ ml/l blood
    - One needs ~ 240ml O_2 /min → ~ 5 L/min flow

Oxygen content




Mixed blood O_2 saturation
50%
60%
70%
80%
85%
90%
95%
Venous O_2 saturation
0
10
20
30
40
50
60
70
80
90
100
ECMO flow as % of total blood flow

Extracorporeal flow needed for oxygenation



Higher extracorporeal flow needed

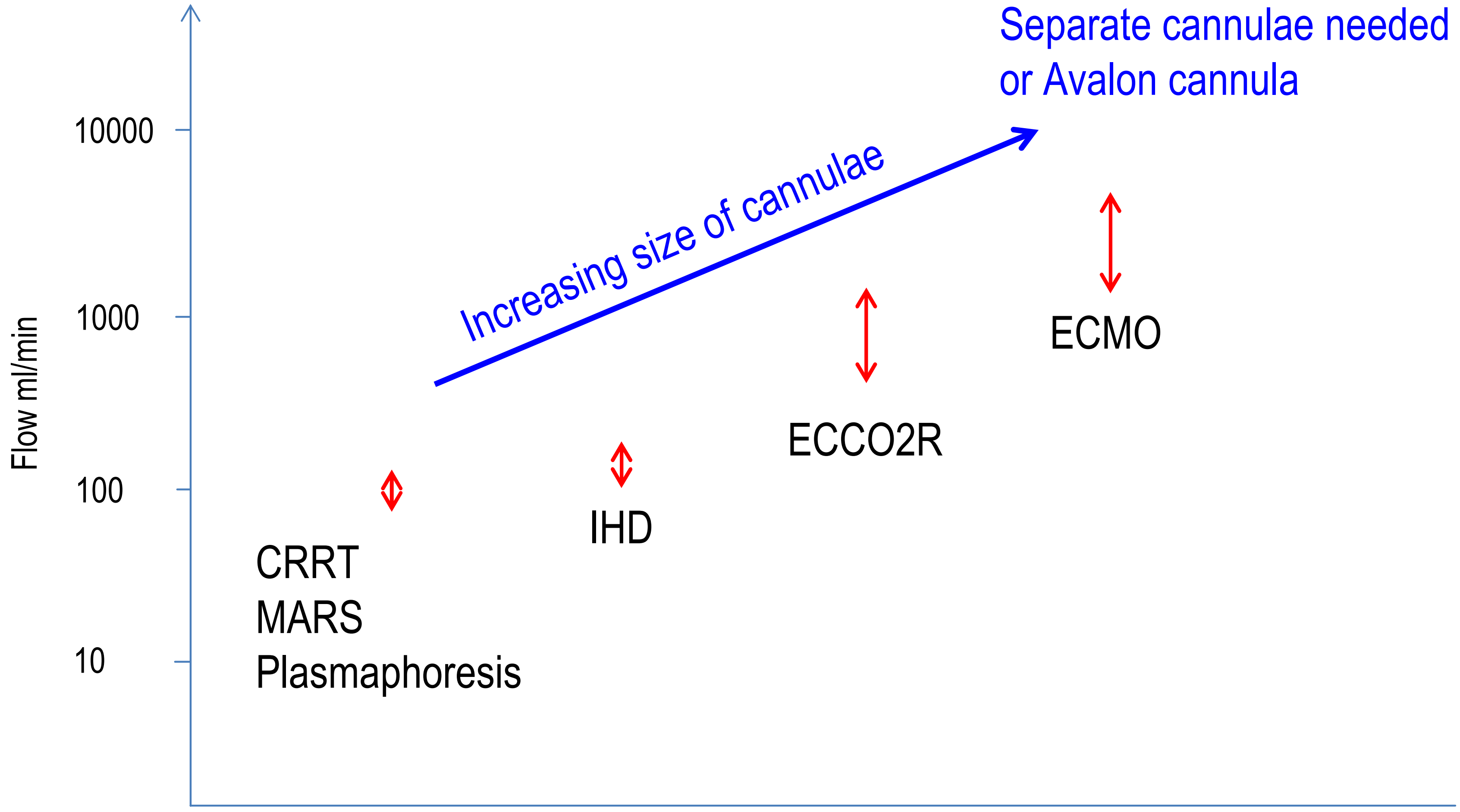
Increasing $PaCO_2$/$PetCO_2$

- Easy to be removed by ECMO
  - cf. Novalung® iLA membrane ventilator
- Increase gas flow
  - Keep V/Q 1:1
  - Avoid lung tissue alkalosis
    - Decrease ventilator minute volume

What's it?

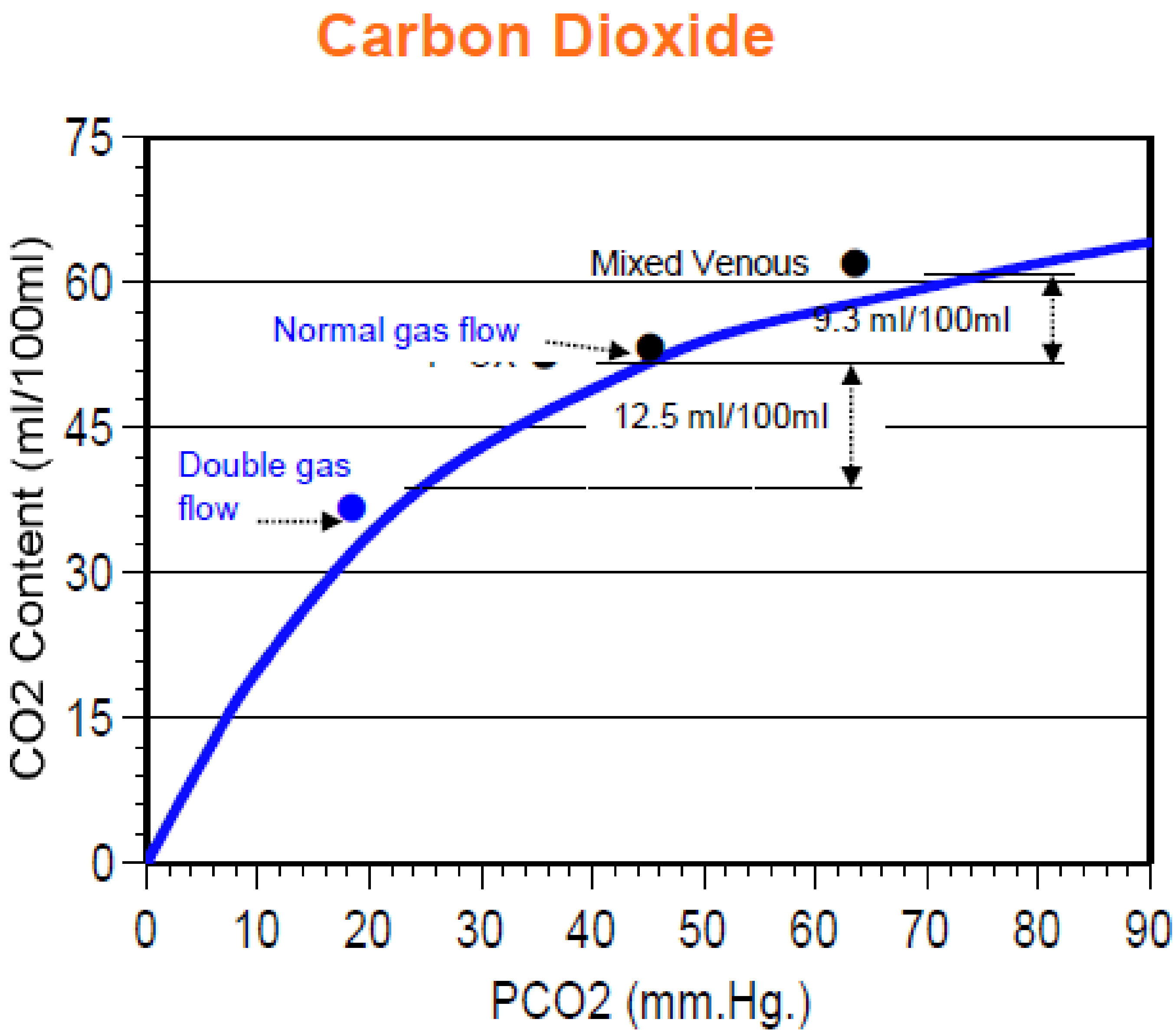
- $ECCO_2R$
  - Lower flow than ECMO needed
    - CO_2 mainly carried by plasma (dissolved bicarbonate)
    - Linear kinetics without saturation
    - 1 L blood carry > 500 ml CO_2
      - CO_2 removal rate < 1 L/min blood flow
    - CO_2 diffuses more readily than O_2 across extracorporeal membrane

Extracorporeal flow needed

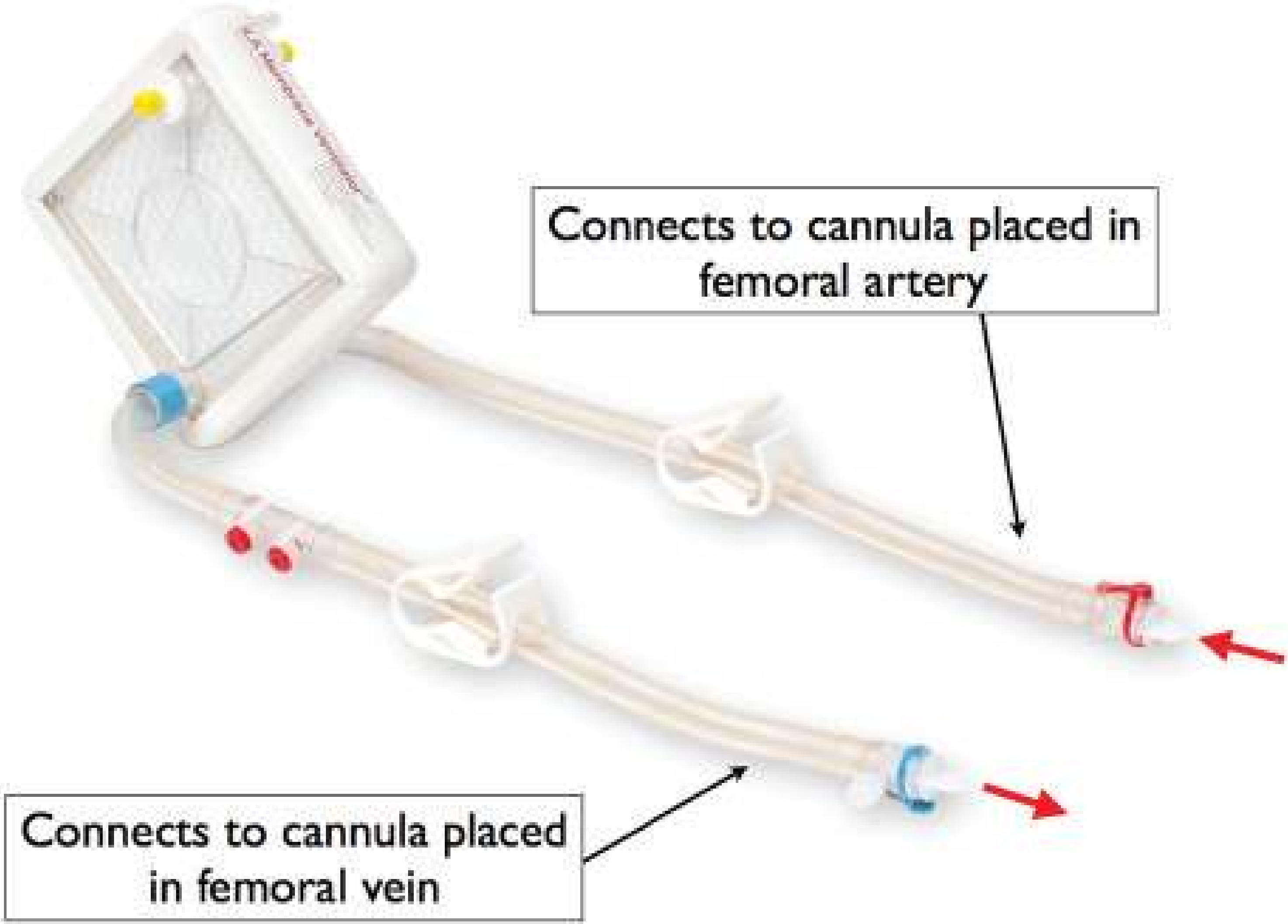


Regional citrate anticoagulation possible

Carbon dioxide Removal

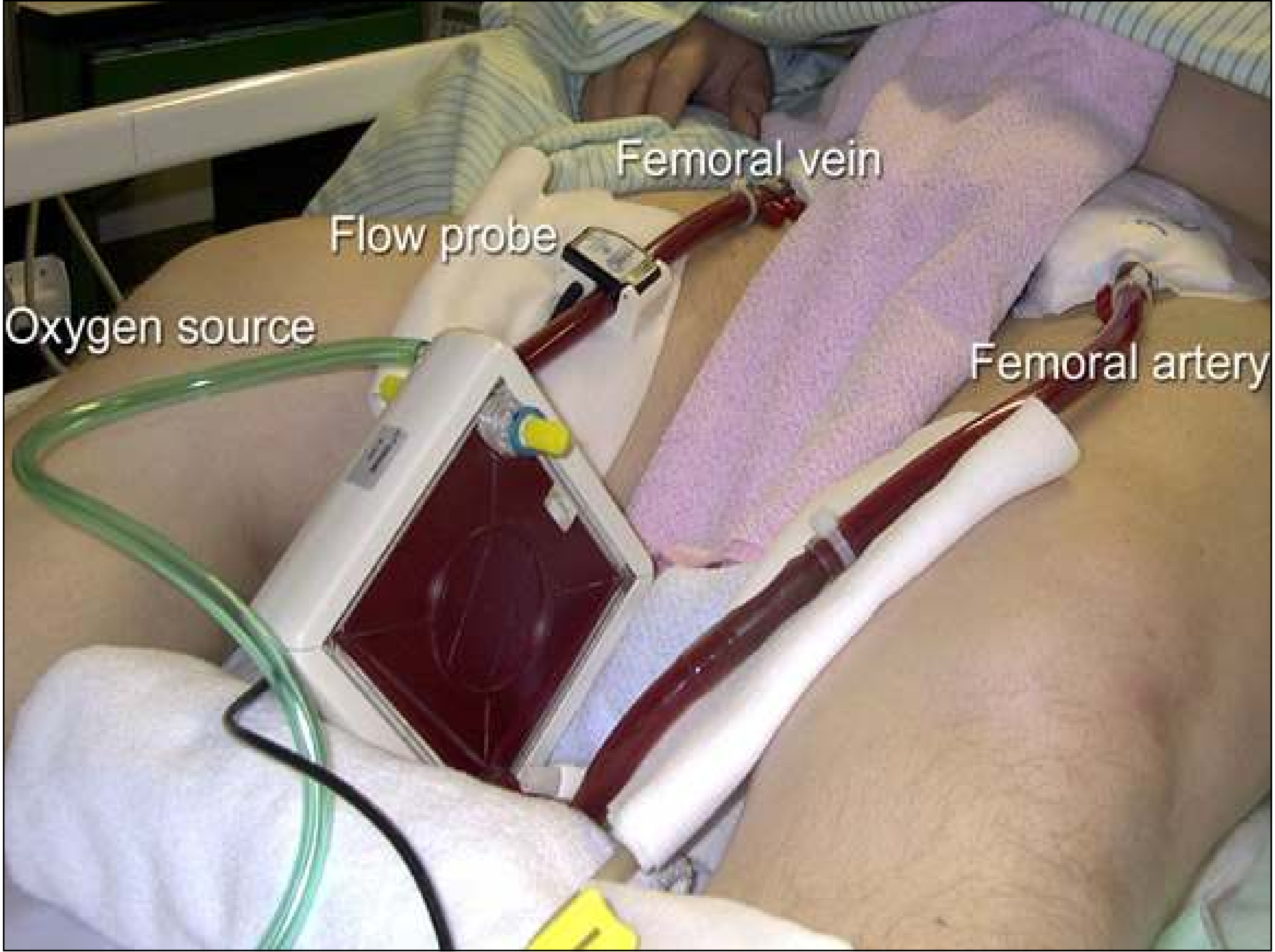


AVCO2R or PECLA



AVCO2R or PECLA

- Novalung: interventional Lung Assist (iLA) membrane ventilator
- Medtronic: Affinity NT
- Hemodynamic should be stable, with MAP >60mmHg
- Flowmeter monitoring is needed
- Risk of distal limb ischemia
- Indications
  - LPV for ALI/ARDS or severe asthmaticus
  - Bridge to lung transplantation

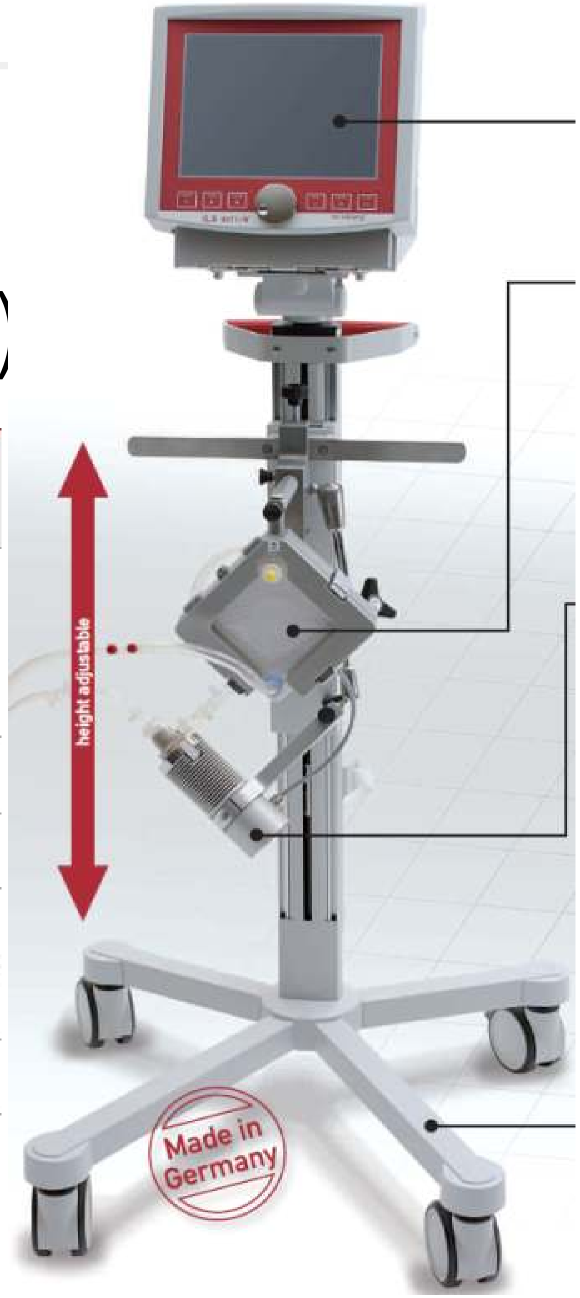

Femoral vein
Flow probe
Oxygen source
Femoral artery

Venovenous CO2 Removal

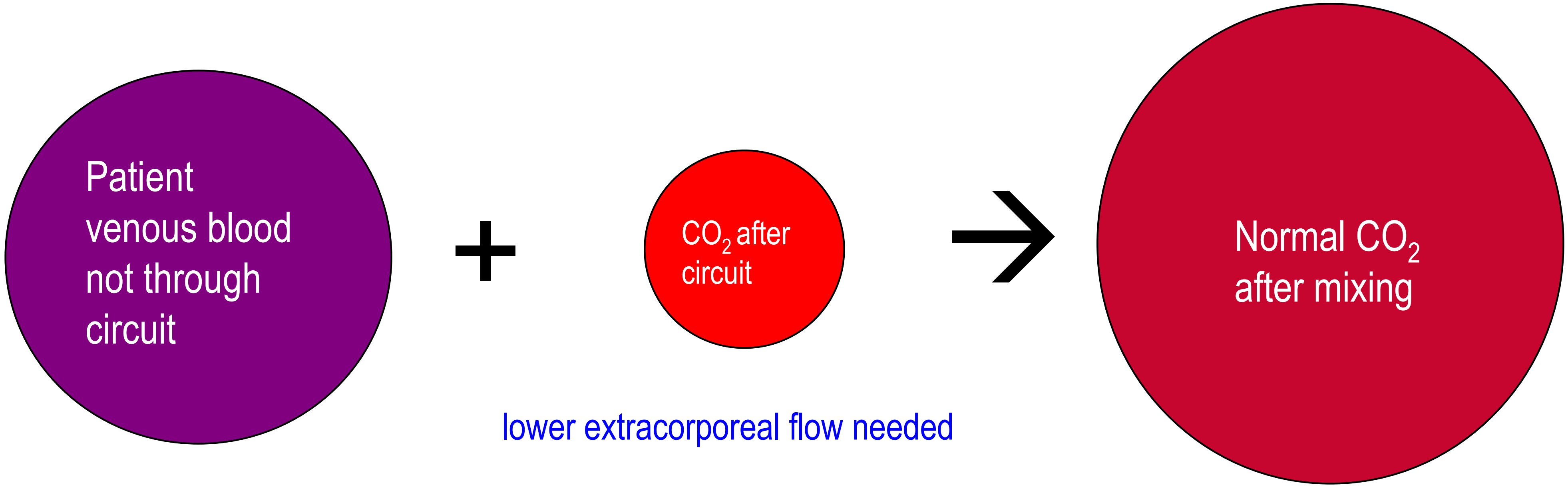
- Move gradually to VV-ECMO
- Novalung: iLA Activve (diagonal pump)

Therapy:	iLA® membrane ventilator	iLA activve®			
Main function:	CO_2 removal + lung protection	CO_2 removal + lung protection	CO_2 removal + lung protection + oxygenation support	CO_2 removal + lung protection + oxygenation	CO_2 removal + lung protection + oxygenation
Vascular access:	arteriovenous	venovenous	venovenous	venovenous	venovenous
Membrane ventilator:	iLA®	MiniLung® petite	MiniLung®	iLA®	XtraLung®
Cannulation:	NovaPort® one	NovaPort® twin	NovaPort® twin	NovaPort® twin or NovaPort® one (+ drainage cannula)	NovaPort® one (+ drainage cannula)
Pump driven:	no	yes	yes	yes	yes
Synonyms:	PECLA, AVCO₂R	ECCO₂R	ECCO₂R, (ECMO)	ECCO₂R, ECMO	ECMO

CAVH CVVH HVHF VHVHF



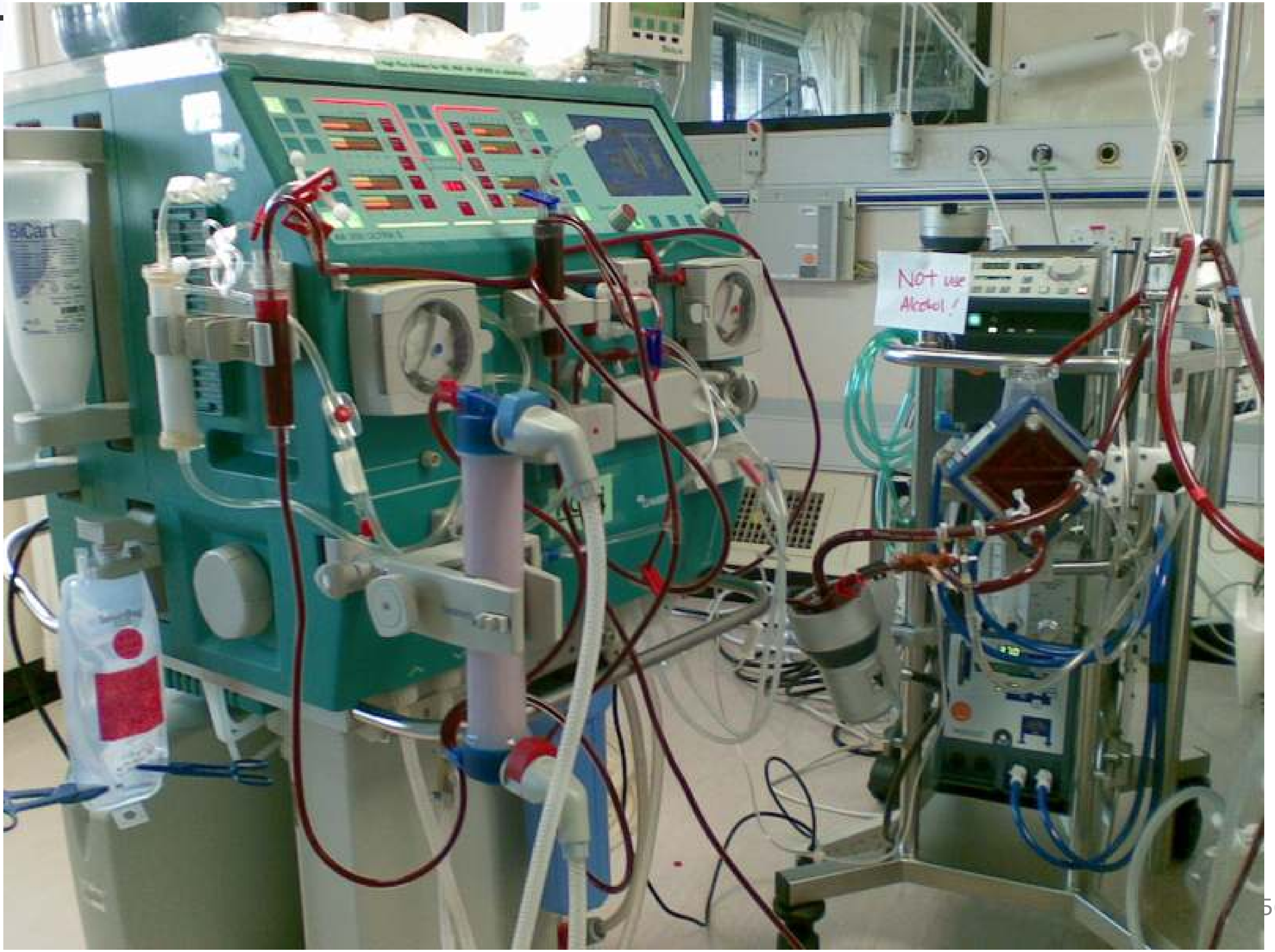
Extracorporeal flow needed for CO_2 removal



Renal circuit

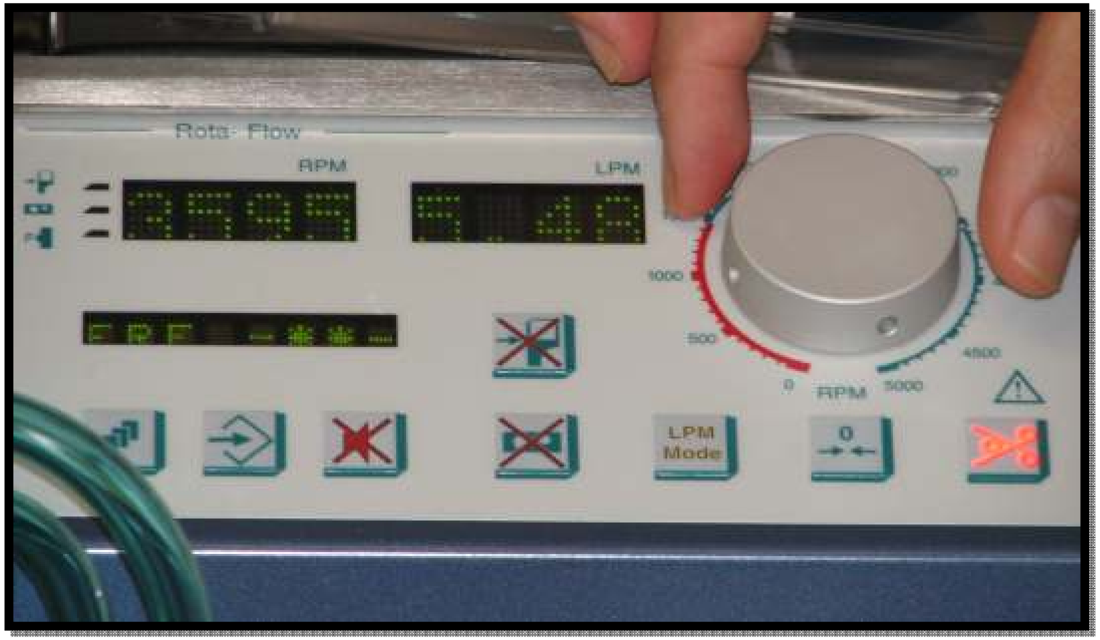
- Post pump
  - Before and after oxygenator
- CRRT
  - Positive pressure allowed in CRRT
    - Prismaflex
    - Gambro AK 200S Ultra

ECMO and CRRT



Monitoring – Extracorporeal circuit

- Extracorporeal circuit
  - Pump speed, blood flow & pump noise
  - Circuit: blood clots, air bubbles, kinking, recirculation
  - Lines: silent or kicking
  - Check cannula placement & stability
  - Gas flow & FiO_2



Monitoring – Patient

- Patient
  - Oxygen delivery
    - SaO_2, Hb, Haemodynamics
  - Monitor APTT & platelet count
  - Observe for bleeding
  - Assess CNS status (if patient not sedated)
  - Monitor plasma free Hb
  - Chest X rays changes

Weaning

- Gas flow$_e$
  - May decrease to zero (test oxygenation & CO2 removal)
- Flow$_e$
  - Can't be zero (minimum >1L/min)
- Gas FiO_2
  - FiO2 0.21→ no O2 get into blood but CO2 removal continue (test oxygenation only)

Membrane Lung vs. Natural Lung

Comparison of physical characteristics of membrane lung vs natural lung		
Characteristic	Membrane lung	Natural lung
Surface area (m2)	0.5 - 4	70
Blood path width (µm)	200	8
Blood path length (µm)	250,000	200
Membrane thickness (µm)	150	0.5
Max O_2 transfer (ml/min) STP	400 - 600	2,000


Team work


Learn together through practice


Continued Education

Questions/Comments?