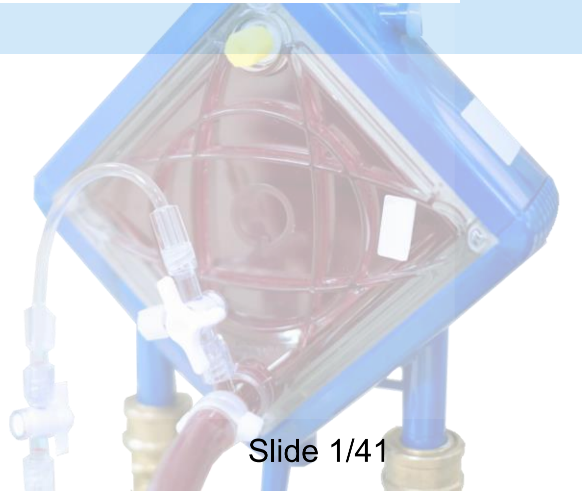
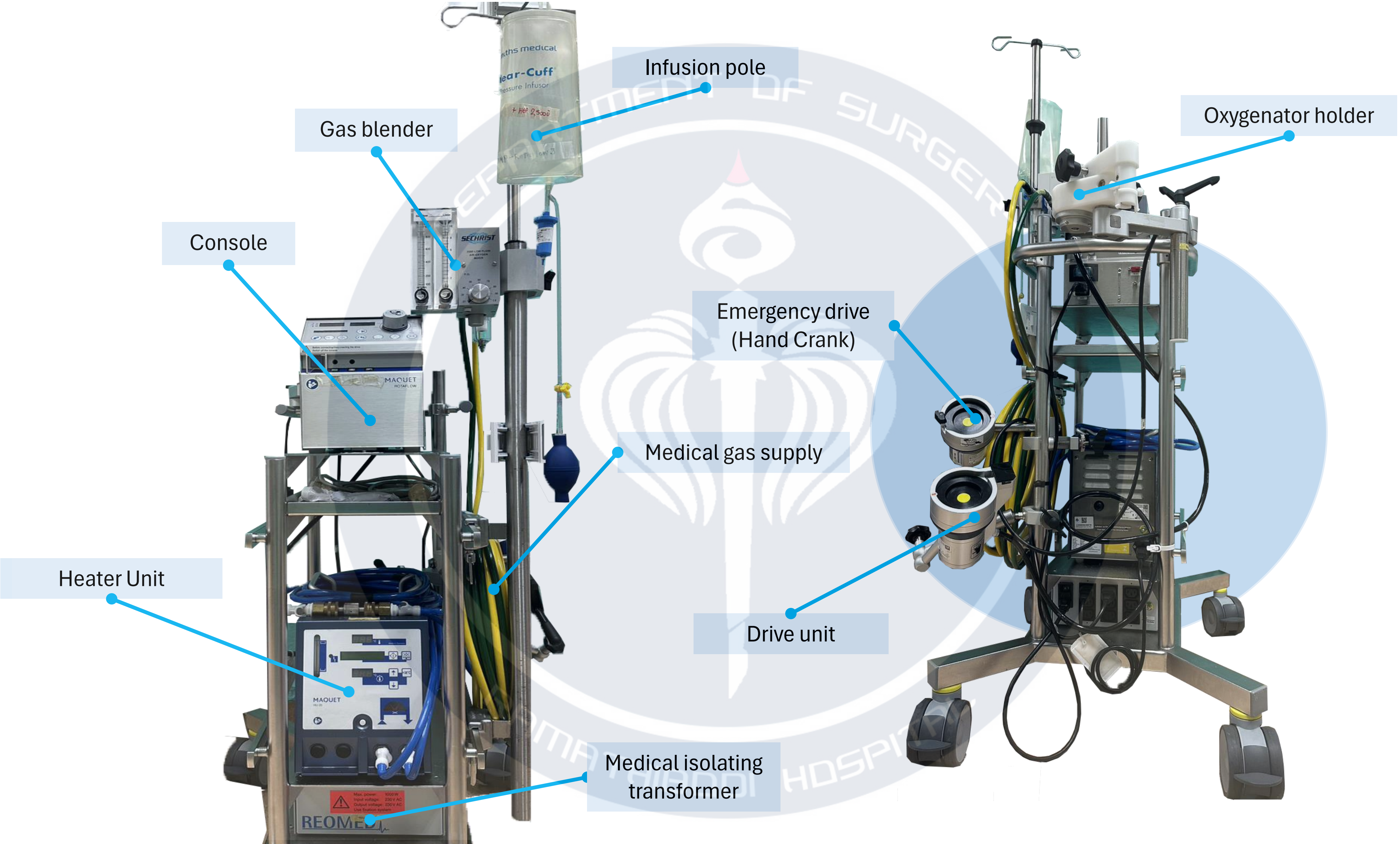
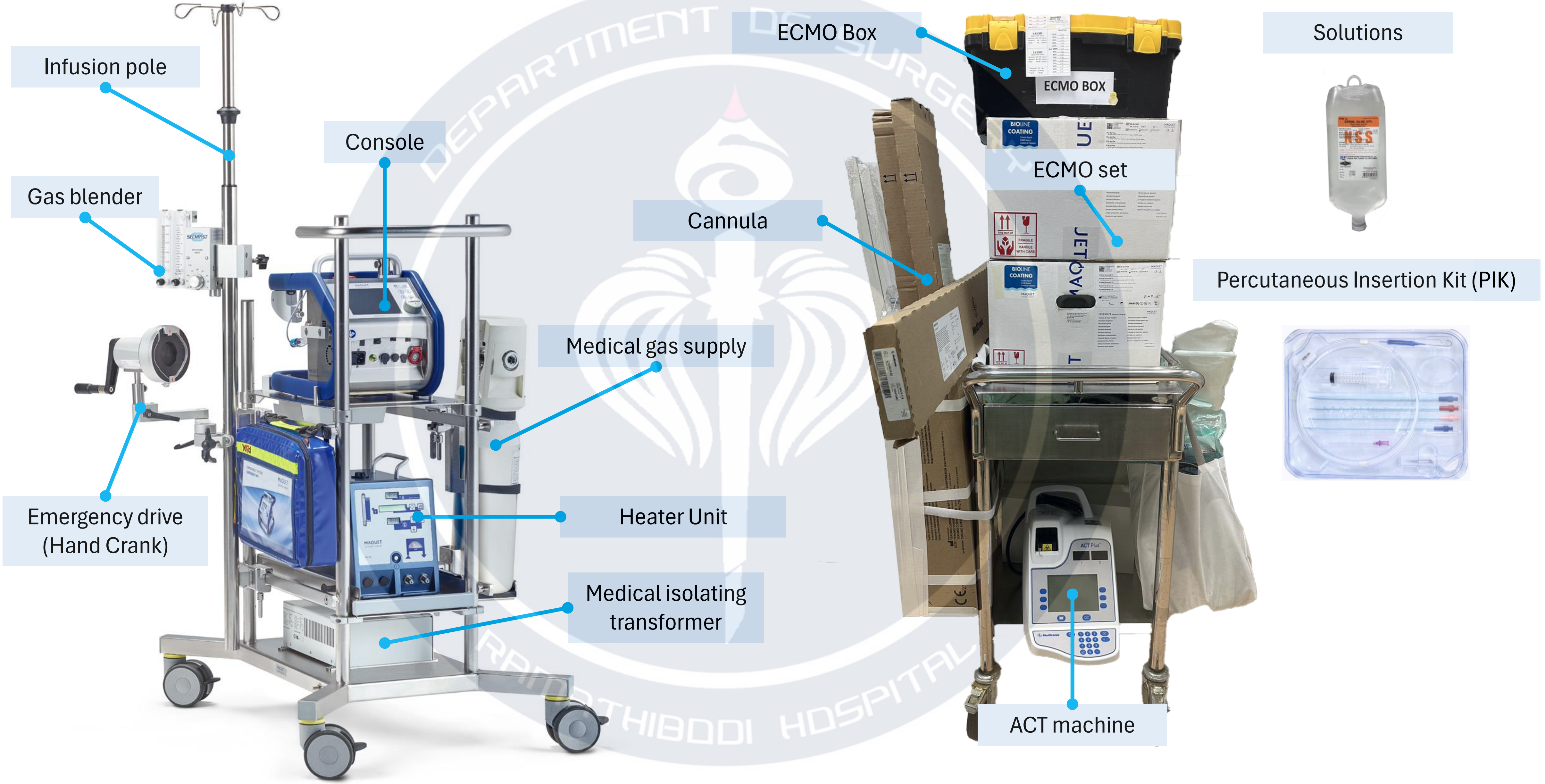
ECMO

Circuit and Monitoring



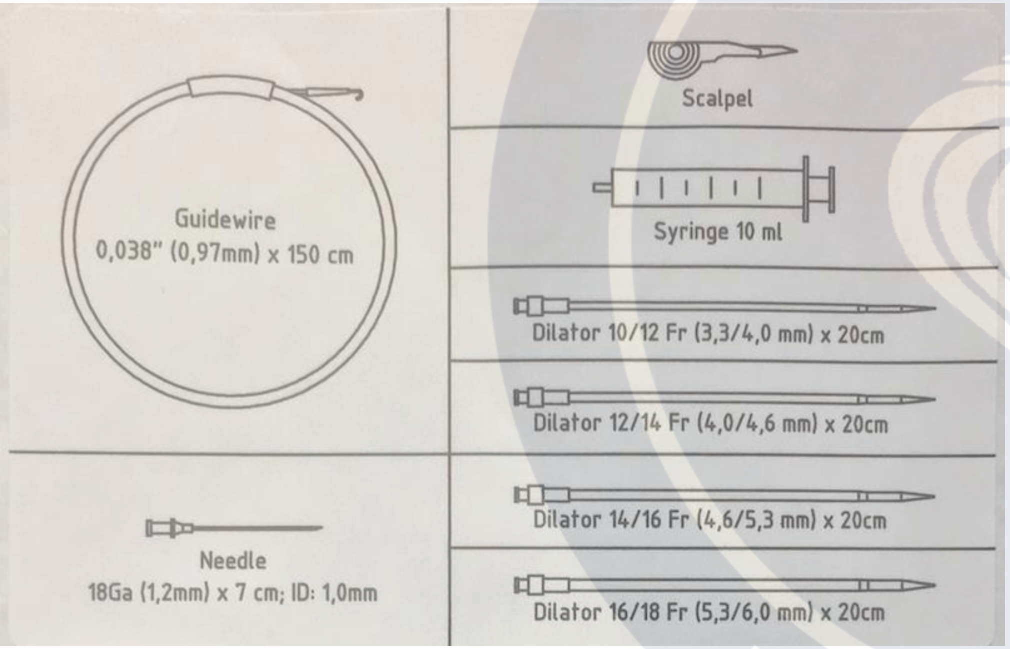
Apirit Chamnanya
Perfusionist, Ramathibodi Hospital

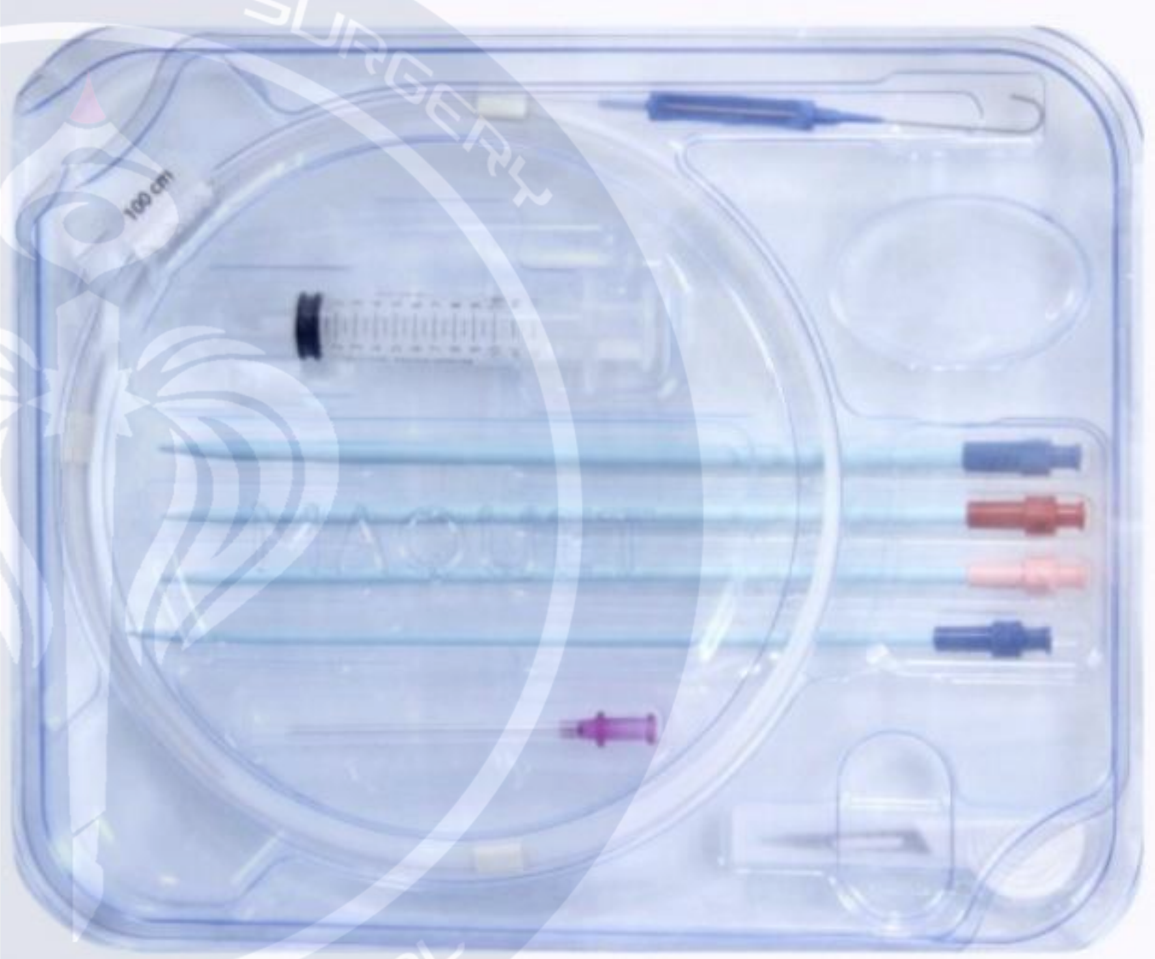

Infusion pole
Gas blender
Console
Oxygenator holder
Emergency drive
(Hand Crank)
Medical gas supply
Heater Unit
Drive unit
Medical isolating
transformer

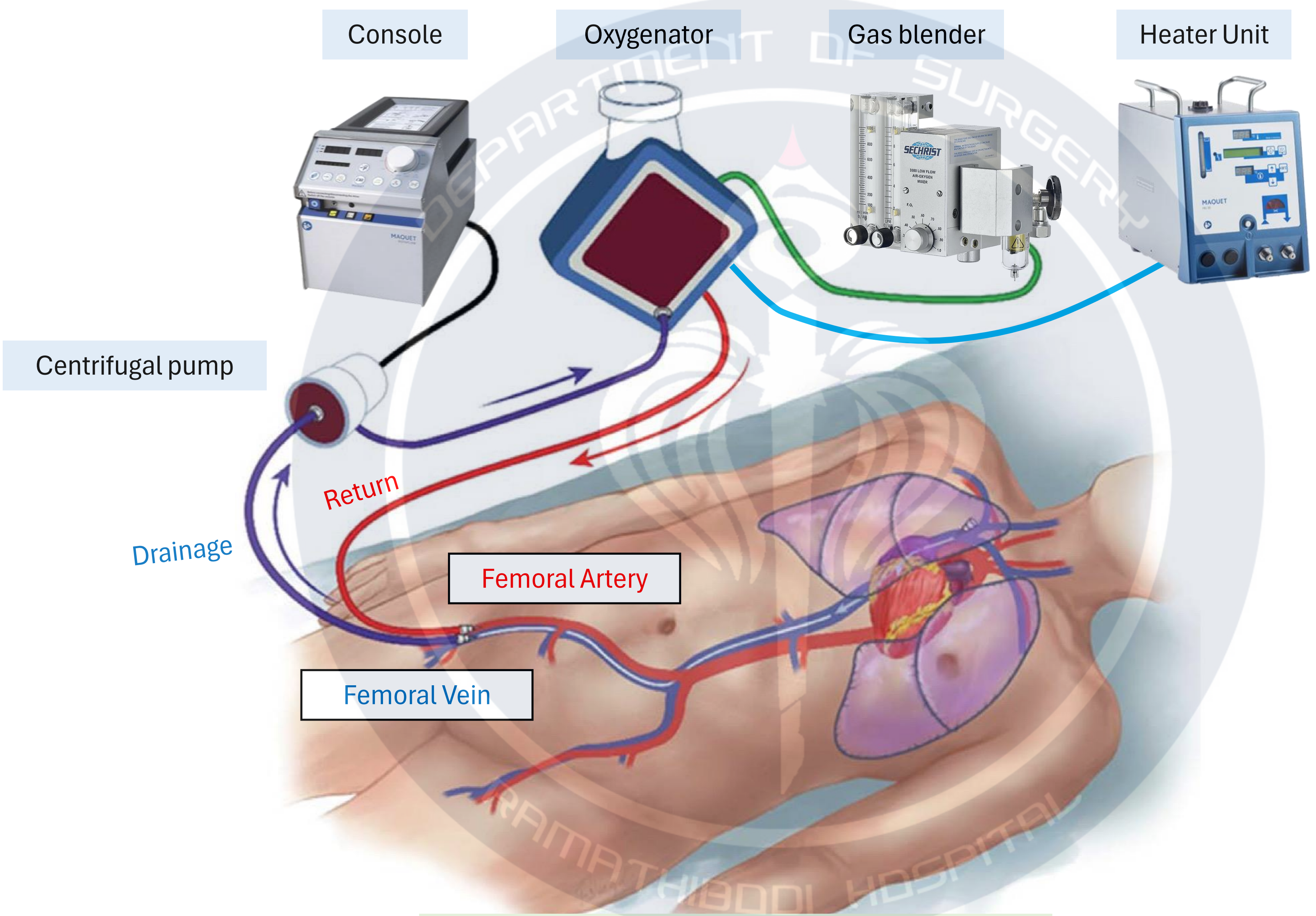

Infusion pole
Console
Gas blender
Emergency drive
(Hand Crank)
Medical gas supply
Heater Unit
Medical isolating
transformer
ECMO Box
ECMO BOX
ECMO set
Cannula
Solutions
Percutaneous Insertion Kit (PIK)
ACT machine

Percutaneous Insertion Kit (PIK)

- Guidewire
- Needle puncture
- Scalpel
- Syringe
- Dilator

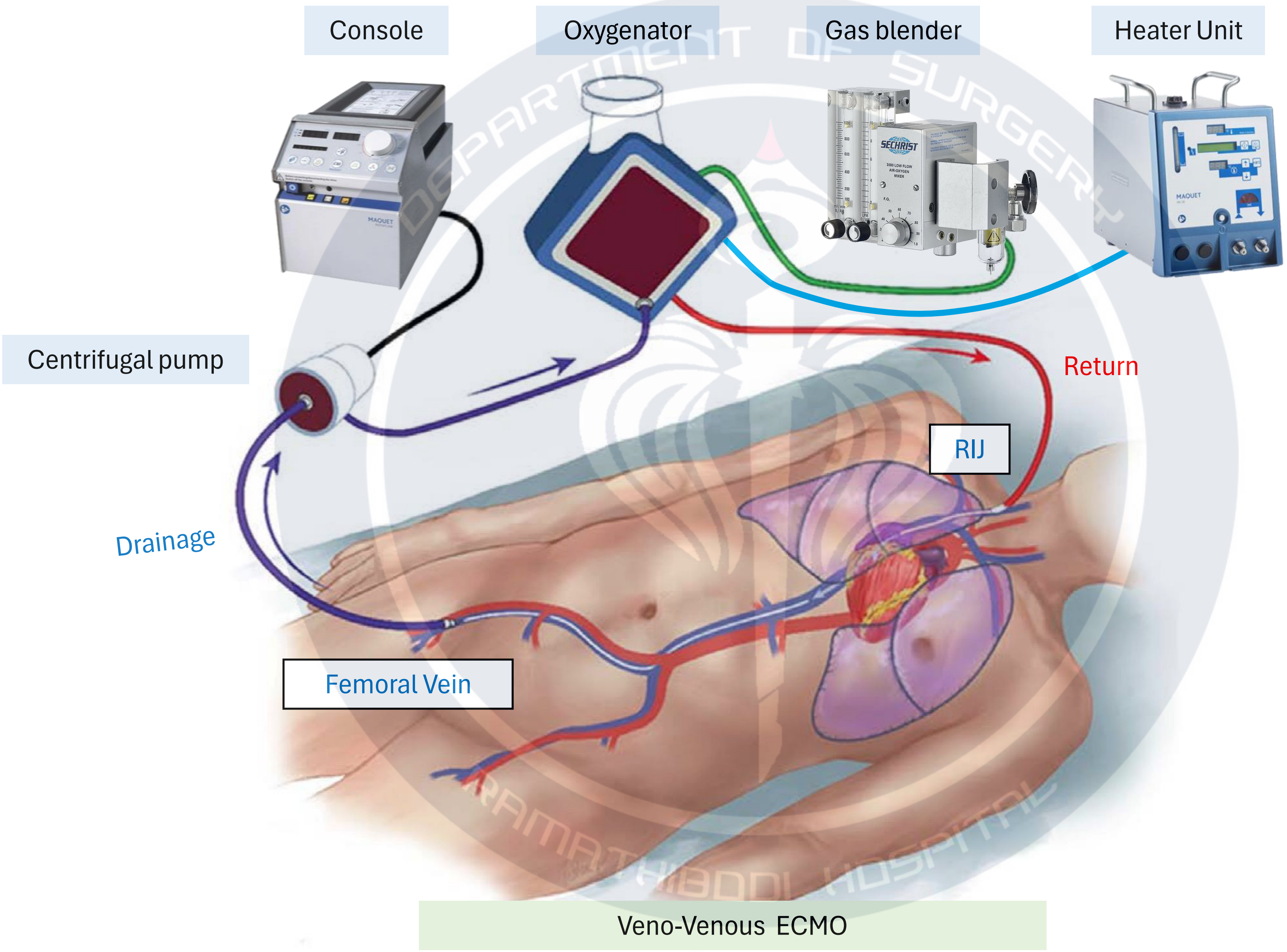




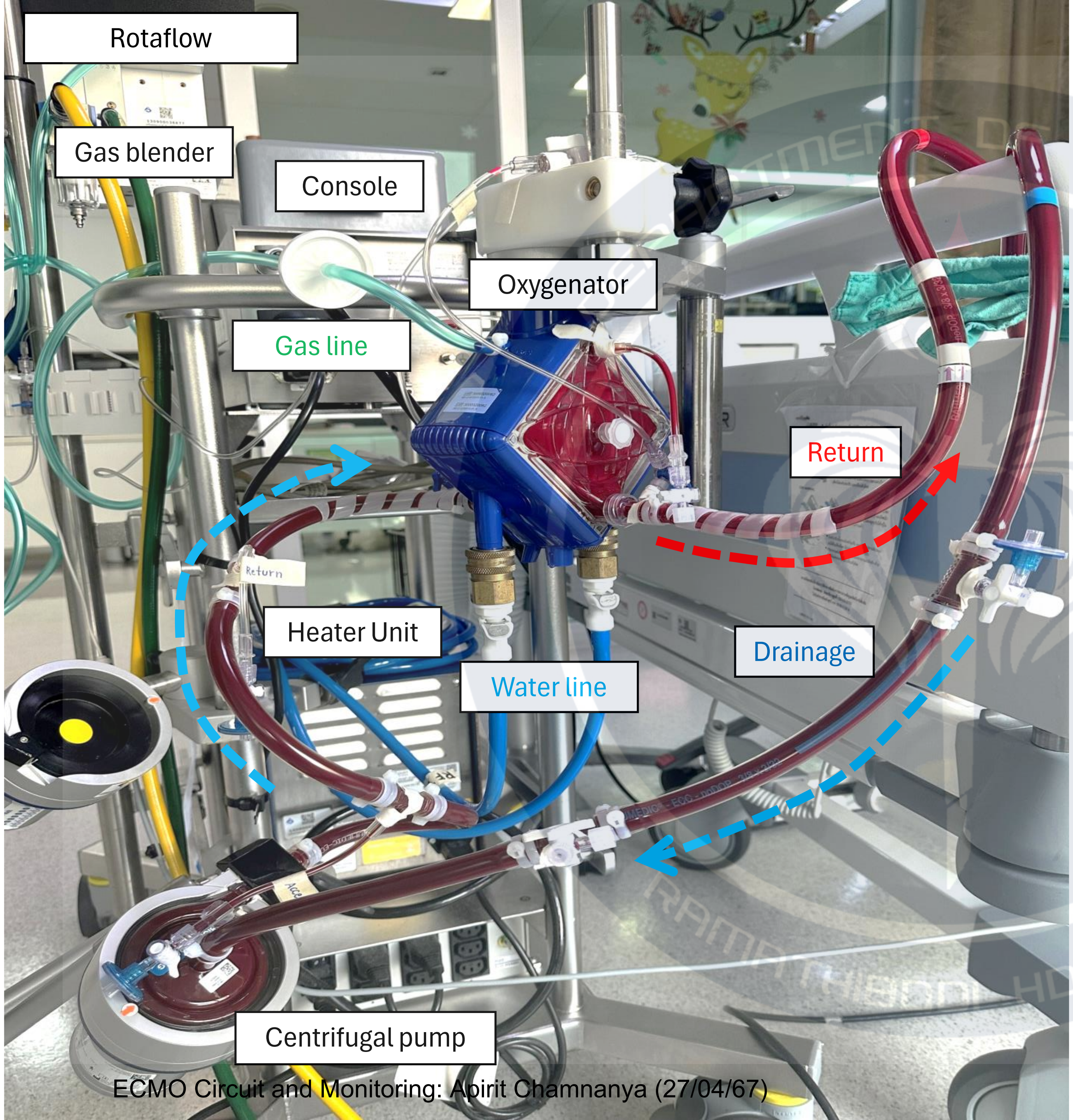


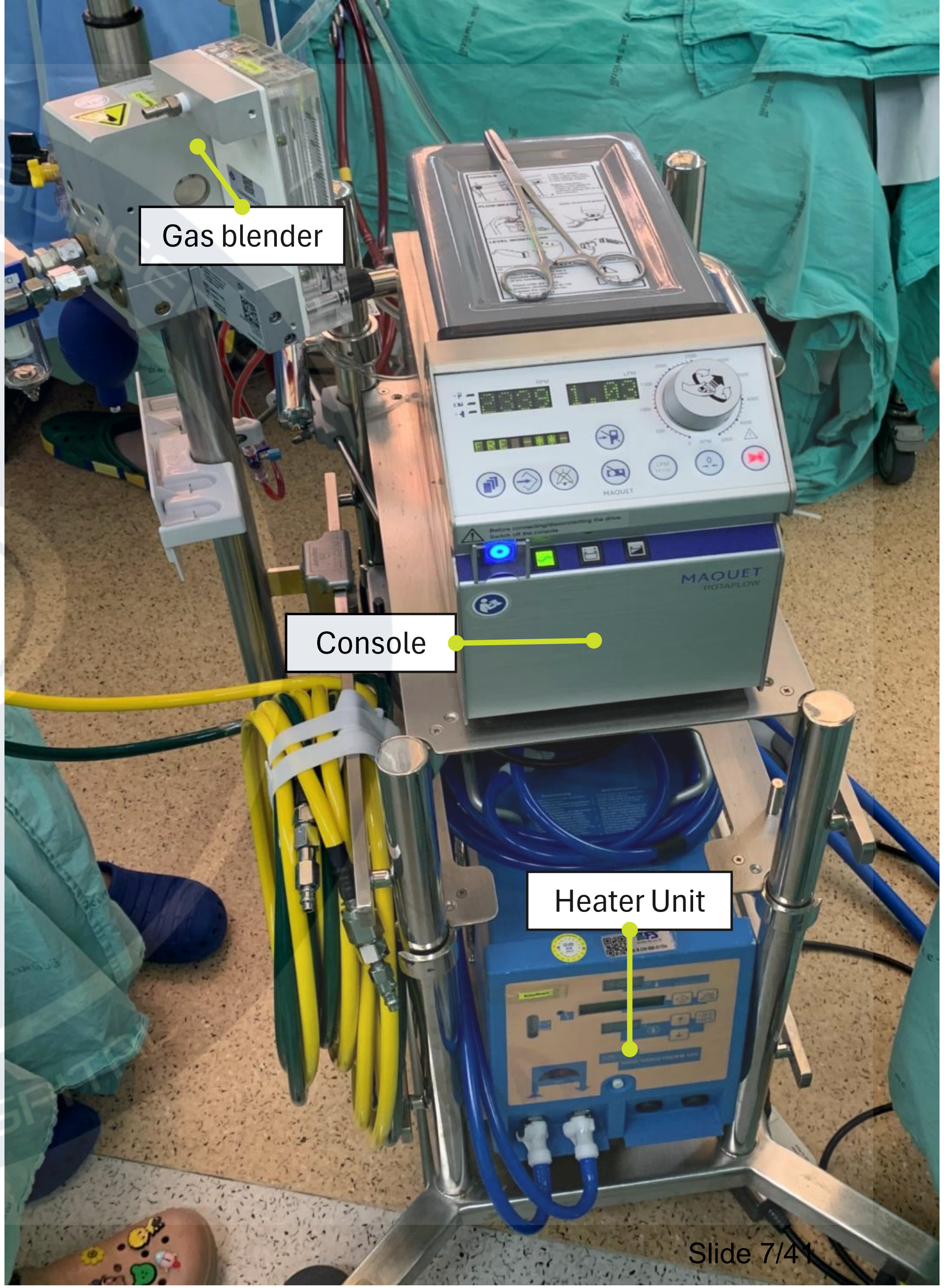
Veno-Arterial ECMO

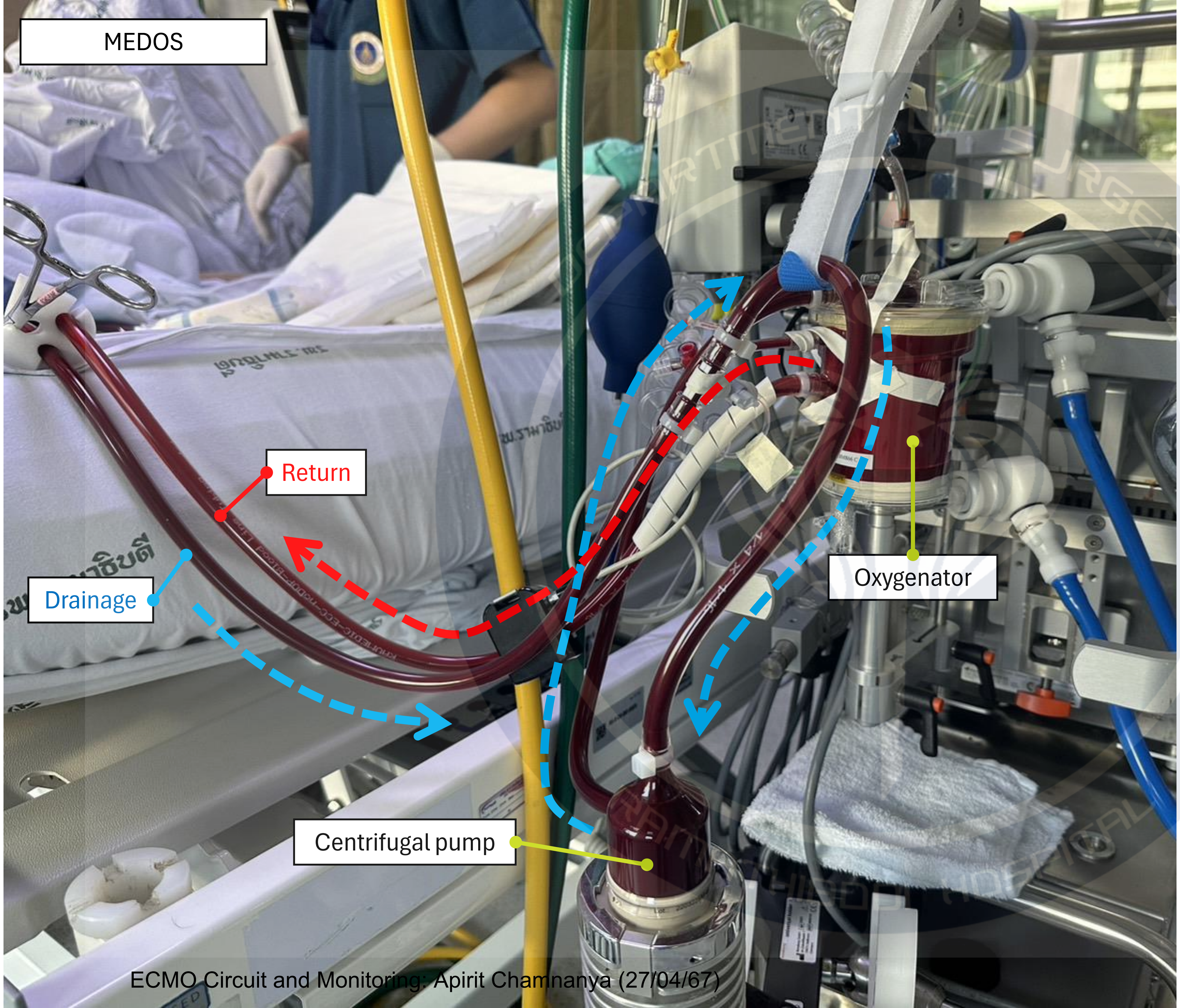
Adapted from ELSO guidelines for adult and pediatric extracorporeal membrane oxygenation circuits: Erratum. (2022). ASAIO Journal, 68(7).

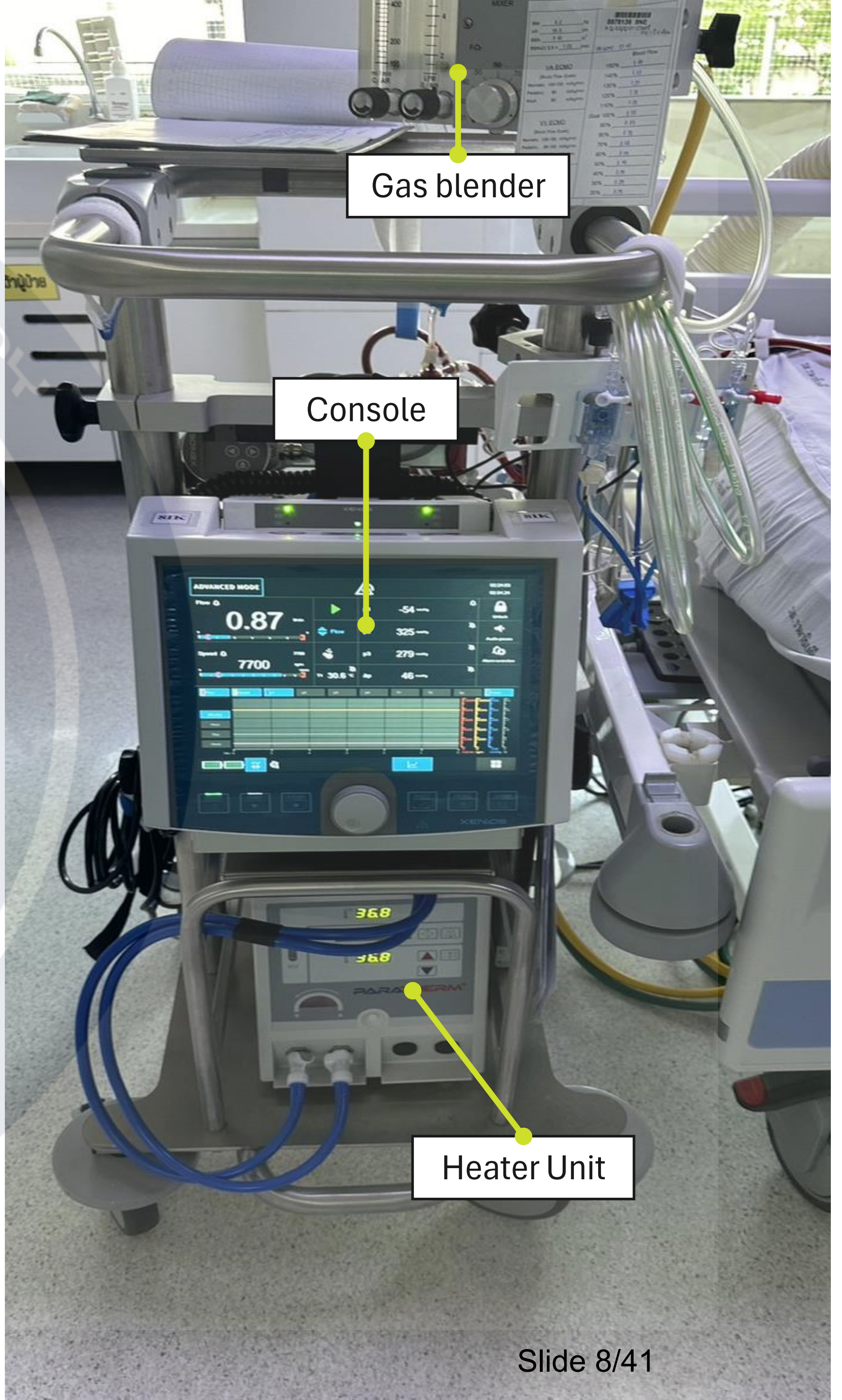


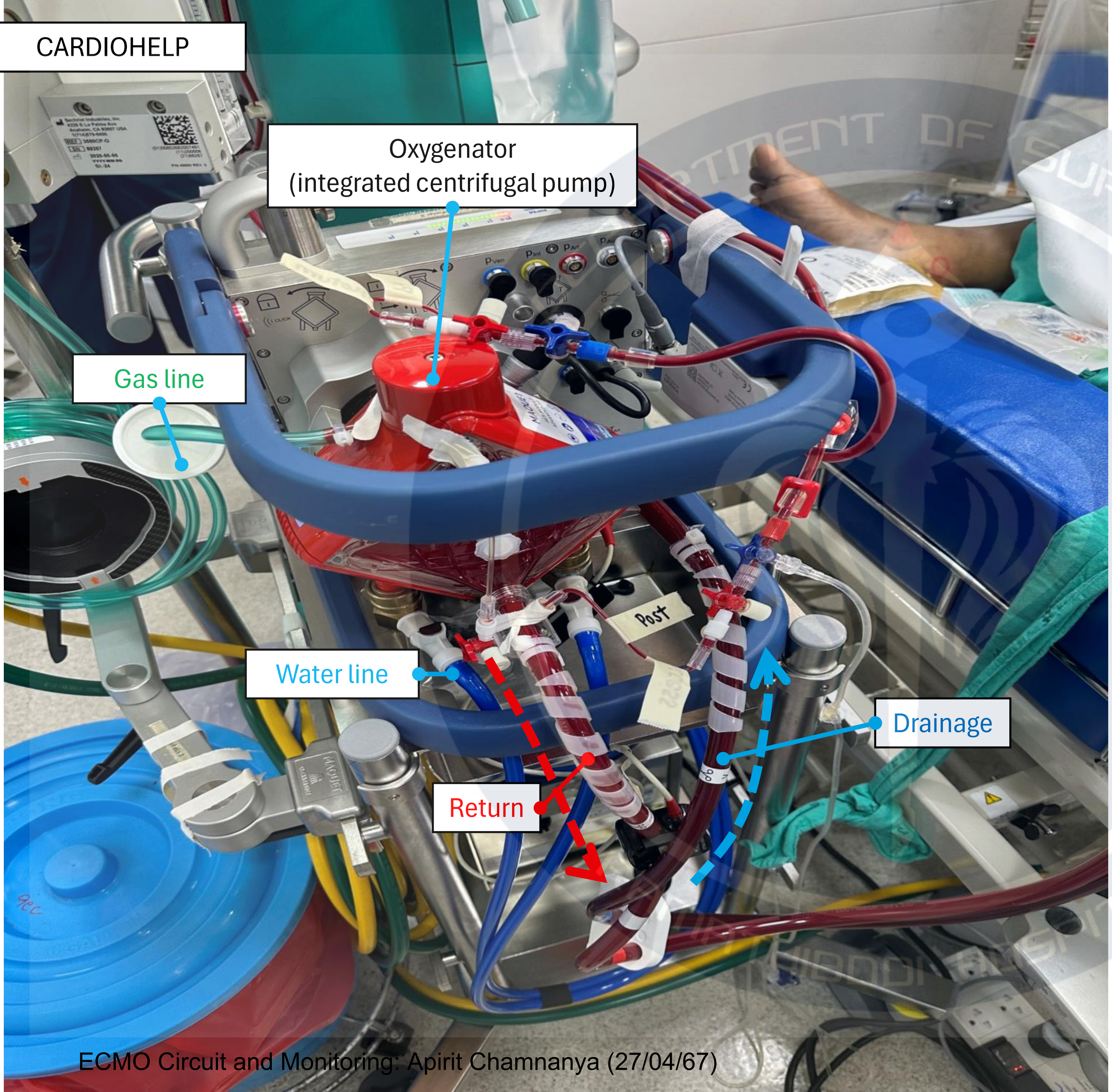
Adapted from ELSO guidelines for adult and pediatric extracorporeal membrane oxygenation circuits: Erratum. (2022). ASAIO Journal, 68(7).


Rotaflow
Gas blender
Console
Oxygenator
Gas line
Return
Heater Unit
Drainage
Water line
Centrifugal pump

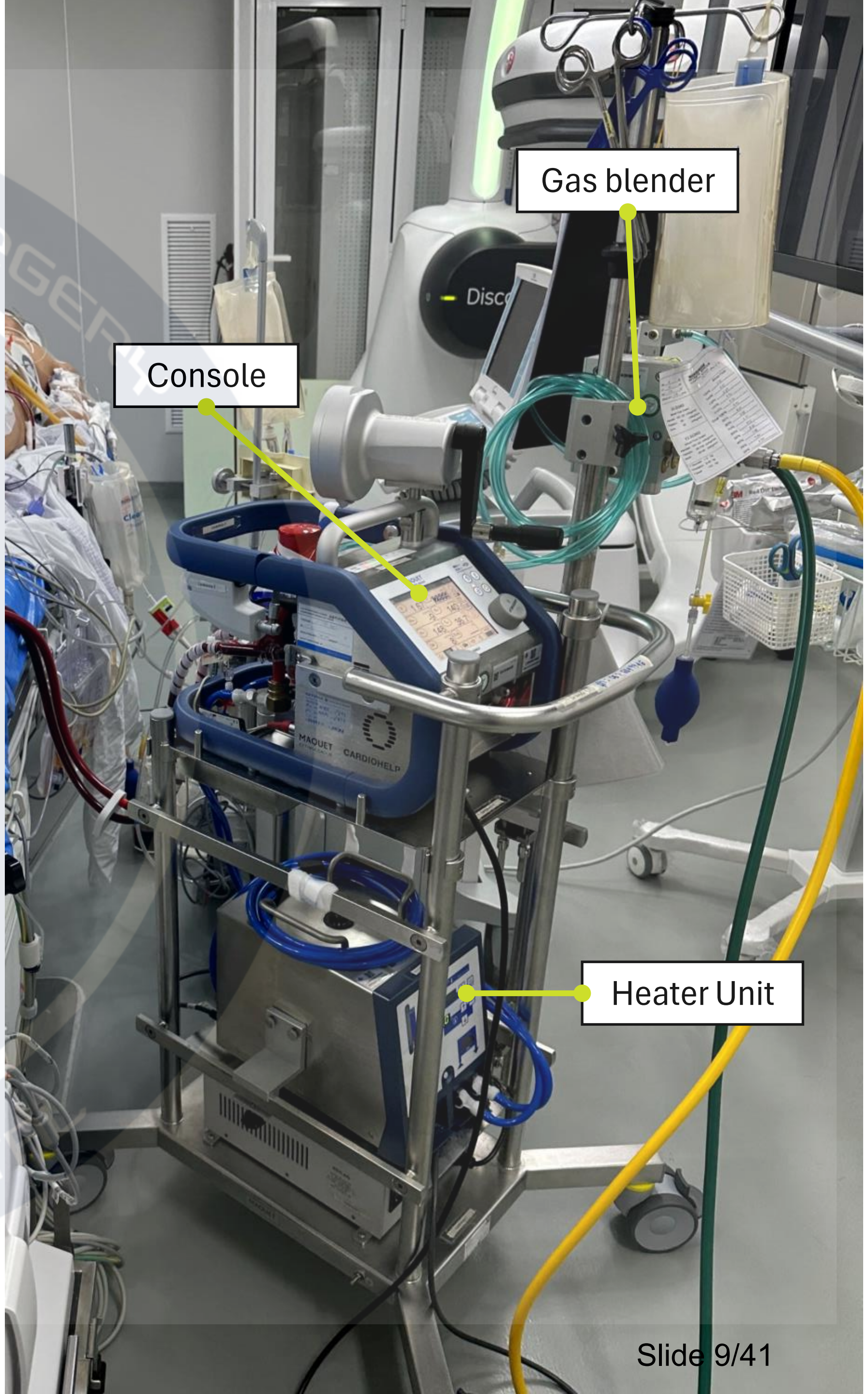

Gas blender
Console
Heater Unit


MEDOS
Return
Drainage
Oxygenator
Centrifugal pump


Gas blender
Console
Heater Unit



CARDIOHELP
Oxygenator
(integrated centrifugal pump)
Gas line
Water line
Drainage
Return
Post



Gas blender
Console
Heater Unit

Cannula Selection

Selection of the right cannula is vital for a successful ECMO run and needs to be carefully selected for each individual patient

- Degree of support
- Size and condition of the vessel
- Patient size
- Site of placement
- Type of insertion procedure
- Desired location of blood drainage and return

Degree of support

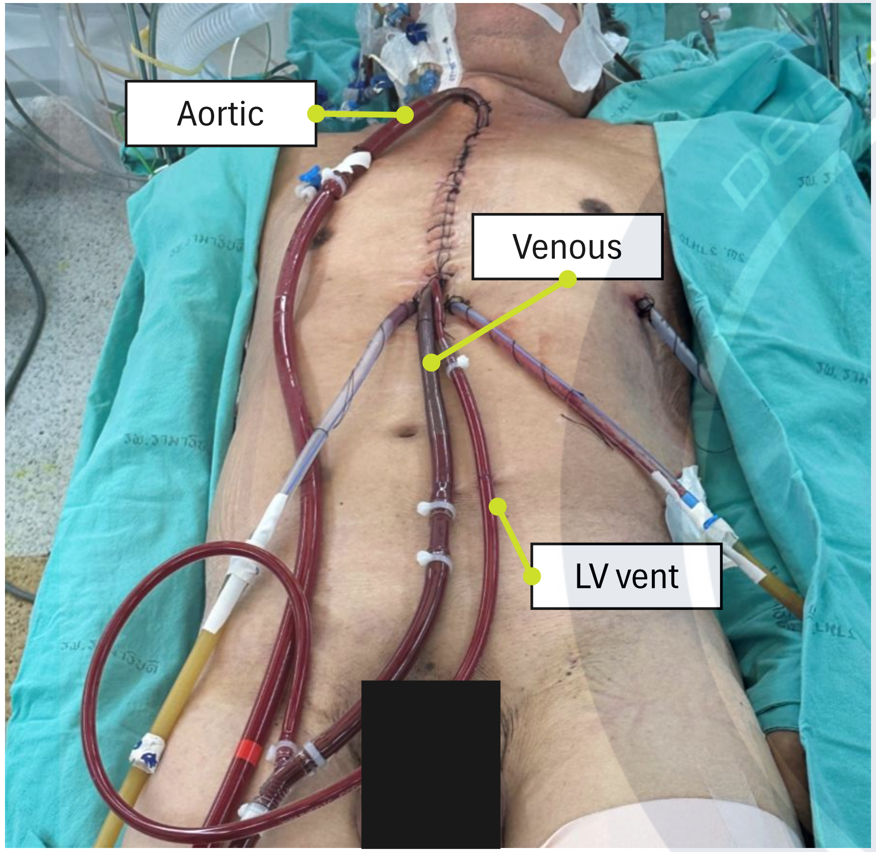
	Flow rate (cc/kg/min)		
	Neonates	Pediatric	Adult
VA ECMO	100	80	60
VV ECMO	120	80-120	60-80

Site of placement

- Central
- Peripheral
  - Jugular vein, Carotid artery
  - Femoral vein, Femoral artery

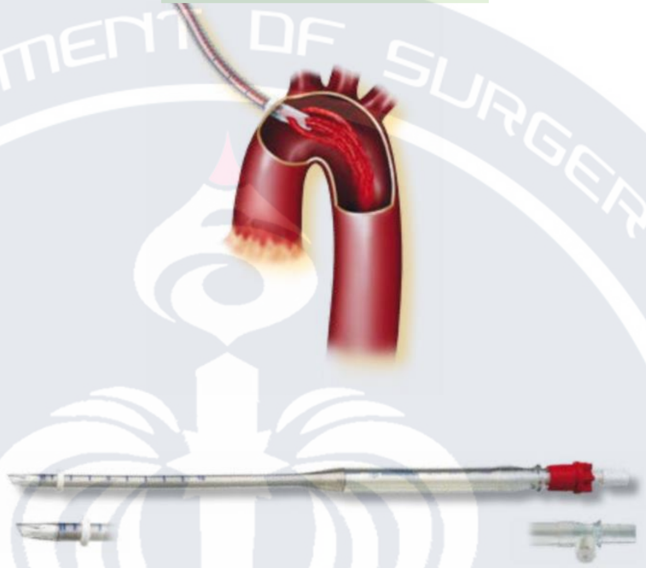
ELSO guidelines for adult and pediatric extracorporeal membrane oxygenation circuits: Erratum. (2022). ASAIO Journal, 68(7).

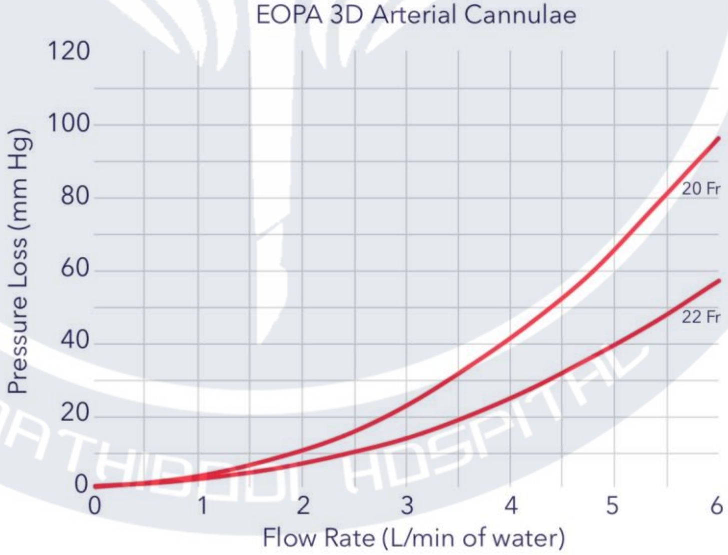
Central cannulation



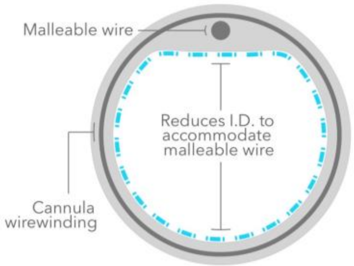
Type	Drainage	Return
Central	Right atrium	Aortic arch

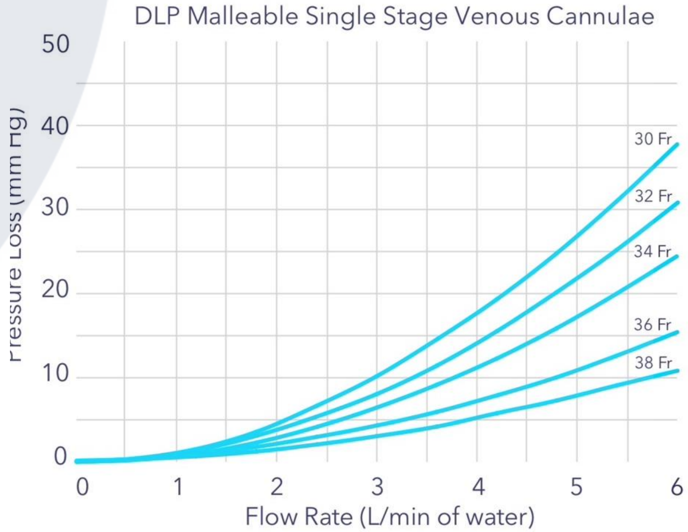
Aortic cannula





Venous cannula

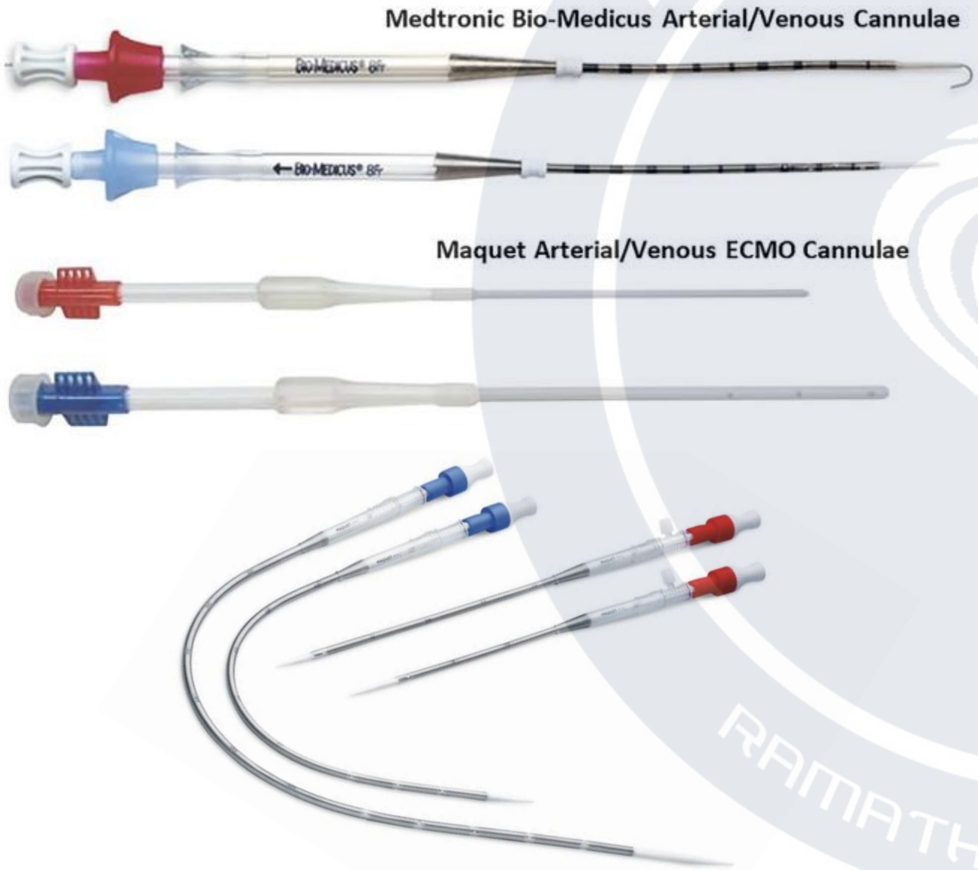




Peripheral cannulation

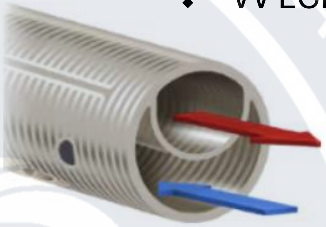
Single lumen

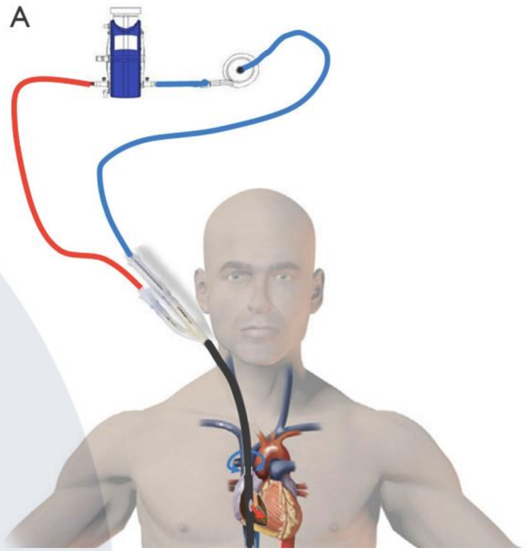
- VV
- VA

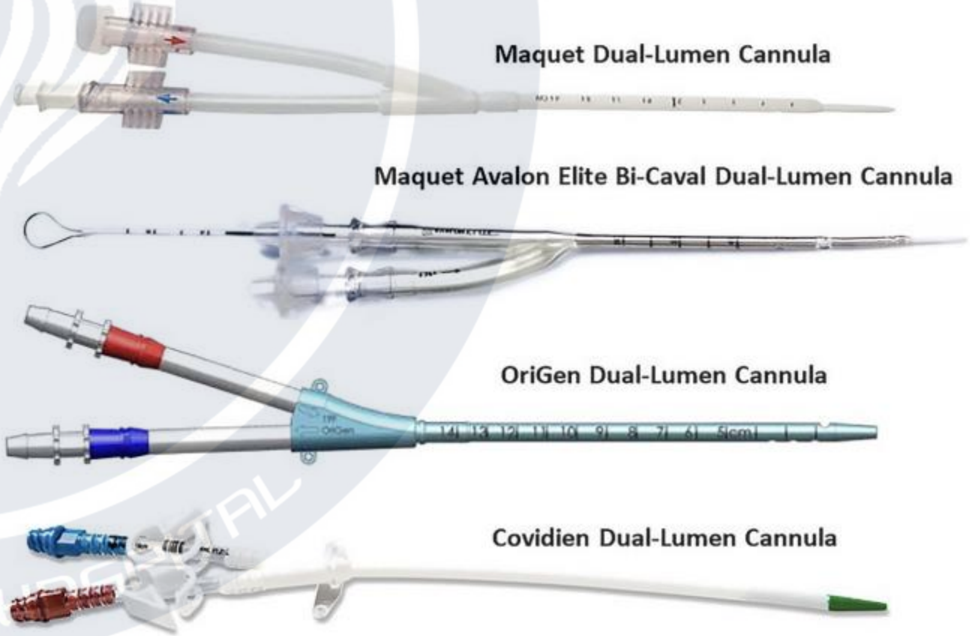


Dual lumen

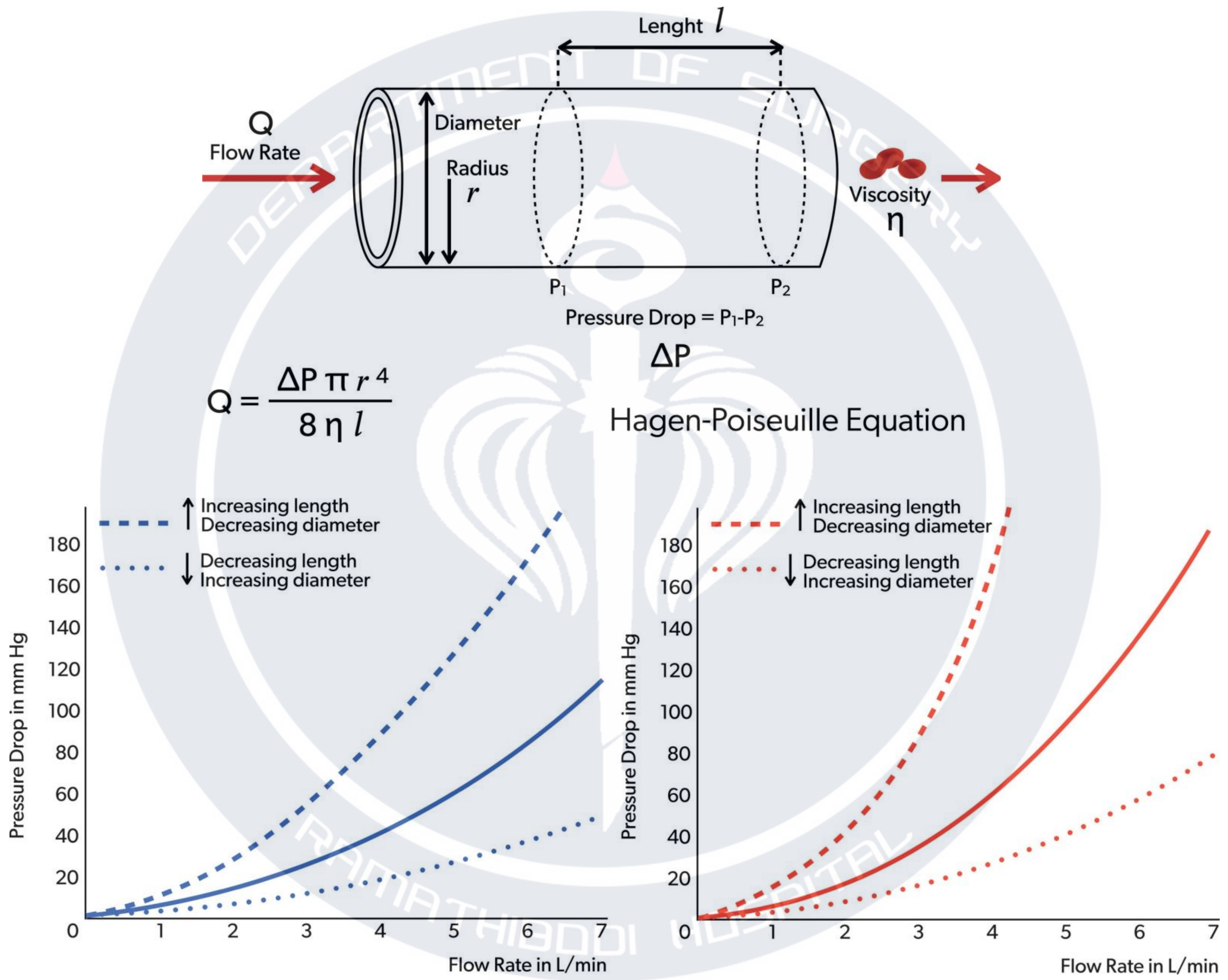
- VV ECMO





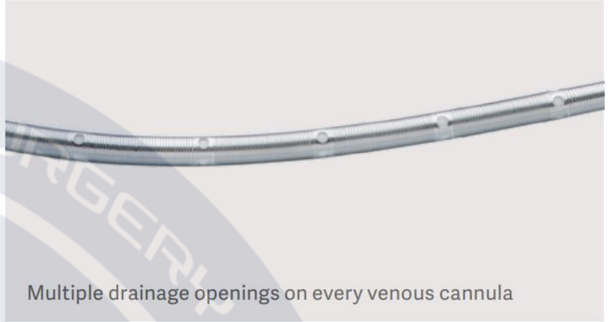


Undar, A., Wang, S., Özyüksel, A., & Rossano, J. W. (2018). Pediatric devices. Mechanical Circulatory and Respiratory Support, 271–297.

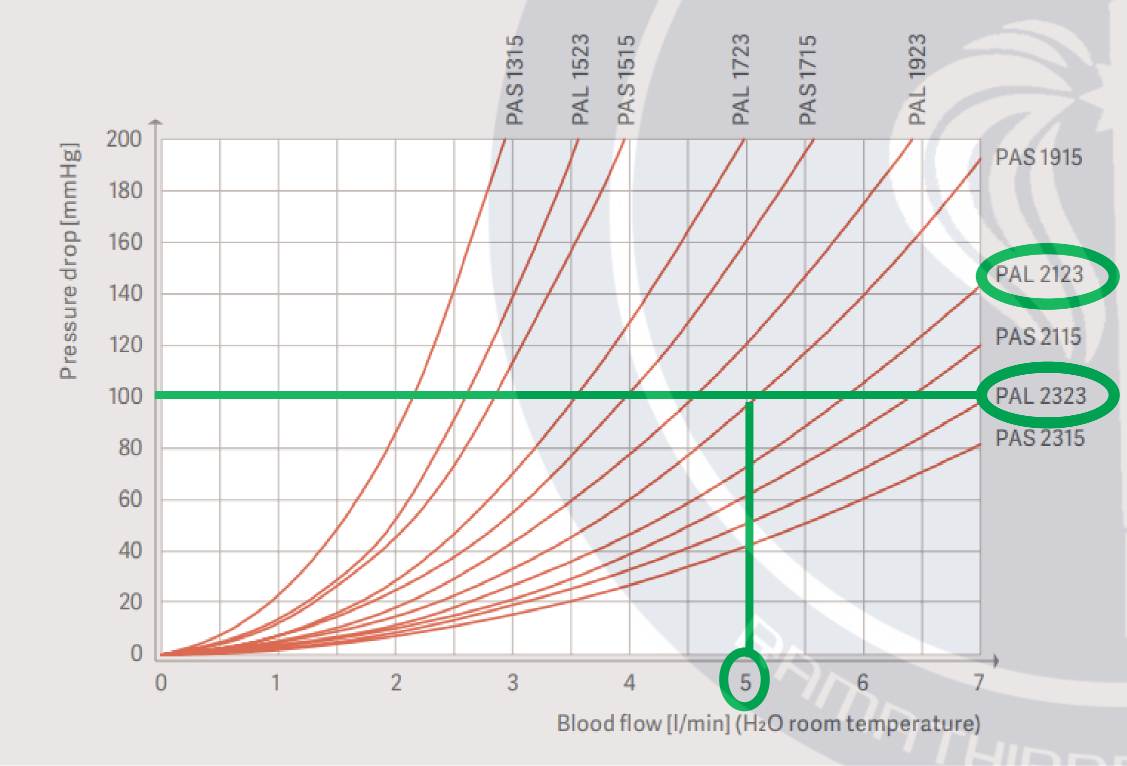


ELSO guidelines for adult and pediatric extracorporeal membrane oxygenation circuits: Erratum. (2022). ASAIO Journal, 68(7).

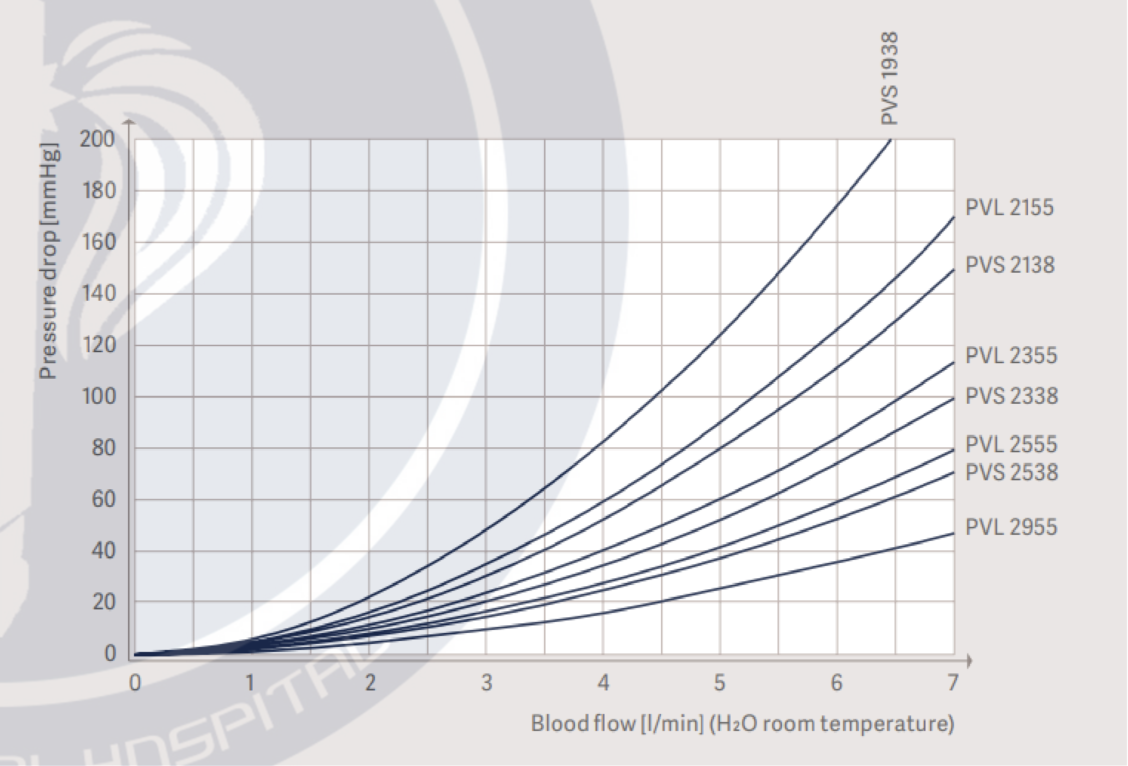

A pair of side holes on every arterial tip


Multiple drainage openings on every venous cannula

Pressure drop for all Arterial HLS Cannula 3⁄8”

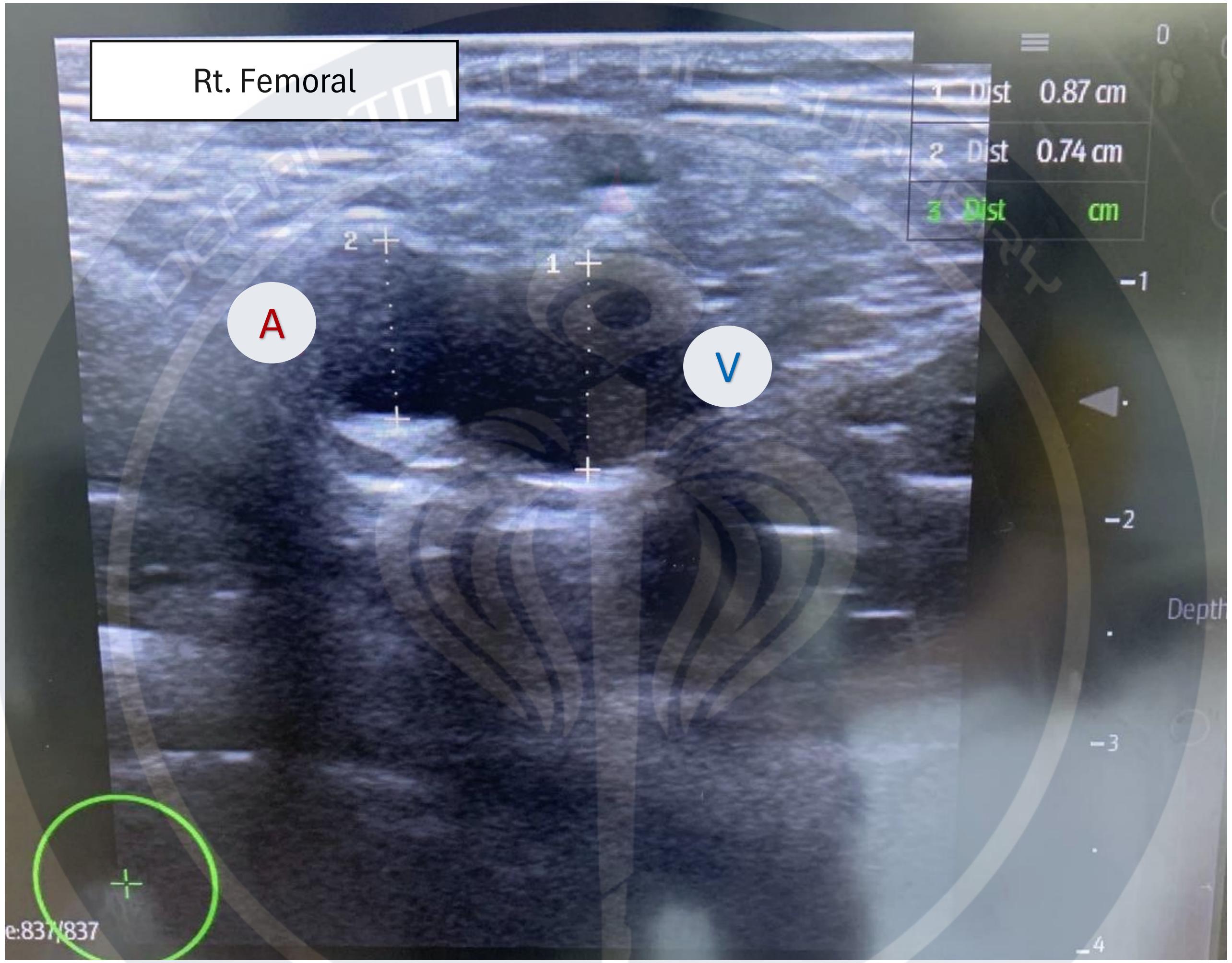


Pressure drop for all Venous HLS Cannula 3⁄8”



The manufacturer charts are tested using water which is an underestimation of the actual pressure drop in the blood

Ultrasound guide



1 mm = 3 Fr.

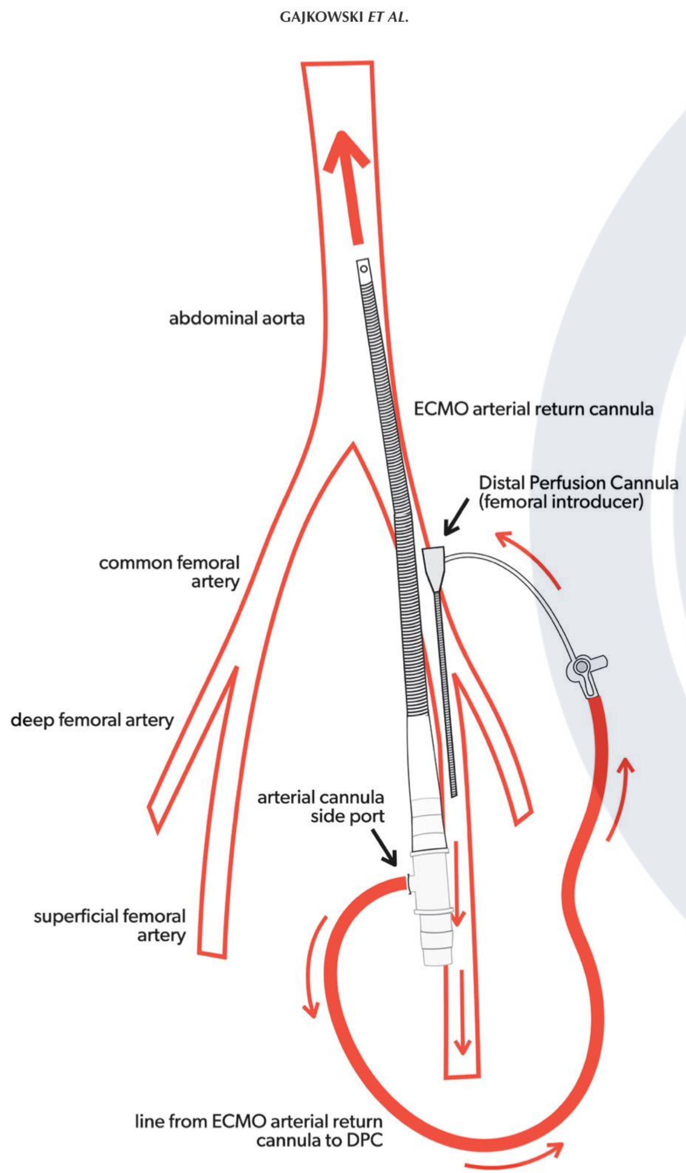
Diameters (mm) x 3 = Fr. Number

A 7.4 mm x 3 = 22 Fr.

V 8.7 mm x 3 = 26 Fr.

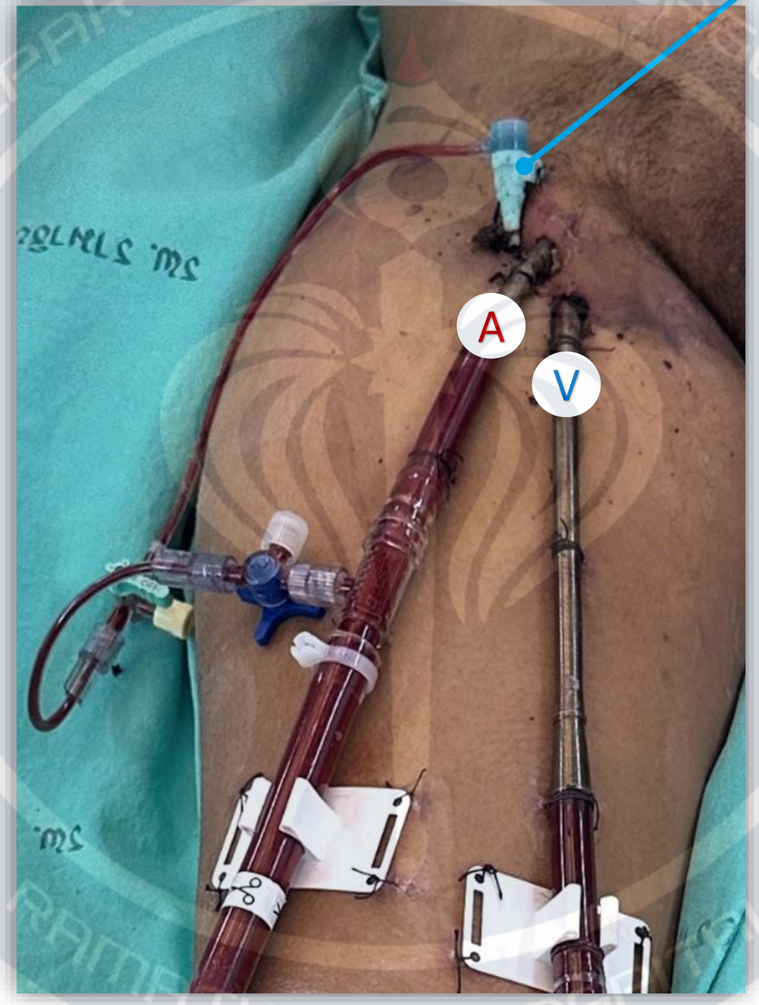
Distal perfusion

Prevent limb ischemia in Femoro-femoral ECMO

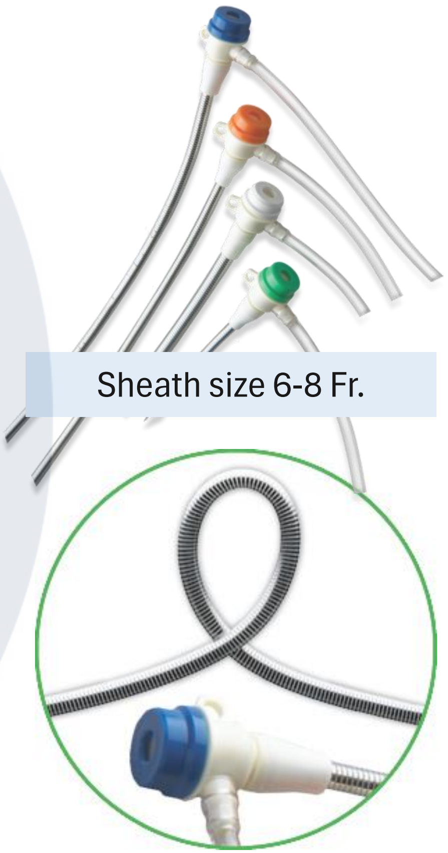


Superficial femoral a.

Distal perfusion cannula



Distal perfusion flow rate 100 – 150 ml/min



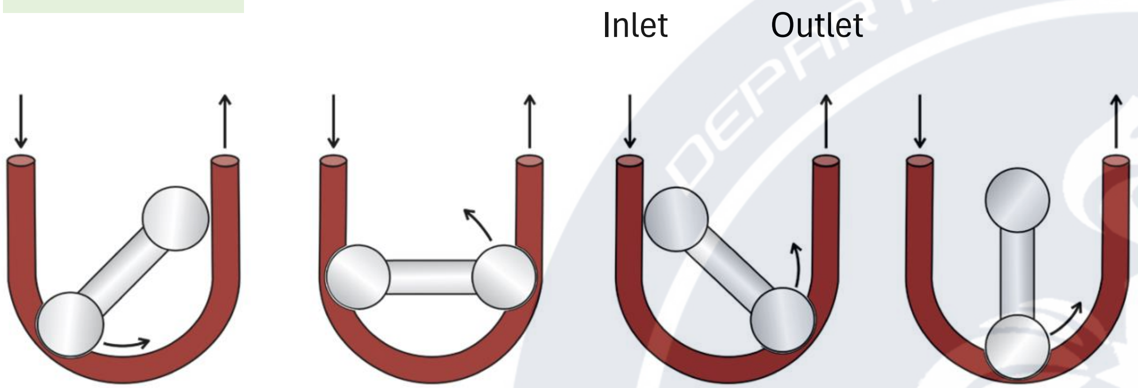
Sheath size 6-8 Fr.

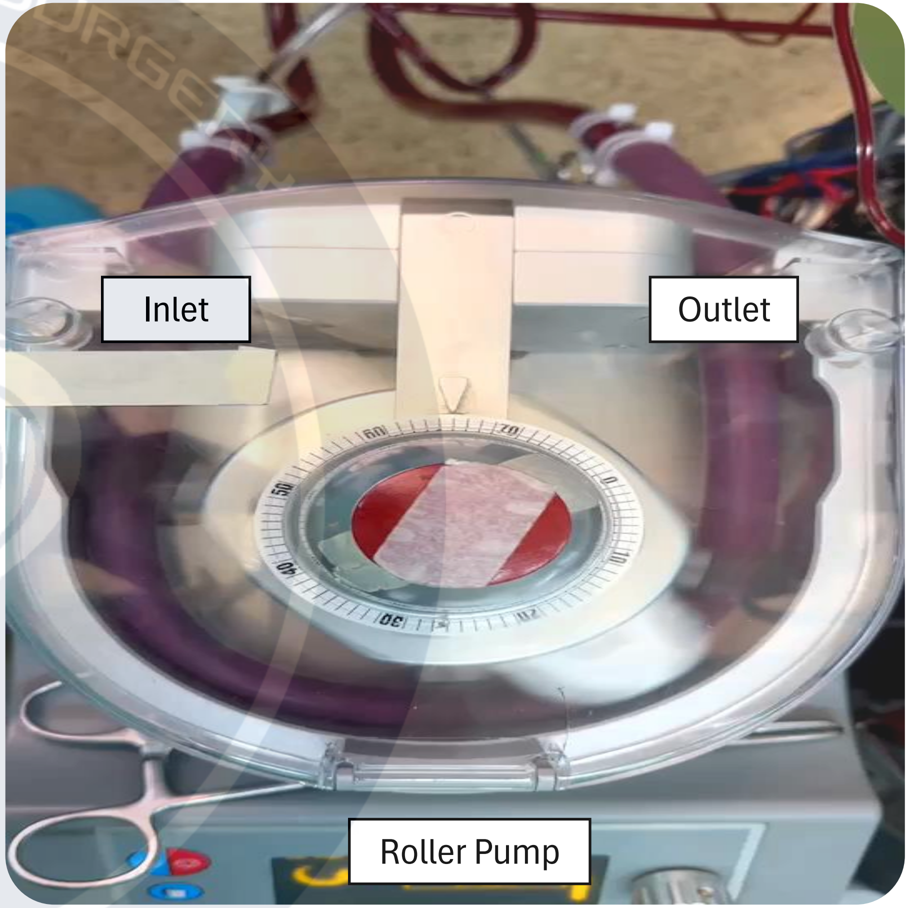
Innovative coil-wire design allows the sheath to flex at any point in any direction without kinking

ELSO guidelines for adult and pediatric extracorporeal membrane oxygenation circuits: Erratum. (2022). ASAIO Journal, 68(7).

Blood Pump

Roller Pump





Roller Pumps Advantages:

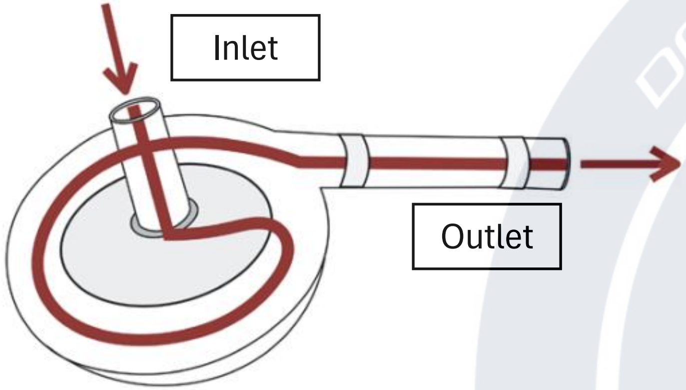
- Less expensive
- Lower prime volume
- Easy to prime
- Reliable Constant Flow Rate
- Do Not Allow Retrograde Flow

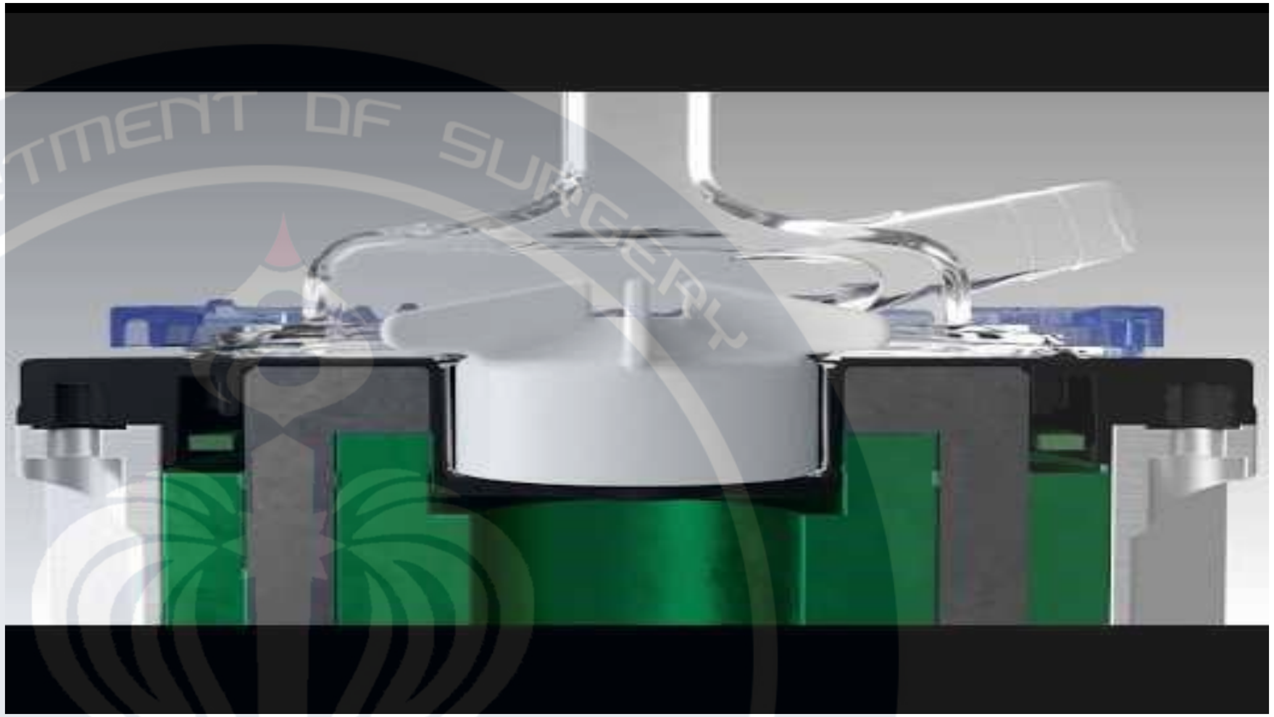
Roller Pumps Disadvantages:

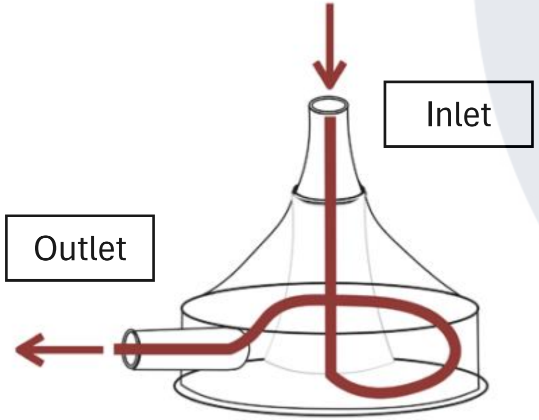
- Occlusive
- Not after load dependent
  (will pump against any resistance and may result in vessel dissection, pump tubing disconnection or rupture)
- Capable of pumping massive air through the outflow line

Centrifugal Pump

Centrifugal pumps are currently the most used







Centrifugal Pumps Advantages

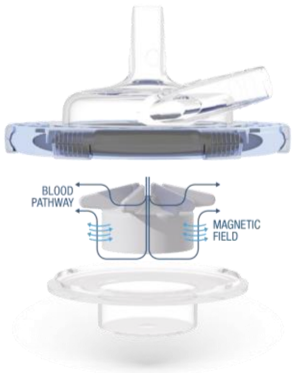
- Non – Occlusive, will not Pump Against any Resistance
- After Load Dependent
- Less likely to Result in Vessel Dissection, Pump Tubing Disconnection or Rupture
- Flow is Preload Dependent
- Less Hemolysis

Centrifugal Pumps Disadvantages

- More Expensive
- Increased Prime Volume
- More Difficult to Prime
- Allow for Retrograde Flow
- Thrombus formation Low Anticoagulation / Long Pump Runs
- Heat Generation (Hemolysis, Clotting)
- Magnetic Decoupling

EUROSETS
EVERY LIFE MATTERS

Fully magnetic-levitated centrifugal pump



- Optimal flow dynamics
- Reduced blood stagnation areas
- Minimal friction and shear stress
- Minimized hemolysis

TECHNICAL FEATURES

	Adult and Paediatric	New Born
LIMITATIONS		
Blood flow range:	0-10 l/min	0-3.0 l/min
Centrifugal pump speed:	0-5000 rpm	0-4500 RPM
Blood pathway volume:	39 ml	21 ml
Max blood pathway pressure:	800 mmHg (107 kPa)	800 mmHg (107kPa)
PORTS		
Blood inlet:	3/8” (9.53 mm)	1/4” (6.35 mm)
Blood outlet:	3/8” (9.53 mm)	1/4” (6.35 mm)

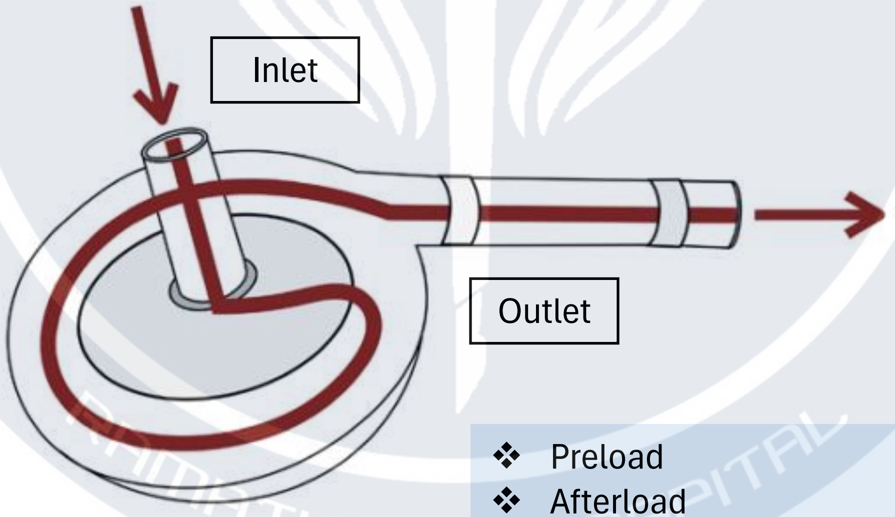
Blood Pump	Medos Deltastream DP3 Diagonal Pump	Maquet Rotaflow Centrifugal Pump	Sorin Revolution Centrifugal Pump	Medtronic Affinity CP Centrifugal Pump	Thoratec PediMag Centrifugal Pump
Priming volume (mL)	16	32	57	40	14
Revolution speed (rpm)	0–10,000	0–5000	0–3500	0–4000	0–5500
Maximal flow rate (L/min)	8	9.9	8	10	1.5
Maximum outlet pressure (mmHg)	–	–	800	760	540
Inlet/outlet port (mm)	9.5	9.5	9.5	9.5	6.4

Undar, A., Wang, S., Özyüksel, A., & Rossano, J. W. (2018). Pediatric devices. Mechanical Circulatory and Respiratory Support, 271–297.

Centrifugal pump flow determinants

$$Q \propto \frac{Pump\ speed}{P0 - Pi\ (delta\ P)}, Q \propto \frac{Pump\ speed}{Afterload - Preload\ (delta\ P)}$$

- Q ; Flow
- Po ; Pressure at outlet port of pump
- Pi ; Pressure at inlet port of pump



- ❖ Preload
- ❖ Afterload
- ❖ Pump Speed (RPM)

Console

ROTAFLOW

MAQUET

ROTAFLOW II

MAQUET

CARDIOHELP

MAQUET

XENIOS

MEDOS

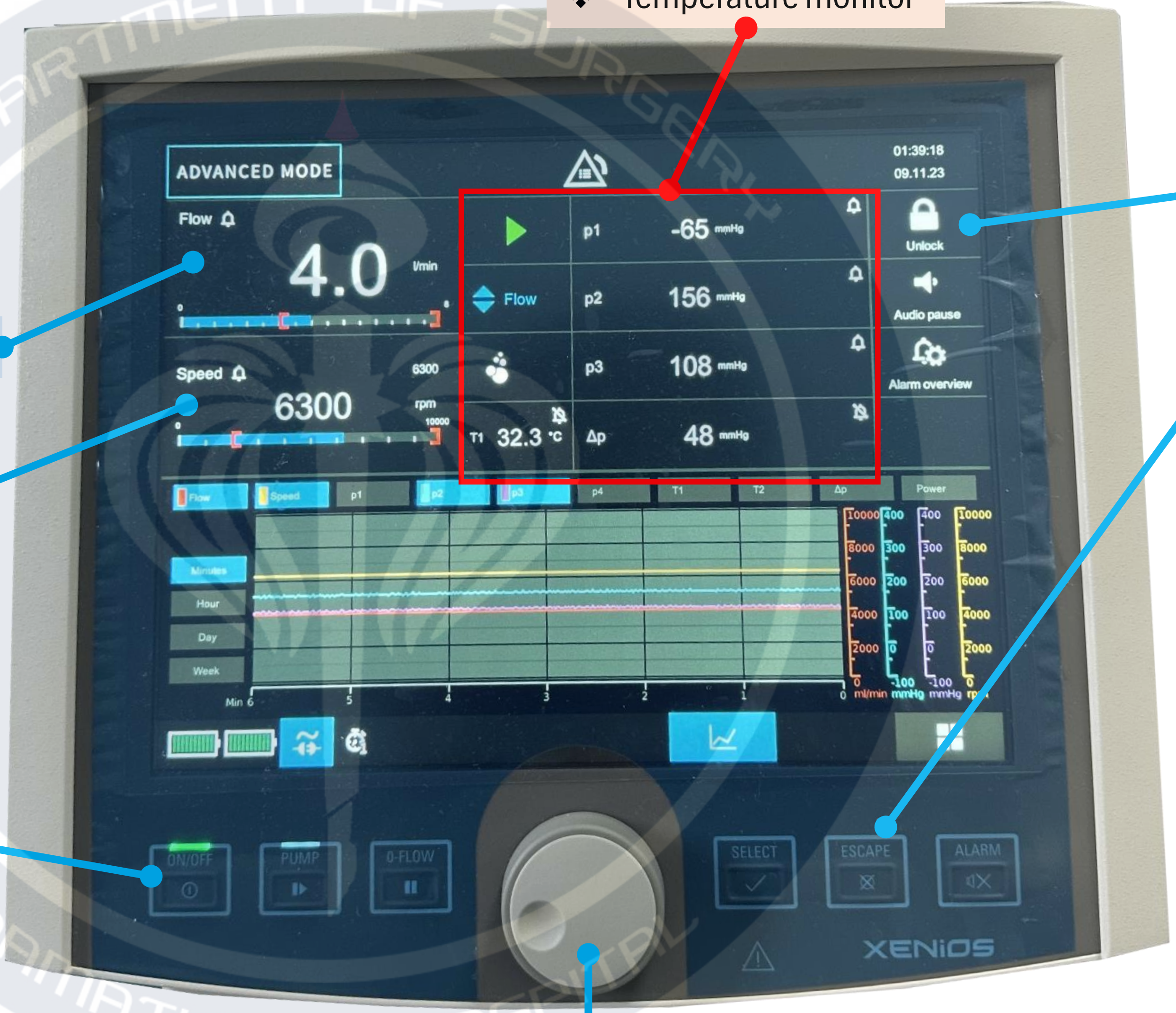
ECMOLIFE

EUROSETS

ROTAFLOW


Pump Flow
LPM
Liter per minute
Pump Speed
RPM
Revolution per minute
Rotary knob
On/Off button
A/C
Battery
Charge

XENIOS (MEDOS)



- Pressure monitor
- Temperature monitor

Pump Flow

LPM

Pump Speed

RPM

On/Off button

Unlock button

Rotary knob

CARDIOHELP

Pump Speed

RPM

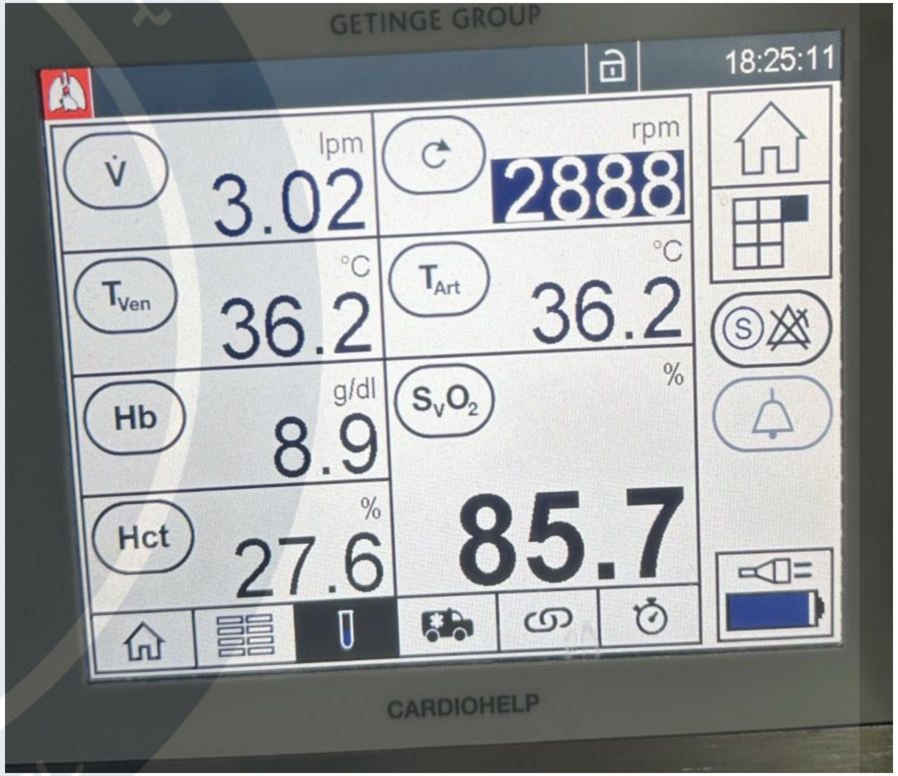
Unlock button

On/Off button

Pump Flow

LPM

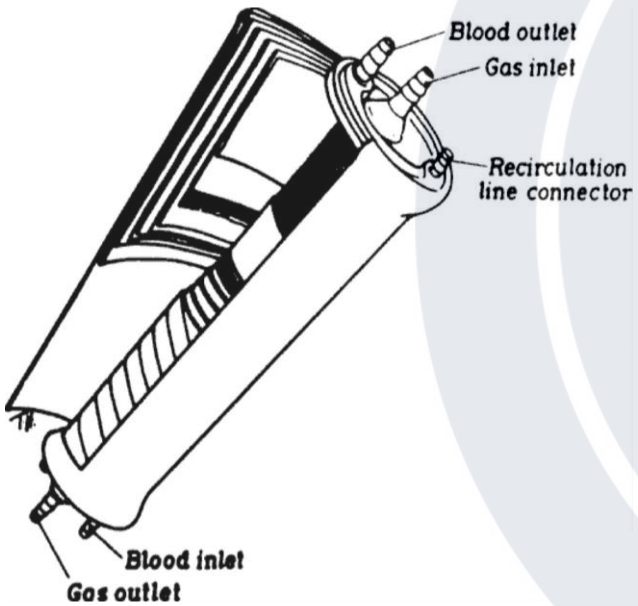
- Pressure monitor
- Temperature monitor
- SvO2



Rotary knob

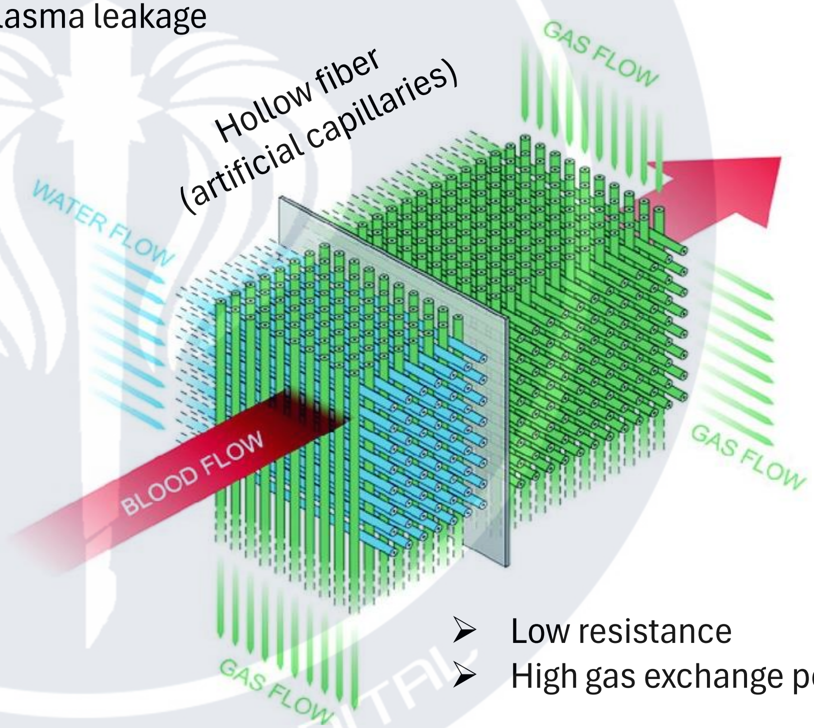
Gas exchange membranes

The first generation	The second generation	The third generation
Homogeneous membrane (dense membrane, nonporous membrane)	Microporous membrane	Composite membrane
Silicone rubber	Polypropylene	Polymethylpentene membrane (PMP)



- ❖ long blood paths
- ❖ high flow resistance

- ❖ Plasma leakage



- ➢ Low resistance
- ➢ High gas exchange performance

Fresh gas is directed into the lumen of the fibers, while blood passes externally and thermo-regulated water flows through adjacent channels

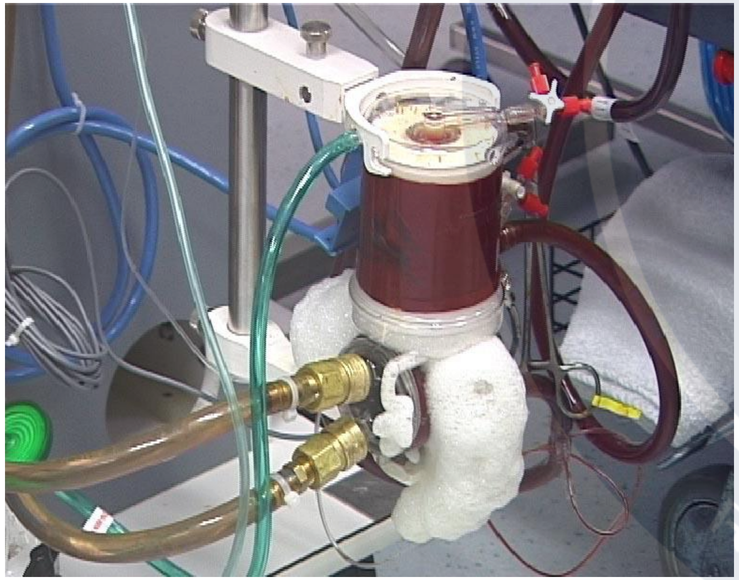
Betit, P. (2018). Technical advances in the field of ECMO. Respiratory Care, 63(9), 1162–1173.

Gas exchange membranes

Dysfunctions of the membrane oxygenator

- ❖ Excessive pressure drop due to blood coagulation/thrombus in the blood flow path
- ❖ Plasma leakage
- ❖ Decrease in the gas exchange rate due to the decrease in the effective membrane area

Plasma leakage

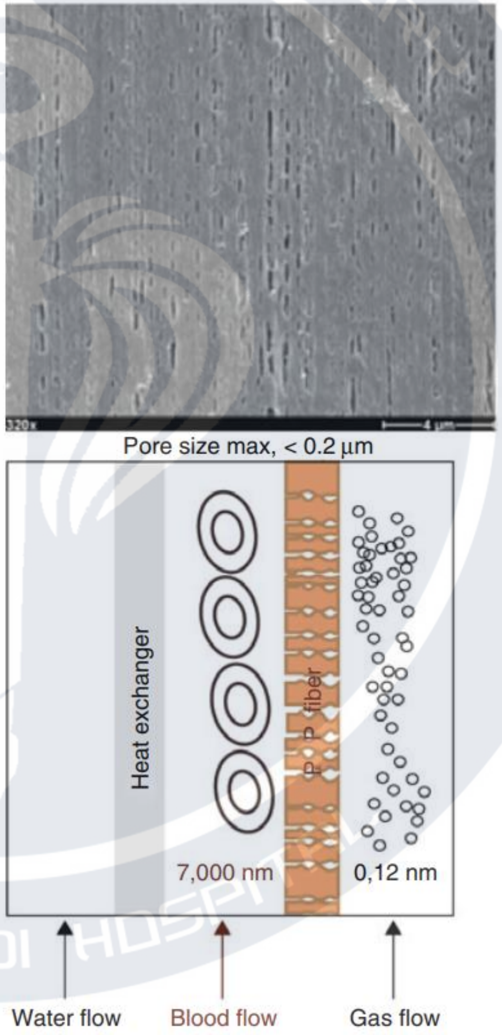


- ➢ Overall gas exchange decreases
- ➢ Increasing the chances of contamination
- ➢ Exposing patients to a new foreign surface

The second generation

Microporous membrane

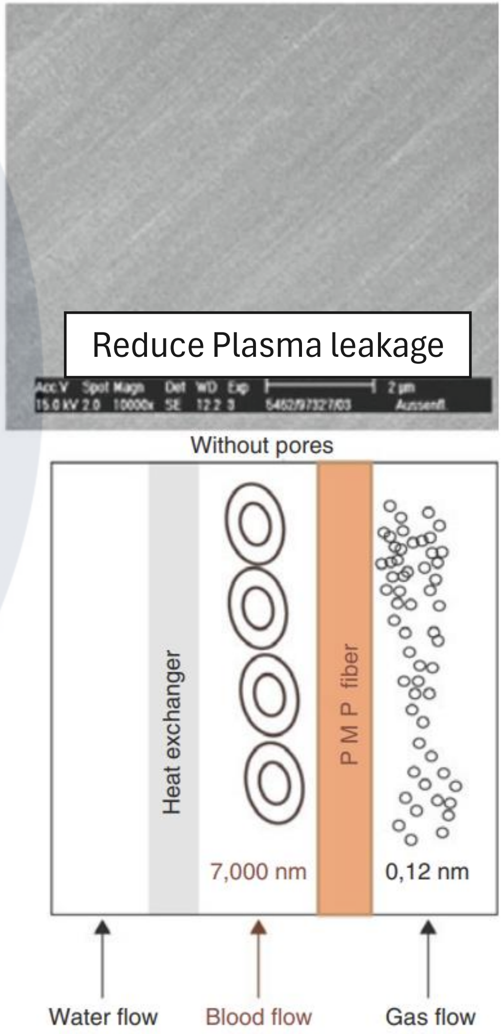
Polypropylene microporous membane (P P)



The third generation

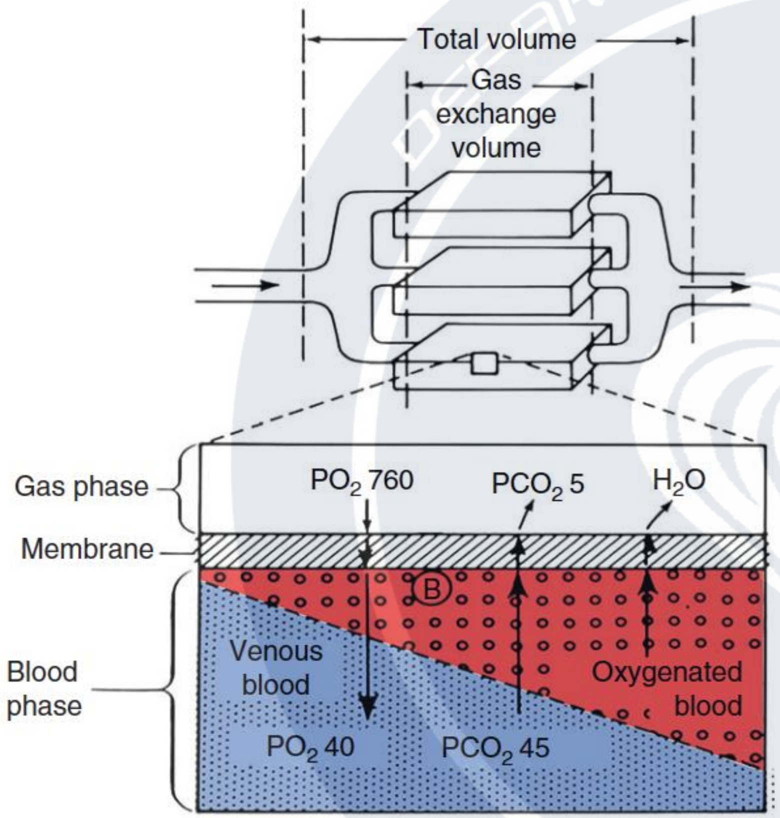
Composite membrane

Polymethylpentene membrane (PMP)

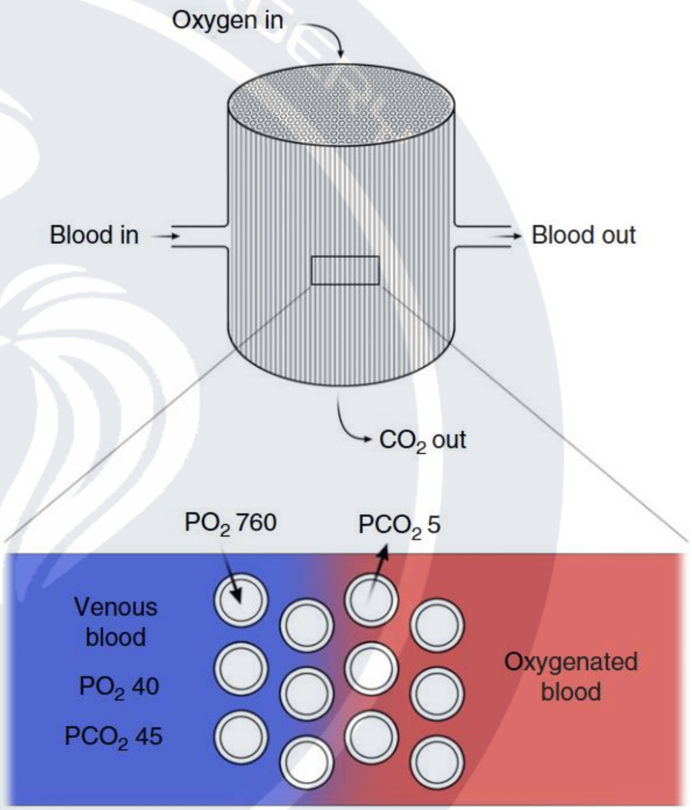


Reduce Plasma leakage

Simple membrane lung



Hollow fiber



Rated flow

Rated flow rate at which venous blood (saturation 75%, Hb 12 mg%) will be fully saturated (95%) at the outlet of the membrane lung

ASAIO Journal68(2):133-152, February 2022.
Bartlett, R. H. (2020). Physiology of Extracorporeal Gas Exchange. Comprehensive Physiology, 879–891.

Oxygenator

Ündar, A., Wang, S., Özyüksel, A., & Rossano, J. W. (2018). Pediatric devices. Mechanical Circulatory and Respiratory Support, 271–297.

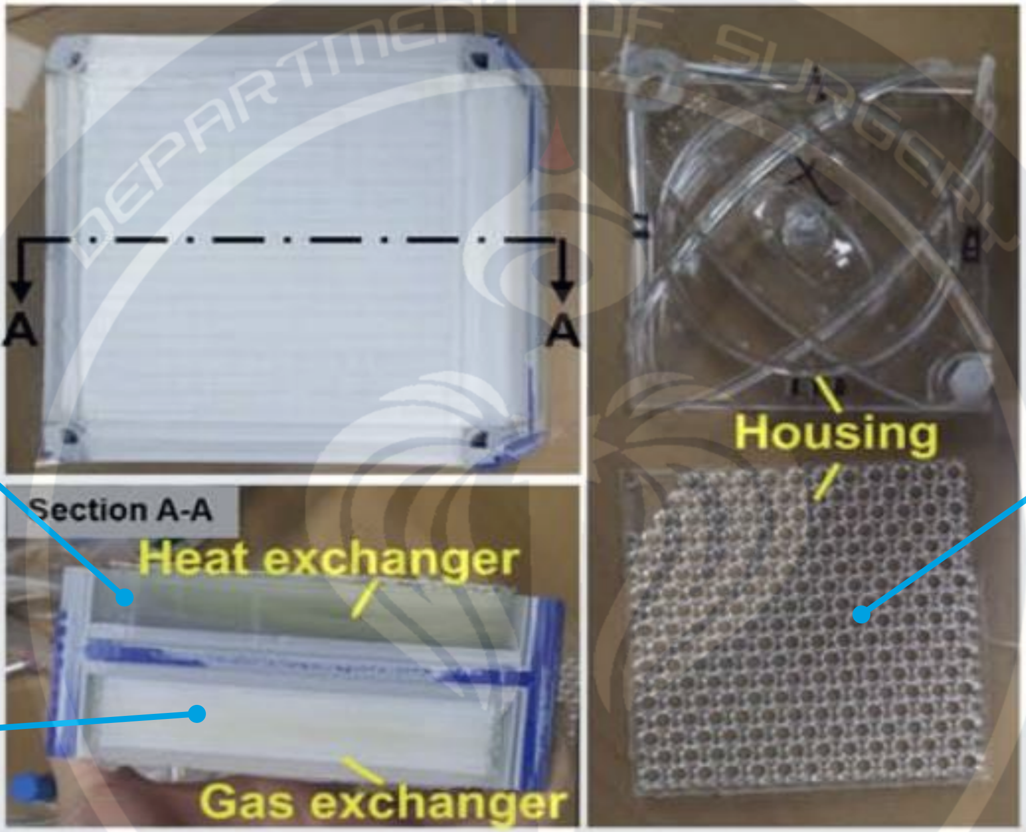
Oxygenator

Oxygenator with integrated centrifugal pump

Heater cooler and heat exchanger

Polyurethane fiber

Polymethylpentene hollow fibers



Polycarbonate

The water temperature is controlled electronically, heated to the set point temperature, and continually pumped in the water circuit via the connected oxygenator heat exchanger.

Autonomous safety shutdown ≥ 40.1°C

Park, J. et al. (2017) 'Investigation of key circuit constituents affecting drug sequestration during Extracorporeal Membrane Oxygenation Treatment', ASAIO Journal, 63(3), pp. 293–298.

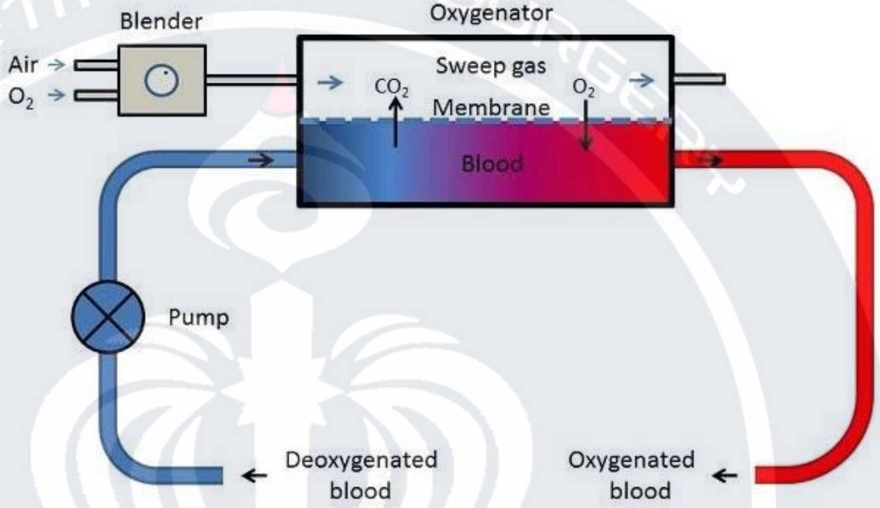
Sweep gas and Gas blender

Sweep gas

PaCO2

FiO2

PaO2



Oxygenation depends on:

The flow : higher flows allow more blood to be oxygenated.
The FiO2: increasing FiO2 achieves a higher partial pressure of oxygen.
The membrane integrity: if there is something present on the membrane (e.g. blood clots) that impairs diffusion, oxygenation will decrease.

Carbon dioxide removal depends on

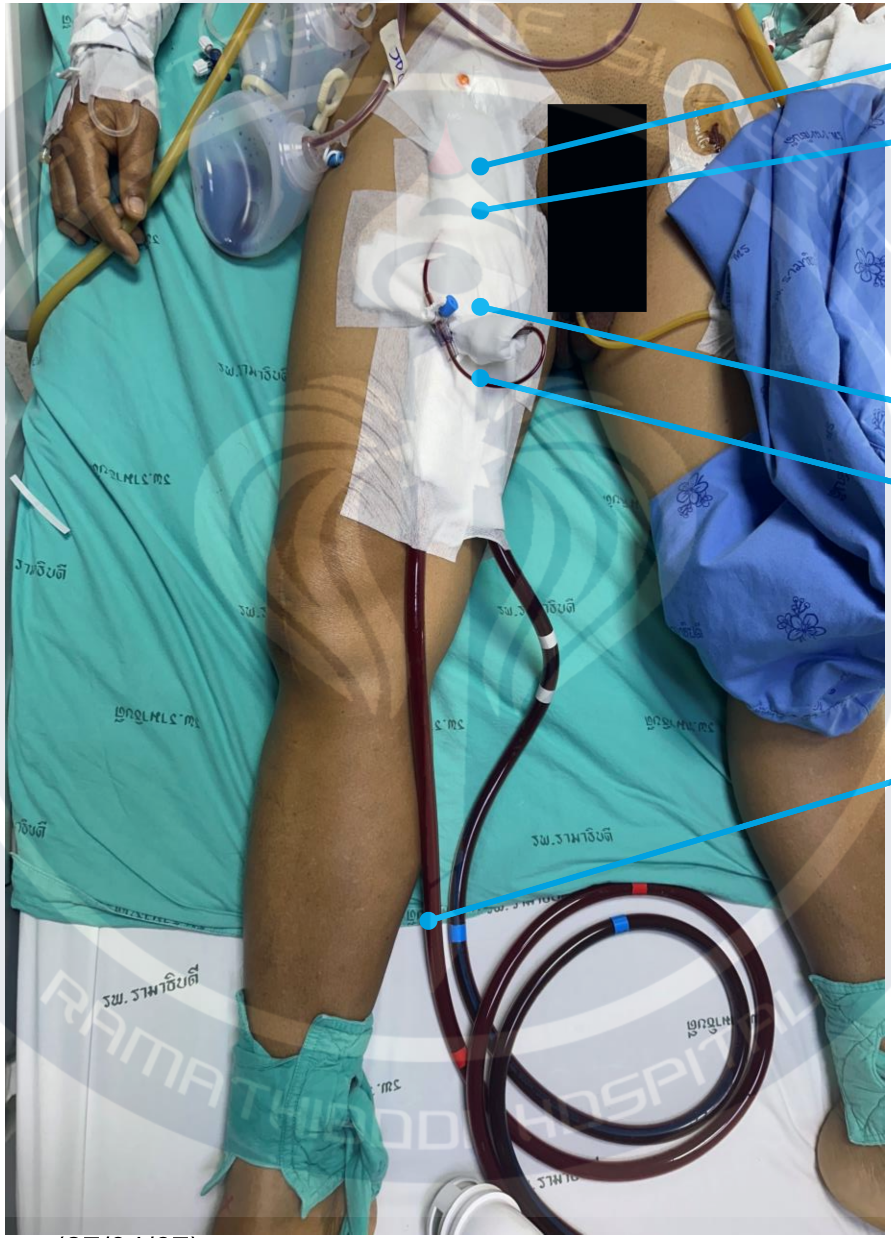
The sweep: higher sweep speeds result in higher CO2 removal.
The flow: if the flow is increased without increasing the sweep, then CO2 removal can be impeded.
The presence of water vapor in the membrane: this can impede CO2 removal.

Water vapor

Gas out port

The ECMO Circuit. icuECMO. Available at: http://icuecmo.ca/icuECMO_content/icuECMO_ECMO_circuit.html.

Monitoring the Circuit



Bleeding

Cannula fixation

Three-way stopcock

Distal perfusion flow

Color differentiation of the tubing

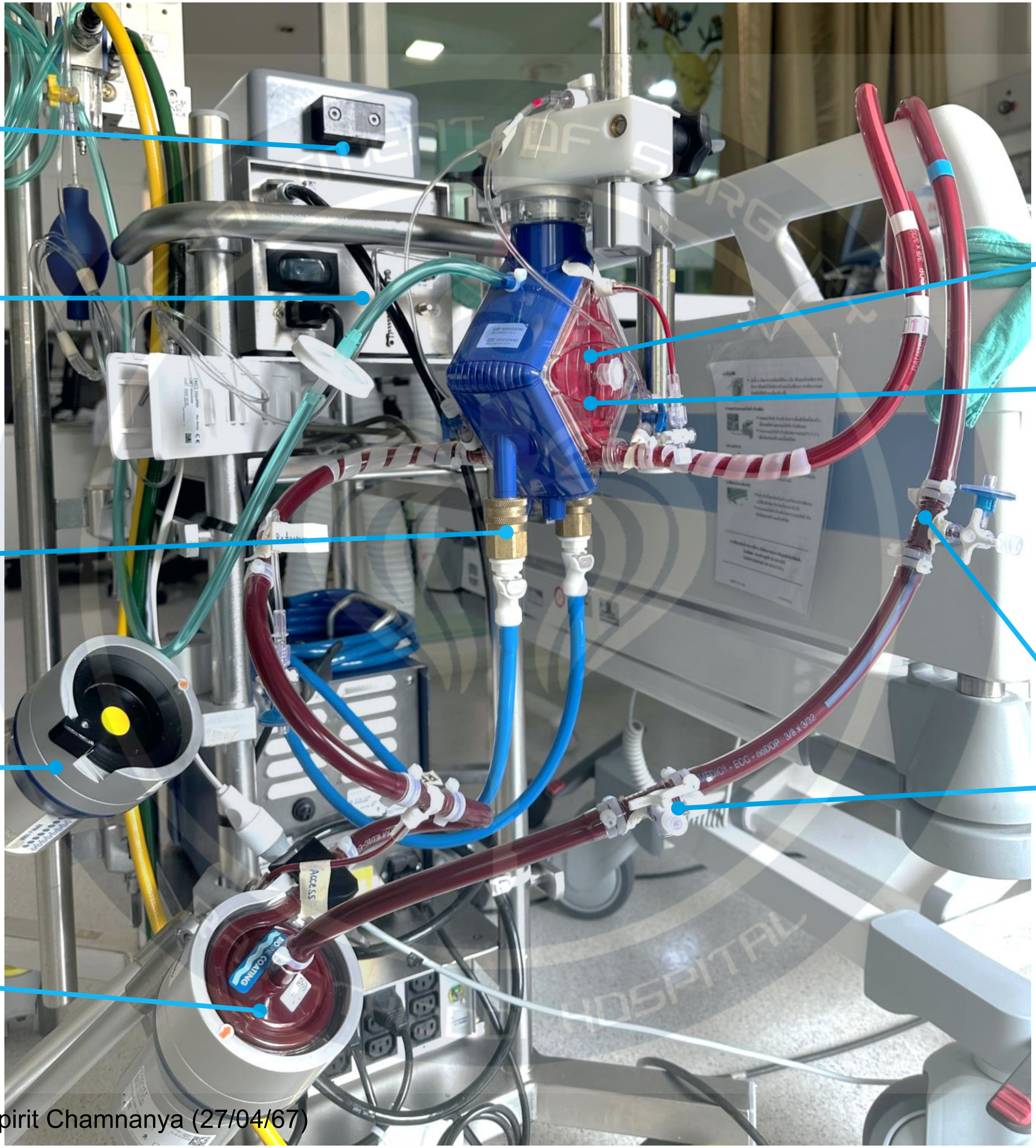
Power supply

Gas line connection

- Water line
- Water temperature
- Water level

Hand crank – ready for use

Centrifugal pump sound

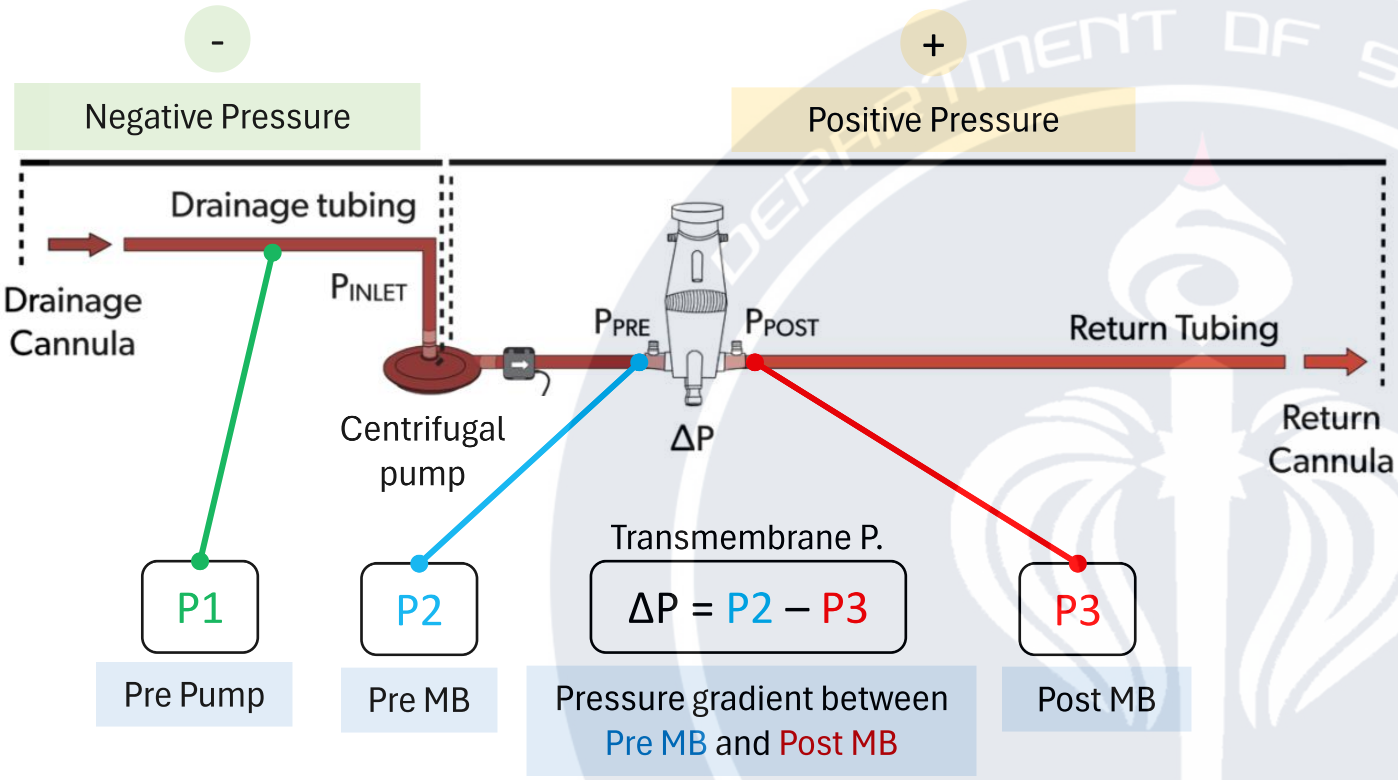


Fibrin, Clot

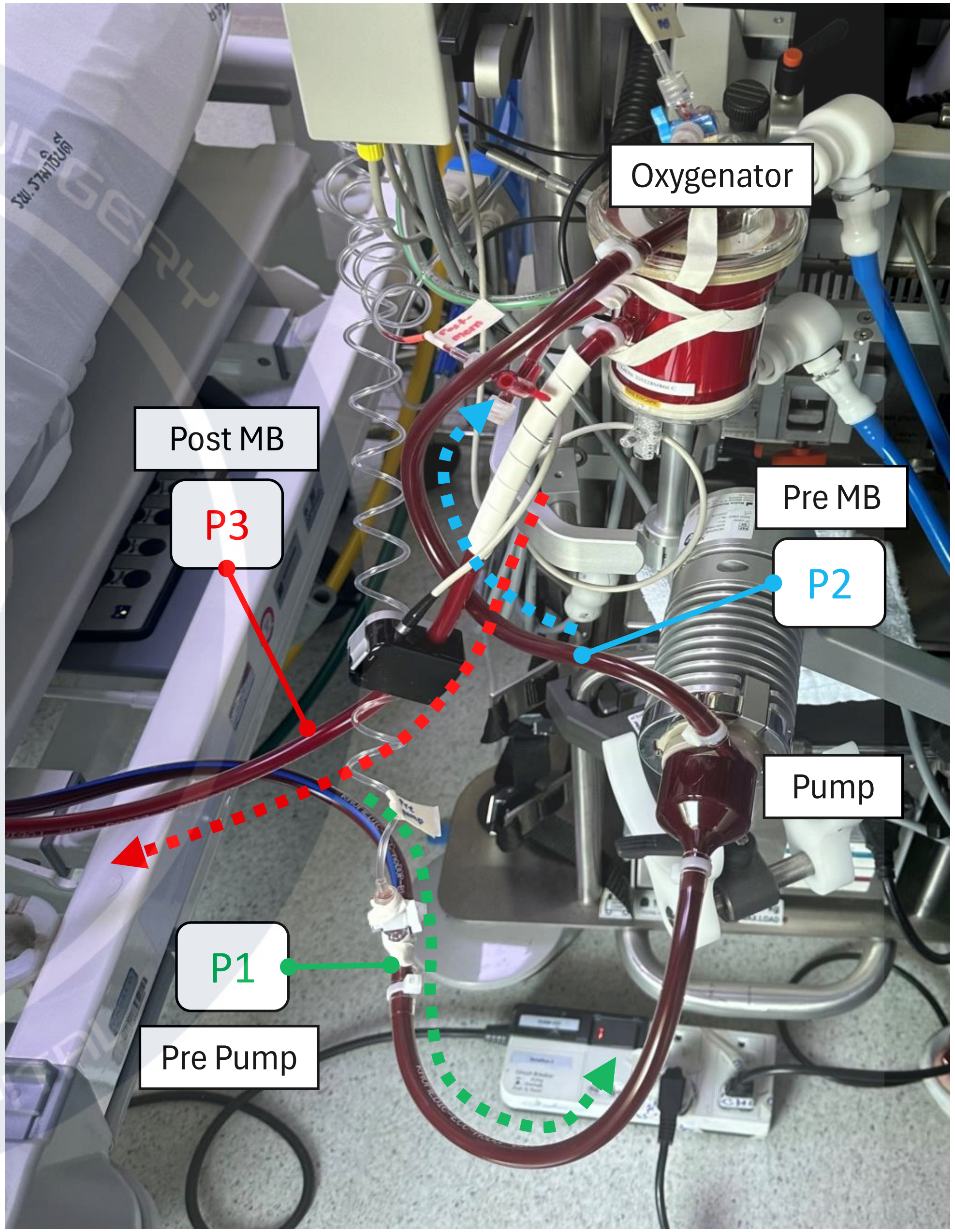
Air

Three-way stopcock

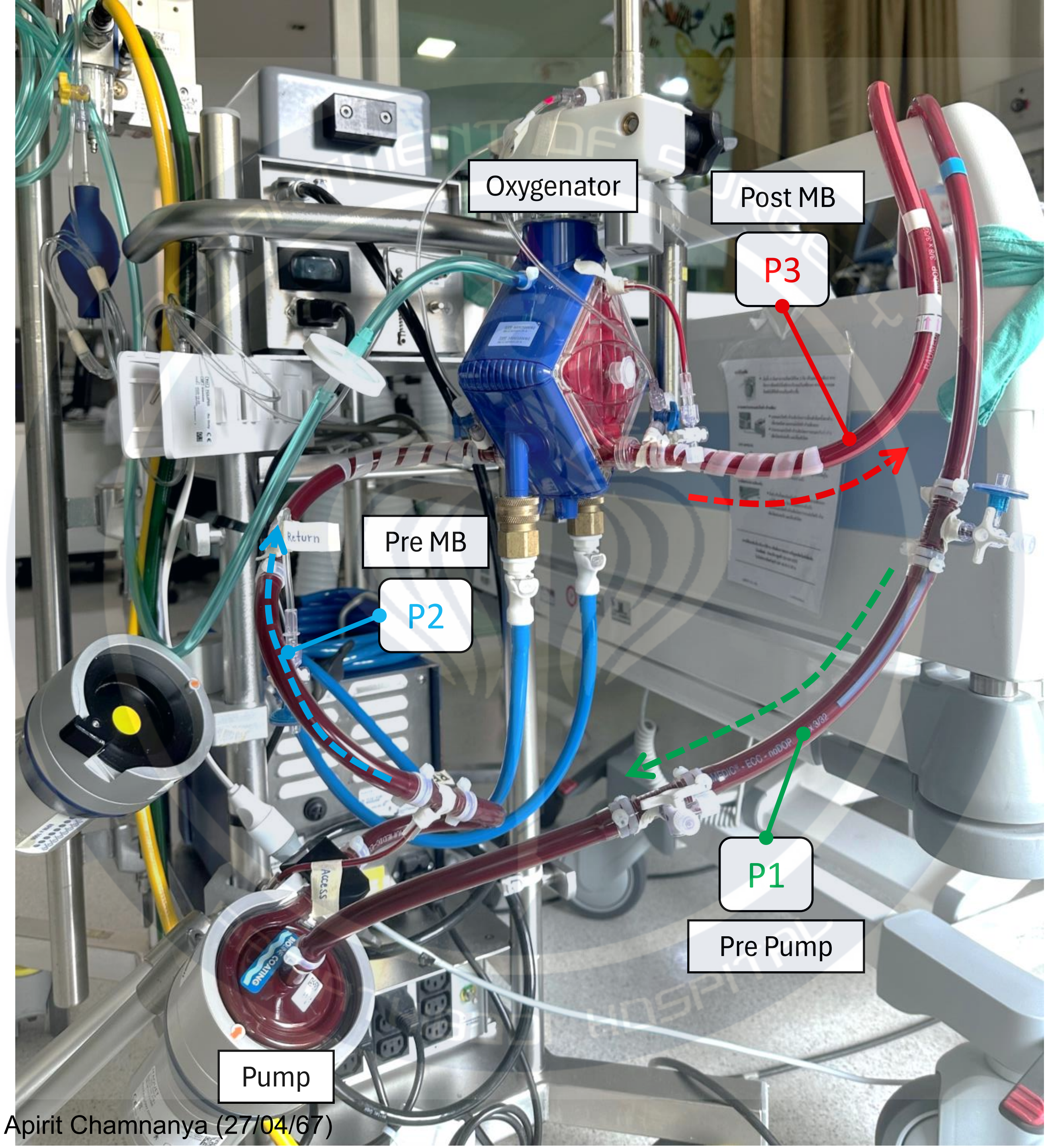
Pressure monitor



Parameters	Pressure limit
- P1	≤ -100
+ P2	≤ 350
+ P3	≤ 300
Transmembrane P. (ΔP)	< 50-100

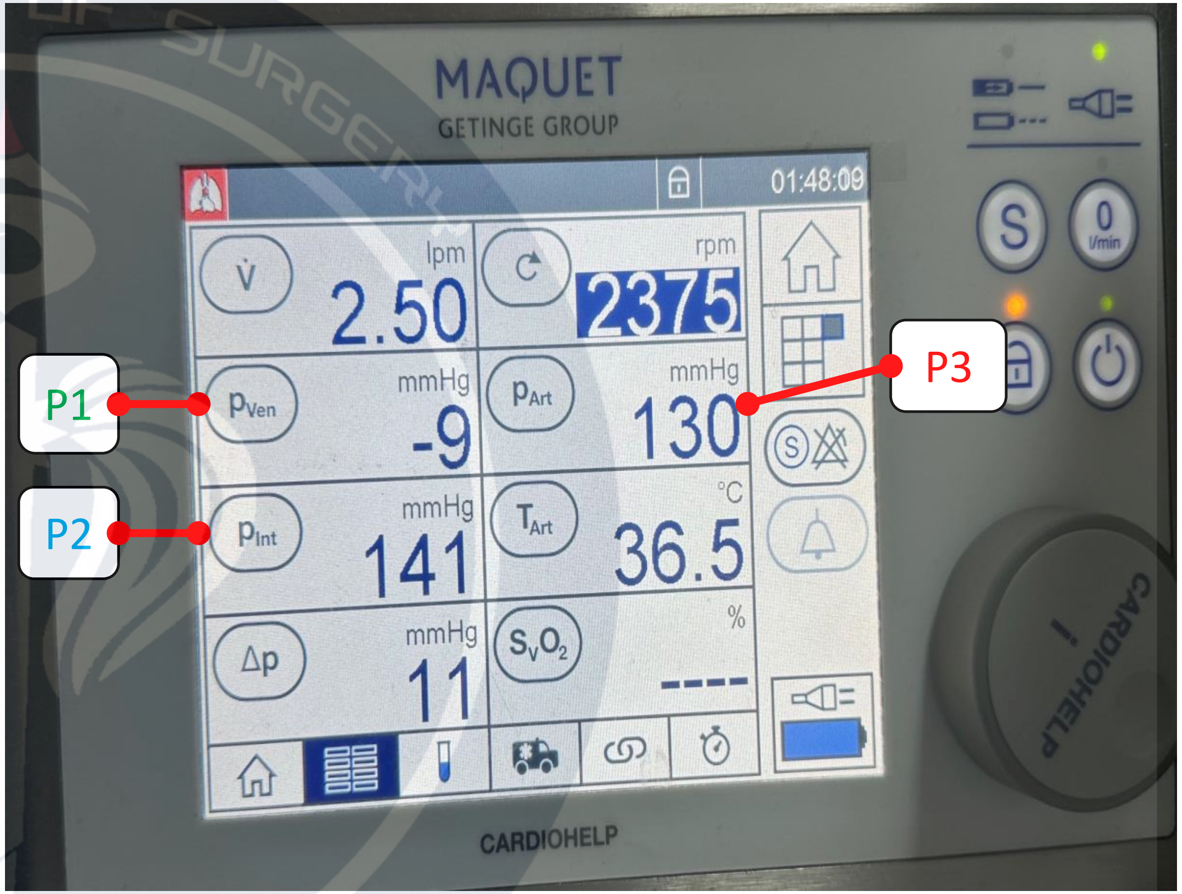


Adapted from ELSO guidelines for adult and pediatric extracorporeal membrane oxygenation circuits: Erratum. (2022). ASAIO Journal, 68(7).


Oxygenator
Post MB
P3
Pre MB
P2
P1
Pre Pump
Pump

MEDOS

CARDIOHELP



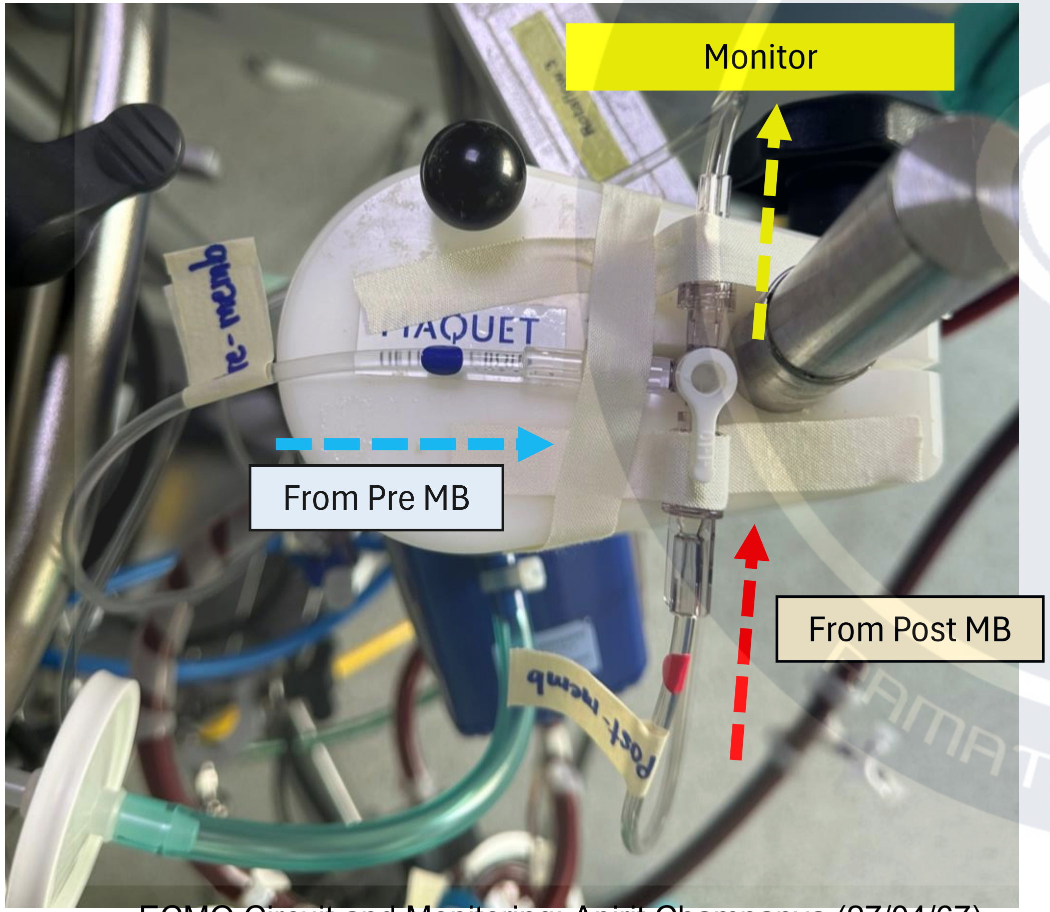
P Ven P1
Venous pressure

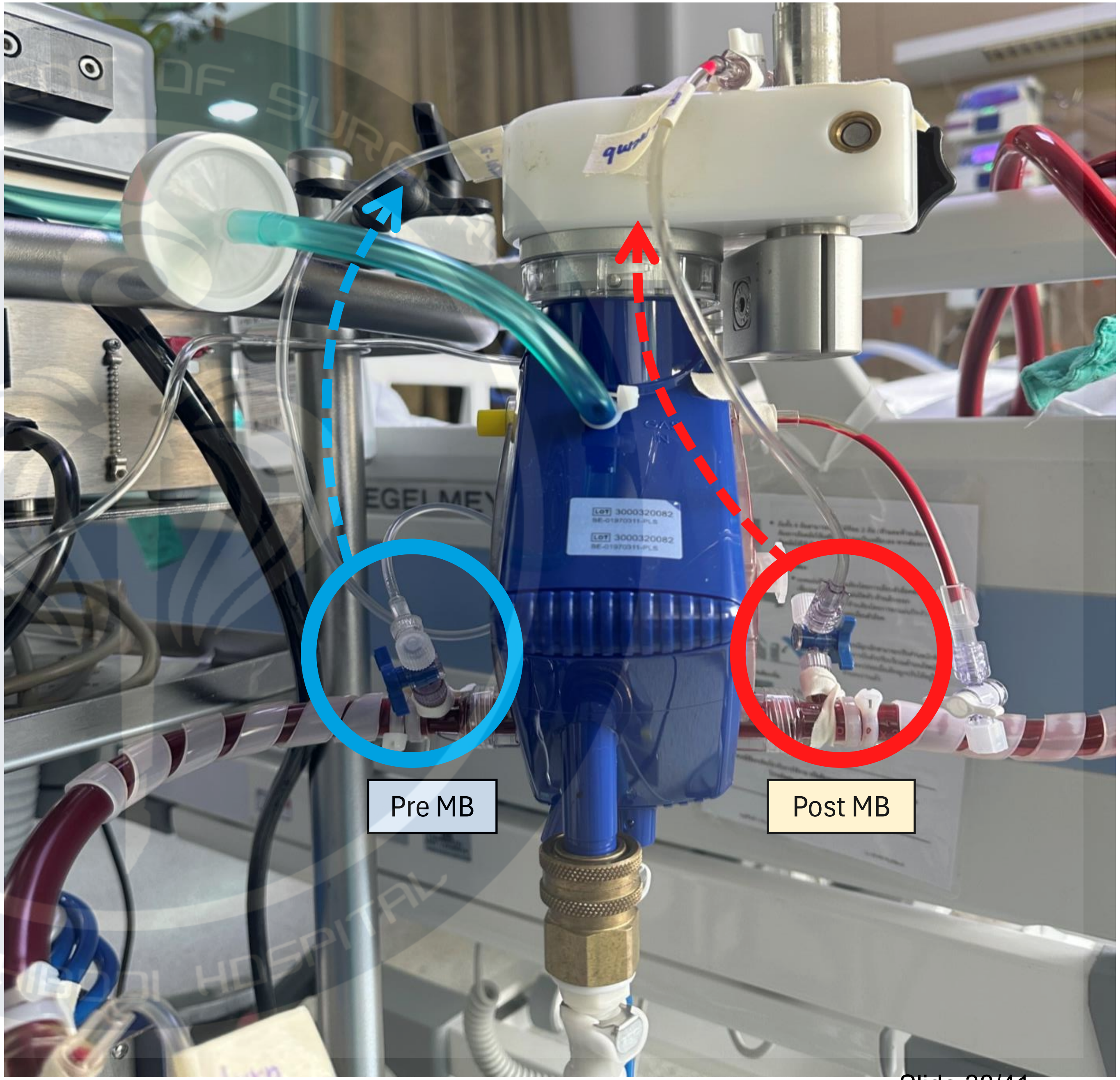
P Int P2
Integrated pressure

P Art P3
Arterial pressure

ROTAFLOW


No Pressure monitor
MAQUET
ROTAFLOW


Monitor
From Pre MB
From Post MB
MAQUET


Pre MB
Post MB


IntelliVue
MP70
9CC 5
Zarra, Ahmed
4 Sep 13:28
Profiles
Screen A
HR
95
Pulse
95
PVC 0
QTc 483
ABP
131/87 (98)
Ao
(191)
ECMO
Pleth
SpO2
100
ΔQTc
-60
Resp
RR
12
QT
384
NBP
PPV
21
Silence
Pause Alarms
NBP Modes
Start/ Stop
Stop All
Zero
Wedge
Vitals Trend
Monitor Standby
Main Setup
Main Screen
PHILIPS

P1 -50/-100	P2 250/350	P3 200/300	ΔP (P3-P2)	Flow	Rpms	Possible causes	Corrective actions
↓	↓	↓	↓	↓	=	Hypovolemia, Tamponade, Pneumothorax Venous cannula malposition or venous line kinking, venous canula clot	Improve patient fluid status, Check for tamponade and pneumothorax Check patency and position of lines & canula
↑	↓	↓	↓	↓	↓ =	Pump failure Clot or air in pump	Hand crank or use back-up pump Remove clotted pump or air
↑	↑	↓	↑	↓	=	Oxygenator failure (thrombosis)	Exchange failing oxygenator
↑	↑	↑	↓	↓	=	Increased pump afterload (hypertension in VA ECMO, arterial line kinking, arterial canula kink or clot)	Check patency and positon of return line & canula

P1 = drainage pressure / P2 = pre oxygenator pressure / P3 = post oxygenator pressure / ΔP = pressure drop over oxygenator

ELSO guidelines for adult and pediatric extracorporeal membrane oxygenation circuits: Erratum. (2022). ASAIO Journal, 68(7).

Thank you