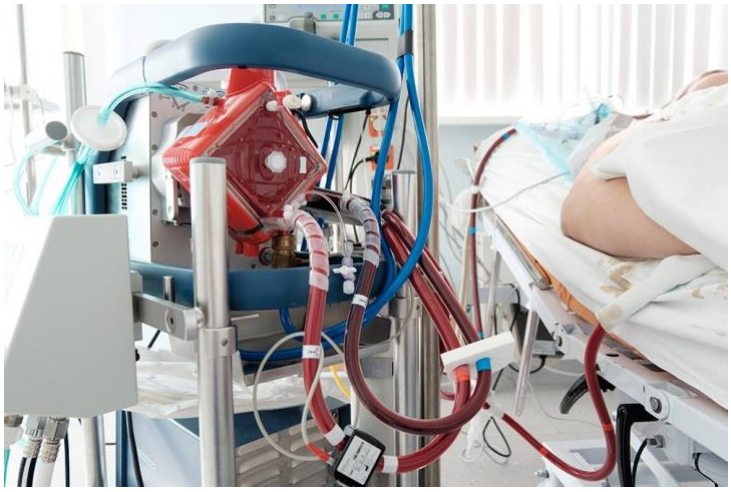
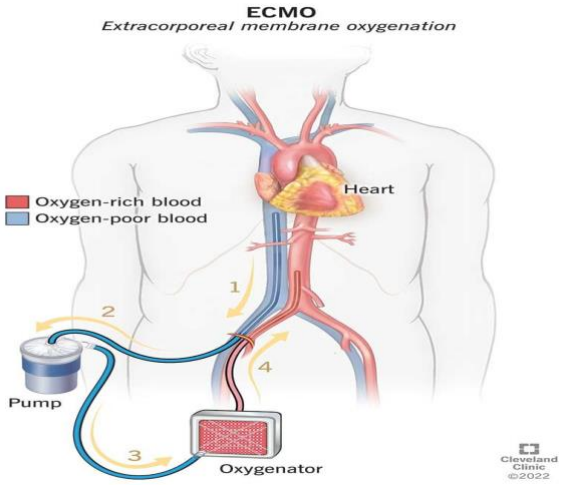
EXTRA CORPOREAL MEMBRANE OXYGENATION

CONTENTS:

WHAT IS ECMO?

ECMO helps in removing deoxygenated blood through a cannula inserted into a vein, driving the blood through a oxygenator that removes co2 and oxygenates the blood and pumping it back into the body through cannula placed into a artery or vein (venoarterial VA ECMO , venovenous VV ECMO)





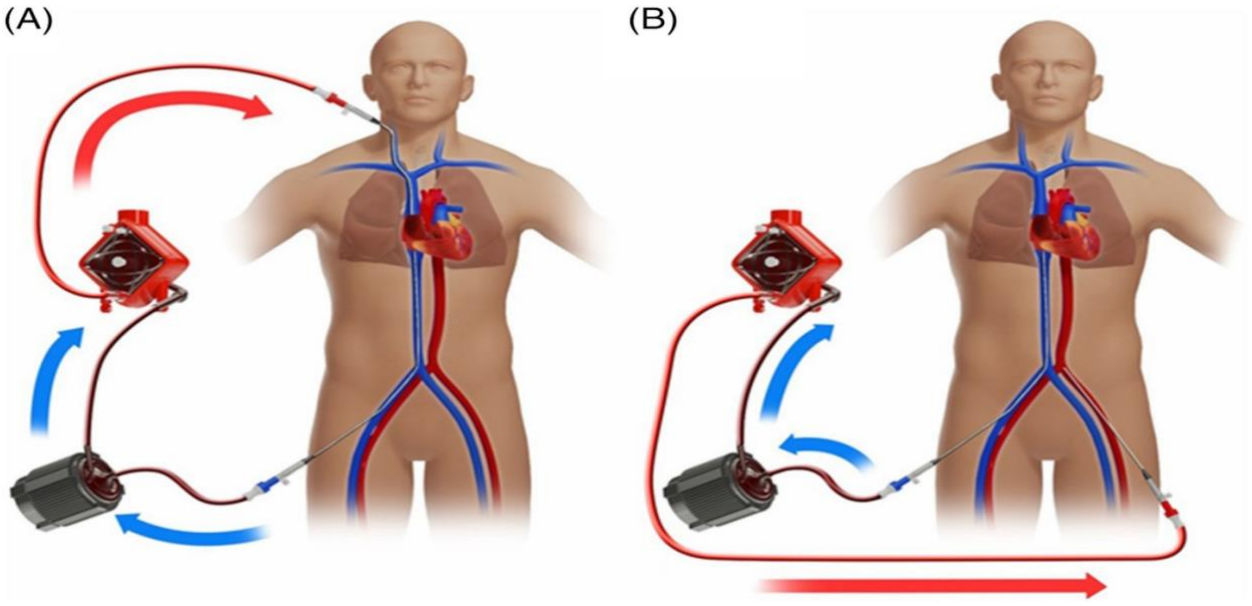
TYPES OF ECMO:

- **VV ECMO:**

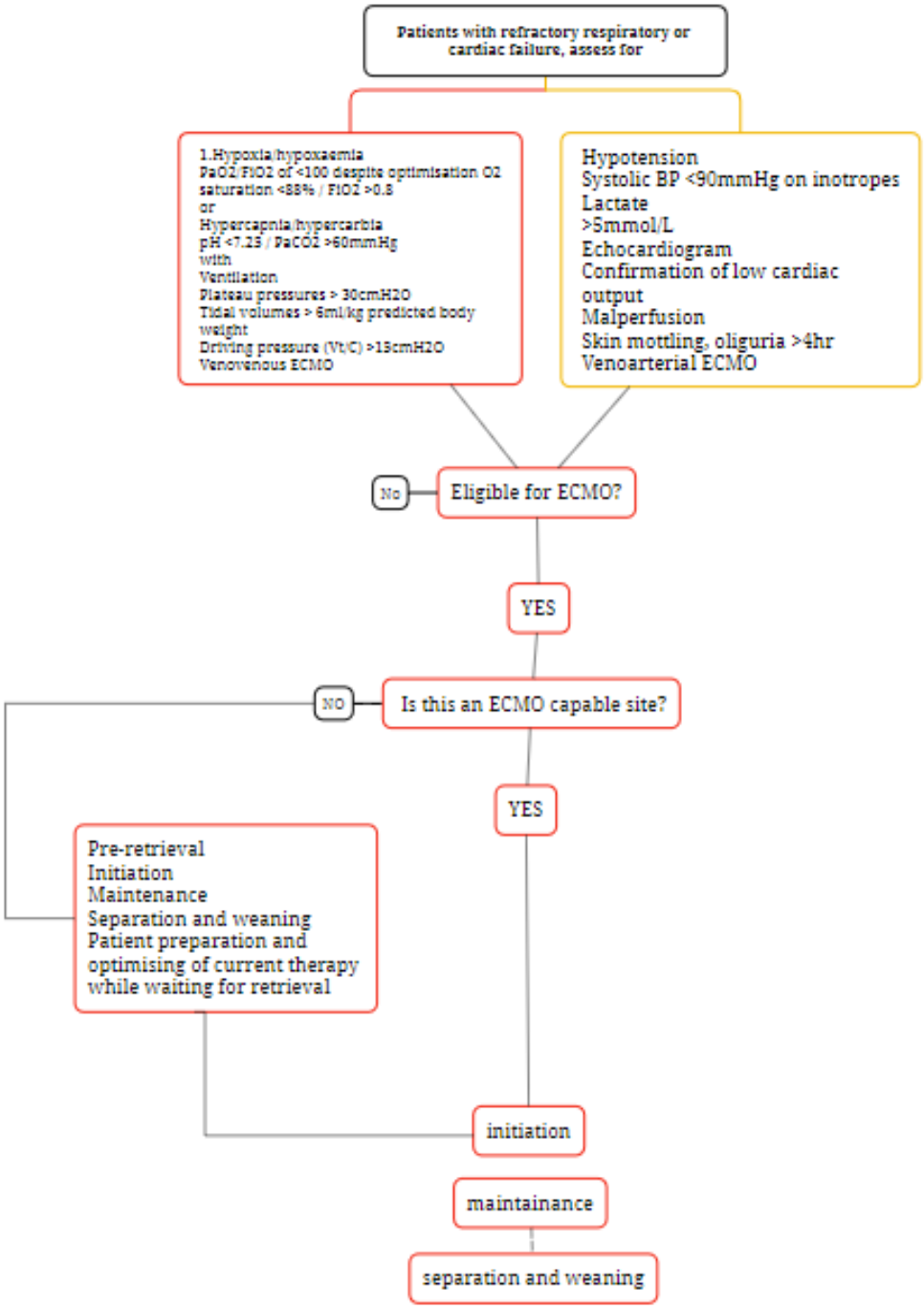
Deoxygenated blood is drained from venous system into the ECMO circuit then the blood is oxygenated via the oxygenator and is returned to the right atrium through major veins.

- **VA ECMO:**

Deoxygenated blood is drained from venous circulation into the ECMO circuit then the blood passes through the oxygenator and returned directly to the arterial system.



ECMO FLOW CHART



CLINICAL CRITERIA:

VV ECMO:

Clinical criteria	Indicator Ranges
Hypoxemia	PO2 / FiO2 < 100 despite optimisation of ventilator settings
Hypercapnia	PH < 7.25 with PCO2 > 60 mmHg
Ventilation	Tidal volume > 6 ml/kg of predicted body weight PEEP > 15 cmH2O

VA ECMO:

Clinical criteria	Indicator Ranges
Hypotension	Systolic BP < 90 mmHg on maximum inotropes
Lactate	> 5 mmol/ L
Echocardiogram	Confirmation of low CO
Malperfusion	Skin mottling, Oliguria > 4 hours

INDICATIONS :

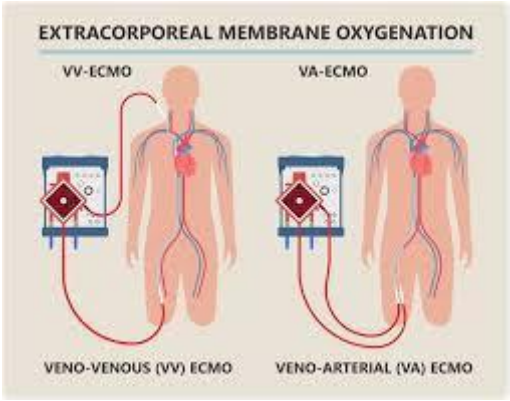
VV ECMO :

- potentially reversible respiratory failure from any cause
- evidence of severe hypoxia , hypercarbia or both
- pneumonia

- pulmonary aspirations
- severe pulmonary haemorrhage
- life threatening asthma
- following lung transplantation.

VA ECMO :

- Post cardiac arrest
- cardiogenic shock
- pulmonary embolus
- drug overdose
- post cardiac surgery
- bridge to transplant
- post heart transplant



VA ECMO cannot provide indefinite cardiac support, and this is important to consider when selecting appropriate patients. It is can be used as a 'bridge to recovery' (eg in myocarditis, drug overdose), 'bridge to intervention' (eg. percutaneous coronary intervention in acute MI, embolectomy in massive PE), or 'bridge to destination' (cardiac support pending urgent heart transplant). In some centres, it is also used as 'bridge to bridge', meaning that VA ECMO is used to provide support until **left ventricular assist device (LVAD)** is implanted, with the ultimate goal of **Cardiac transplantation.**

CONTRAINDICATIONS:

- non recoverable cardiac or respiratory failure, who are not candidates for transplantation
- pre-existing conditions incompatible with recovery (severe neurologic injury, end-stage malignancy)
- contraindications to therapeutic anticoagulation (such as active bleeding)
- severe peripheral arterial disease, severe aortic regurgitation and aortic dissection
- pre-existing severe multi-organ failure
- advanced age.
- Active malignancy, graft versus host disease or significant immunosuppression (Including post bone marrow, renal, liver transplant or heart/lung transplant beyond 30 days)
- Advanced liver disease

- AIDS with any of: secondary malignancy, prior hepatic or renal (Cr >250umol/l) impairment or need for salvage anti-retroviral therapy.
- Burns >70%

CANNULATION :

- **Peripheral cannulation :**

  Venous cannulation is performed most commonly through the right IJ vein or a femoral vein, and arterial cannulation is performed through the right carotid artery or a femoral artery. Femoral access is more commonly used in larger children (>30 kg), adolescents, and adults.

- **Central cannulation :**

  Used when the patient's flow requirements exceed the ow limits of cannulas placed peripherally or when direct cannulation and venting of the LA is required. Short, wide-bore cannulas are placed directly into the RA and the ascending aorta through a median sternotomy. Use in paediatric

CANNULATION TECHNIQUES:

Cannulas can be placed via:

1. Cut down

2. Percutaneously by a vessel puncture, guidewire placement, and serial dilation (Seldinger technique) by a combination of cut down exposure and Seldinger cannulation

3. by direct cannulation of the right atrium and aorta via sternotomy (Central ECMO)

Cut down exposure of the neck vessels is usually necessary in neonates and small children. Percutaneous cannulation is commonly used for VV-ECMO in children over two and in adults. Direct cardiac cannulation is usually used for patients who cannot come off CPB in the OT, using the CPB cannulas. VV access can be gained with a double lumen cannula, or two separate venous cannula.

Cannulation sites :

1. VV ECMO :

- Drainage cannula
    - Right femoral vein
    - Left femoral vein
    - Internal Jugular vein
- Return cannula
    - Internal jugular vein
    - Femoral vein
- Double lumen cannula (drainage- IVC & SVC, return - Right Atrium)

2. VA ECMO
- Drainage cannula
    - Right femoral vein
    - Left femoral vein
- Return cannula
    - Femoral artery
    - Subclavian artery

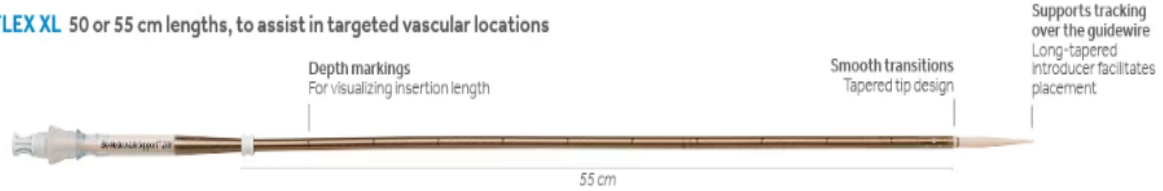
DISTAL LIMB PERFUSION

- All patients undergoing femoral VA ECMO cannulation require Distal Limb Perfusion cannula.
- All Distal Perfusion cannula are 14-16 Gauge in diameter and placed into the ipsilateral femoral artery in an antegrade fashion, using a side port on the main femoral arterial cannula for distal arterial inflow.

CANNULA SELECTION

FLEX Up to 18 cm insertion length (See FIGURE A below for flow data)

FLEX XL 50 or 55 cm lengths, to assist in targeted vascular locations

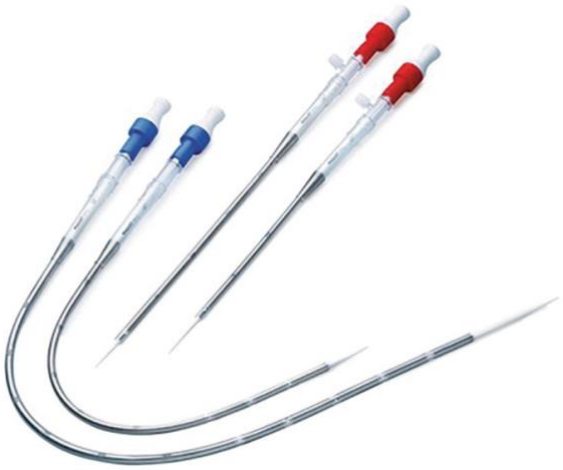


MULTI 38 cm length for drainage from inferior vena cava

MULTI XL 55 and 61 cm lengths, longer insertion length allows various tip placements to support drainage flow

MINI 10-11.5 cm for return

MINI 10-11.5 cm for drainage



Percutaneous Cannulae Dimensions and Flows.

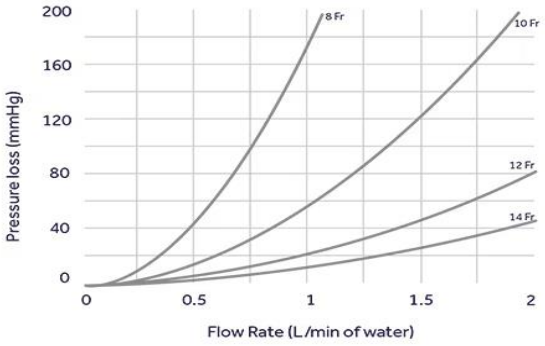
Diameter (Fr)	Arterial cannula	Venous cannula
15	2.3	1.5
17	3.05	2.0
19	3.9	2.7
21	5.0	3.5
23	6.5	4.5

Flow (L/min) through single cannula at pressure drop of 60 mmHg.

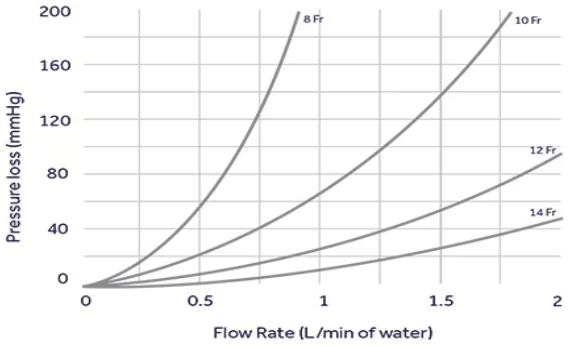
Arterial Cannulae (Fr) \ Venous Cannulae (Fr)	15	17	19	21	23
15	3.8	4.55	5.4	6.5	8.0
17	4.3	5.05	5.9	7.0	8.5
19	5.0	5.75	6.3	7.7	9.2
21	5.8	6.55	7.4	8.5	10.0
23	6.8	7.55	8.4	9.5	11.0

Flow (L/min) through any two access cannulae combined with a pressure drop of 60 mmHg.

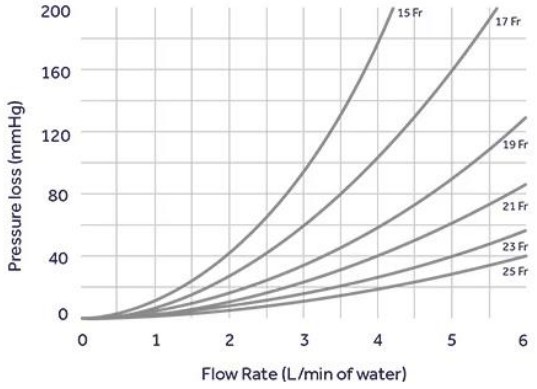
Flow rate of Bio-Medicus NextGen Pediatric Venous Cannulae



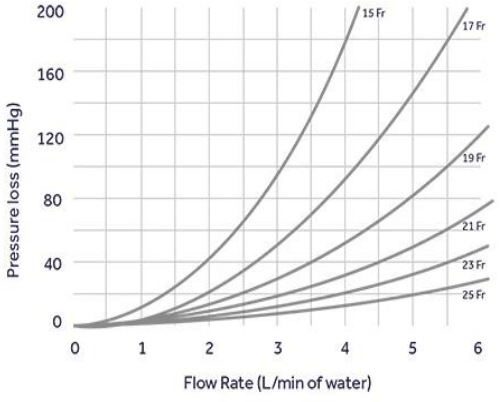
Flow rate of Bio-Medicus NextGen Pediatric Arterial Cannulae



Flow rate of Bio-Medicus NextGen Jugular Venous Cannulae



Flow rate of Bio-Medicus NextGen Femoral Arterial Cannulae



PATIENT WEIGHT	NECK (MEDTRONIC BIOMEDICUS)	NECK (MEDTRONIC BIOMEDICUS)	GROIN (MAQUET HLS)	GROIN (MAQUET HLS)	CENTRAL (MEDTRONIC DLP)	CENTRAL (MEDTRONIC DLP)	CENTRAL (MEDTRONIC DLP)	TUBING
	VENOUS	ARTERIAL	VENOUS	ARTERIAL	Rt ATRIAL	Lt ARTERIAL	ARTERIAL	
<2KG	8/10	8			14	12	8	1/4
2-2.9KG	10	8			16	12	8	1/4
3-3.9KG	12	10			16	12	10	1/4
4-4.9KG	12	10			18	14	10	1/4
5-5.9KG	12	10			20	14	12	1/4
6-6.9KG	14	10			20	14	12	1/4
7-7.9KG	14	10			20	16	12	1/4
8-8.9KG	14	12			20	16	12	1/4
9-9.9KG	14	12			20	16	12	1/4
10-12KG	14	12			20	16	14	3/8
13-14KG	14	14			22	18	14	3/8
15-16KG	14	14			22	18	14	3/8
17-18KG	MAY NEED NECK CANNULA DUE TO SIZE	MAY NEED NECK CANNULA DUE TO SIZE	19	15	22	18	14	3/8
19-20KG	MAY NEED NECK CANNULA DUE TO SIZE	MAY NEED NECK CANNULA DUE TO SIZE	19	15	24	18	14	3/8
21-25KG	MAY NEED NECK CANNULA DUE TO SIZE	MAY NEED NECK CANNULA DUE TO SIZE	19	15	24	18	16	3/8
26-30KG			21	15	24	18	16	3/8
31-35KG			21	15	24	18	16	3/8
36-40KG			23	17	26	18	16	3/8
41-45KG			25	17	26	20	16	3/8
46-50KG			25	17	26	20	16	3/8
51-60KG			29	19	28	20	18	3/8
61-65KG			29	21	28	20	20	3/8
66-70KG			29	21	28	20	20	3/8
>70KG			29	21	30	20	22	3/8

OXYGENATOR SELECTION :

OXYGENATOR	FLOW
MAQUET PLS	2.5 - 7 L/min
MAQUET HLS	2.5 – 7L/ min
SORIN ADULT	< 5 L/min
QUADROX PAEDIATRIC	< 2. 8 L/ min
SORIN PEDIATRIC	< 2.3 L/min

MACHINES AND DISPOSABLES:

1. ECMO machine (Rotaflow/ Cardiohelp)
2. Heater unit (HCU-30)
3. ACT Machine

PRIMING:

1. Oxygenator (PLS/ HLS)
2. Kabilyte
3. 3 way stopcock
4. Priming set
5. sterile clamps
6. syringe 10 cc
7. Ultrasonic sterile cream (ECMO gel)

CANNULATION:

1. Venous drainage cannula
2. Return cannula
3. 14 g single lumen catheter (distal perfusion)
4. Insertion kit (90 cm & 180 cm)
5. Recirculation line (distal perfusion)

PREPARATION AND INITIATION OF ECMO:

PERFUSIONIST REQUIREMENT FOR ECMO INITIATION:

MACHINE / EQUIPMENTS:

1. ECMO machine (Rotaflow/ Cardiohelp)
2. Heater unit (HCU-30)
3. ACT Machine

PRIMING:

1. Oxygenator (PLS/ HLS)
2. Kabilyte
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CANNULATION:

1. Venous drainage cannula
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3. 14 g single lumen catheter (distal perfusion)
4. Insertion kit (90 cm & 180 cm)
5. Recirculation line (distal perfusion)

ASSEMBLING & PRIMING OF CIRCUIT:

ROTAFLOW (PLS)

- Assemble the circuit following sterility protocols.
- Connect the Centrifugal cone to the venous line.
- Insert 3 way stopcocks on all the ports.
- Remove the vent cap from the oxygenator.
- Clamp the line between the stopcocks in the venous line.
- Connect quick prime lines on both the stopcocks in the venous line.
- Connect the other ends of the quick prime line to the Priming Bag and priming fluid respectively.
- Initially fill the circuit with priming fluid by gravity.
- Once the Centrifugal cone is completely de-aired clamp the post pump line .
- Now apply ultrasonic sterile cream on the cone and place the cone in the pump.
- Set the RPM at 1500 and release the clamp on the post -pump side.
- Gradually increase the rpm and make sure adequate fluid is connected .
- Connect both priming lines in the priming bag.
- De-air the oxygenator and the tubings by tapping constantly.
- De-air the stop-cocks using a 10 ml syringe
- Once the pump is primed completely , disconnect the priming bag .
- Clamp both the venous and arterial line of the circuit .

CARDIOHELP (HLS)

- Open the sterile package and take the priming bag from the kit.
- Fill the priming bag with priming fluid (approx. 1500 ml)

- Connect 3 way stopcock on all the ports of the oxygenator.
- Remove the vent cap from the oxygenator.
- Fix the oxygenator to the cardiohelp machine.
- Calibrate all the readings in the Cardio-help monitor.
- Connect the arterial and venous line to the priming bag respectively.
- Set the RPM to 1500
- Remove the clamps from both arterial and venous line .
- Gradually increase the rpm.
- Let the circuit de-air completely.
- Allow the pump to run for 3-5 mins.
- De-air all the 3 way stopcock with 10 cc syringe.
- Close the vent port.
- Once de-aired completely clamp both the arterial and venous line

INITIATION OF ECMO:

- Cannulation site - prepared & draped for initiation.
- Percutaneous insertion - vessel size assessed through ultrasound guidance.
- Cannulation done.
- ECHO confirmation – cannula position.
- Heparinization done and baseline ACT checked (> 180 seconds)
- Tubing de-aired and circuit connected to cannula.
- Ensure the RPM is set to more than 1500.
- Ensure if the gas line is connected to the oxygenator.
- Clamps released and flow achieved.
- RPM adjusted according to target flows.
- Check for colour change in the arterial line.

- Transfuse blood/ volume if required.

TITRATION :

Following cannulation, the patient is connected to the ECMO circuit and the blood flow is increased until respiratory and hemodynamic parameters are satisfactory. Reasonable
targets include:

●An arterial oxyhemoglobin saturation of >90 percent for VA ECMO, or >80 percent for VV ECMO

●A venous oxyhemoglobin saturation 20 to 25 percent lower than the arterial saturation, measured on the venous line

●Adequate tissue perfusion, as determined by the arterial blood pressure, venous oxygen saturation, and blood lactate level

OXYGENATOR CHANGEOUT PROTOCOL:

THINGS REQUIRED

1. ECMO OXYGENATOR
2. PRIMING BAG
3. THREE WAY STOP COCK -5
4. KABILYTE-4
5. QUICK PRIME LINE
6. 3/8 STRAIGHT CONNECTOR
7. STERILE GOWN
8. STERILE GLOVES
9. STERILE CLAMPS (2) – UNSTERILE CLAMPS (2)
10. BLADE -22 G
11. ECMO GEL
12. 1/4 TUBE
13. PREPARATION THINGS (GAUZE – BETADINE- PAINTING TRAY- DRAPE SHEET)

ROTAFLOW (PLS)

1. Assemble the circuit following sterility protocols.

2. Connect the Centrifugal cone to the venous line.
3. Insert 3 way stopcocks on all the ports.
4. Remove the vent cap from the oxygenator.
5. Clamp the line between the stopcocks in venous line.
6. Connect quick prime lines on both the stopcocks in venous line.
7. Connect the other ends of quick prime line to Priming Bag and priming fluid respectively.
8. Initially fill the circuit with priming fluid by gravity.
9. Once the Centrifugal cone is completely de-aired clamp the post pump line .
10. Now apply ultrasonic sterile cream on the cone and place the cone in the pump.
11. Set the RPM at 1500 and release the clamp on the post -pump side.
12. Gradually increase the rpm and make sure adequate fluid is connected .
13. Connect both priming lines in the priming bag.
14. De-air the oxygenator and the tubings by tapping constantly.
15. De-air the stop-cocks using a 10 ml syringe
16. Once the pump is primed completely , disconnect the priming bag .
17. Clamp both the venous and arterial line of the circuit .

CARDIOHELP (HLS):

1. Open the sterile package and take the priming bag from the kit.
2. Fill the priming bag with priming fluid (approx. 1500 ml)
3. Connect 3 way stopcock on all the ports of the oxygenator.
4. Remove the vent cap from the oxygenator.
5. Fix the oxygenator to the cardiohelp machine.
6. Calibrate all the readings in the Cardio-help monitor.
7. Connect the arterial and venous line to the priming bag respectively.
8. Set the RPM to 1500
9. Remove the clamps from both arterial and venous line .
10. Gradually increase the rpm.
11. Let the circuit de-air completely.
12. Allow the pump to run for 3-5 mins.
13. De-air all the 3 way stopcock with 10 cc syringe.
14. Close the vent port.
15. Once de-aired completely clamp both the arterial and venous

COMPLICATIONS IN ECMO:

THROMBOSIS:

- The risk of thrombosis is managed by anticoagulation and observation of the circuit for signs of clot formation .
- Routine inspection of all connectors and monitoring of the pressure gradient across the oxygenator is recommended
- A sudden change in the pressure gradient is suggestive of a clot. Large or mobile clots require immediate circuit change.

BLEEDING:

- The requirement for anticoagulation, the consumption of coagulation factors and platelets and in some cases, heparin-induced thrombocytopenia, all heighten the risk of haemorrhage, which can occur in any organ.
- Bleeding is often seen at the cannulation sites.
- Meticulous surgical technique, maintaining platelet counts greater than 50,000/mm3 and maintaining an activated partial thromboplastin time (APTT) target all reduce the likelihood of bleeding.
- Bleeding is the most common complication of ECMO which may cause Haemorrhage in the brain that could be life - threatening.

INFECTION :

- Infective complications are often related to the cannulation sites and strict aseptic technique is required when handling the cannulae.

MECHANICAL FAILURE:

- Mechanical equipment failure is very uncommon with modern systems but can be disastrous.
- The hand crank should always be kept next to the ECMO machine for such situations.

NEUROLOGICAL COMPLICATIONS:

- Neurological complications are generally related to thrombosis with infarction, or haemorrhage.

CANNULA RELATED :

- Cannula related complications such as vessel perforation with haemorrhage, arterial dissection, distal ischemia and incorrect location can also occur.

COMPLICATIONS SPECIFIC TO VA ECMO:

- such as vessel perforation with haemorrhage, arterial dissection, distal ischemia and incorrect location .
- coronary or cerebral hypoxia due to preferential perfusion of oxygenated blood to the lower extremities and the abdominal area.

INITIATION OF ECMO:

- Cannulation site - prepared & draped for initiation.
- percuatanoeus insertion - vessel size assessed through ultrasound guidance (R/O thrombus)
- Cannulation done.
- ECHO confirmation – cannula position.
- Heparisation done and baseline ACT checked (> 180 seconds)
- Tubing de-aired and circuit connected to cannula.
- Ensure the RPM is set more than 1500.
- Ensure if the gas line is connected to the oxygenator.
- Clamps released and flow achieved.

- RPM adjusted according to target flows.
- Check for colour change in the arterial line.
- Tranfuse blood/ volume if required.

TITRATION

Following cannulation, the patient is connected to the ECMO circuit and the blood flow is increased until respiratory and hemodynamic parameters are satisfactory. Reasonable targets include:

●An arterial oxyhemoglobin saturation of >90 percent for VA ECMO, or >85 percent for VV ECMO

●A venous oxyhemoglobin saturation 20 to 25 percent lower than the arterial saturation, measured on the venous line

●Adequate tissue perfusion, as determined by the arterial blood pressure, venous oxygen saturation, and blood lactate level

DISTAL LIMB PERFUSION

- All patients undergoing femoral VA ECMO cannulation require Distal Limb Perfusion cannula.
- All Distal Perfusion cannula are 14-16 Gauge in diameter and placed into the ipsilateral femoral artery in an antegrade fashion, using a side port on the main femoral arterial cannula for distal arterial inflow.

MANAGEMENT :

- Once the initial respiratory and hemodynamic goals have been achieved, the blood flow is maintained at that rate.
- Frequent assessment and adjustments are facilitated by continuous venous oximetry, which directly measures the oxyhemoglobin saturation of the blood in the venous limb of the ECMO circuit.
- When the venous oxyhemoglobin saturation is below target, interventions that may be helpful include increasing one or more of the following: blood flow, intravascular volume, or hemoglobin concentration
- Decreasing the systemic oxygen uptake by reducing the temperature may also be helpful.

FLOW MANAGEMENT :

- For VV ECMO target flow rates must provide adequate arterial oxygenation while allowing non injurious lung ventilation.
- For VA ECMO target blood flows in combination with native cardiac function must provide adequate systemic oxygen delivery.

FLUID MANAGEMENT:

- In order to establish the patient on ECMO and achieve adequate flow rates, volume loading is usually required. This will usually result in a net positive fluid balance in the first 24 hours of ECMO treatment.
- After day 1, the goal should be to achieve daily negative fluid balance. To do this, minimal fluid input should be targeted with use of concentrated infusions and feeds, diuretic infusions may be used, and fluid may be removed with CRRT.
- Consider albumin infusion if hypo-albuminaemic.

ANTICOAGULATION MANAGEMENT:

- Anticoagulation is sustained during ECMO with a continuous infusion of **unfractionated heparin** or direct thrombin inhibitor titrated to an activated clotting time (ACT) of 180 to 210 seconds.
- In case of Heparin Resistance and Target ACT is not achieved despite adequate systemic heparinisation, **Bivalirudin** (DTI) is considered for anticoagulation.
- The ACT target is decreased if bleeding develops.
- ACT is easily determined at the point of care, but plasma APTT (1.5 times normal) can also be used.

Thromboelastography is a useful adjunct to attend ECMO patients.

- The following lab parameters are monitored on daily basis for anticoagulation management.
    1. Activated partial thromboplastin time (APTT) - 6th hourly
    2. D-dimer – daily
    3. Fibrinogen - daily
    4. Lactate dehydrogenase (LDH)
    5. Anti-thrombin iii & Anti-X a

Anticoagulant Infusion during HIT

- HIT may be difficult to diagnose in this cohort of patients as they have many potential causes of thrombocytopenia.
- If HIT is suspected, the pre-test probability should be ascertained, and if intermediate or high, all forms of heparin should be stopped whilst awaiting investigations and a heparin alternative considered.

ROLE OF PERFUSIONIST IN ECMO MANAGEMENT IN ICU:

- Ensure if perfusionist is available 24/7 to attend ECMO patients.
- Routine monitoring during ECMO run.

MONITORING PARAMETERS:

- Maintenance of stable flows and hemodynamic parameters.

- Check for clots in the oxygenator.
- Check for colour change in arterial line.
- Check tubing position and secure the tubings accordingly.
- Ensure proper placement of Cannula.
- Secure IJV cannula with proper head tie.
- Monitor ECMO chart on bed side. (RPM, LPM, Sweep gas & FiO2)
- Transduce Delta Pressure if required and monitor frequently.
- Maintain Perfusion chart for every ECMO patient.
- Check proper functioning of ECMO machine (Battery back-up)
- Check proper functioning of Hemotherm.
- Check availability of Hand crank and steel clamps.
- If needed, take pre and post oxygenator blood sample for blood gas monitoring.
- Transfuse volume on pre-pump port whenever required. As per instructions from the duty- doctor.

DELTA PRESSURE MONITORING:

- Delta pressure – difference between pre -oxygenator and post – oxygenator pressure.
- Monitored when required to check oxygenator efficacy and clots.
- Transduced using a Double Transducer kit connected to pre and post oxygenator sample port.
- Target Delta Pressure value is less than 50 mmHg.

- If delta pressure value more than 50 mmHg , may require a oxygenator change-out .

Indications for circuit change

- The indications for changing the ECMO circuit are outlined below.
- Regardless of the site of dysfunction (eg oxygenator, pumphead, etc) the entire circuit is changed because it is simpler and safer than changing a component. **Absolute indications:**
- Circuit clotting causing inadequate pump flow
- Intravascular haemolysis, where pump head clot is known or suspected.

  Relative indications:
- Impaired patient oxygenation (SaO_2 < 85%) and post membrane PO_2 < 200 mmHg
- Impaired patient CO_2 removal (PCO_2 > 50-60mmHg) necessitating fresh gas low >10L/min*
- Increased transmembrane pressure gradient (>50 mmHg)

  These values chosen are arbitrary and intended to represent a moderate level of oxygenator dysfunction. The goal is to allow for a semi-elective circuit change and avoid an urgent/emergent change-out in the middle of the night.

<u>TEMPERATURE MANAGEMENT :</u>

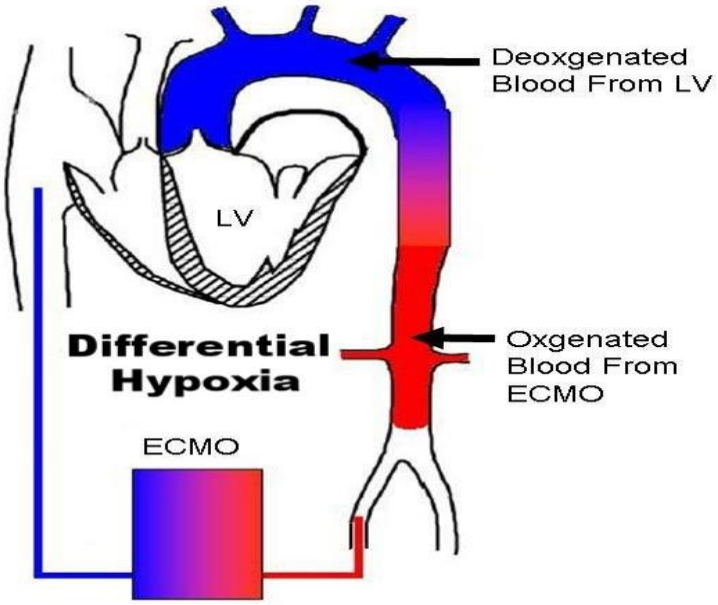
- As a heater-cooler is attached to the oxygenator, the patient's temperature may be regulated.
- The aim is usually to maintain normothermia but where clinically indicated, mild hypothermia (to 35Cº) may be accepted.

CRRT ON ECMO:

- For most ECMO configurations, the ECMO circuit provides the optimal access for CRRT, and a separate dialysis catheter is not required.
- The CRRT circuit is connected to the POSITIVE pressure side of the ECMO circuit (ie. post- pump), to avoid the risk of air entrainment associated with any connection to the negative side (pre- pump) of the ECMO circuit.
- The commonest way to connect the CRRT circuit to the ECMO circuit is to attach the access and return lines for CRRT to the two three-way stopcock between the inlet of the pump head and the oxygenator. This is done by perfusioniost only.

NORTH- SOUTH SYNDROME

- Harlequin Syndrome is a complication with VA ECMO in which deoxygenated blood in the right side of the heart is ejected through the PA to the left side of the heart and then out into the aorta.
- Those patients with compromised lung function in the setting of VA ECMO are unable to oxygenate that blood resulting in relatively deoxygenated blood with oxygenated blood from the ECMO circuit.
- This can result in hypoxia to the vessels most proximal in the aorta including the coronaries, brachiocephalic and right and left carotids
- This may be a sign of returning cardiac function as the heart is able to pump/
- It would be optimal to convert the patient to **V-AV ECMO** with drainage from the Femoral vein and return to both the Femoral Artery and Internal Jugular Vein .
- By doing so oxygenated blood is delivered to the Heart which in turn pumps the blood.



VV-A ECMO

- The aim of VV-A ECMO is to provide high flows.
- An additional venous cannula is included for better drainage which in turn results in high flow.
- An additional cannula may be inserted in the Internal Jugular Vein for better flows.
- It is required in severe cases of respiratory failure where single access cannula circuit flow is insufficient for maintaining optimal saturation.

WEANING OF ECMO:

VV- ECMO:

- One or more weaning trials should be performed prior to discontinuing ECMO permanently.
- V-V ECMO weaning trials are performed by eliminating all countercurrent sweep gas through the oxygenator.
- Extracorporeal blood flow remains constant but gas transfer does not occur.
- Patients are observed for several hours, during which the ventilator settings that are necessary to maintain adequate oxygenation and ventilation are determined.

WEANING OF VV ECMO
Re-establish patient on mechanical ventilation
Turn off O2 to oxygenator

Maintain ECMO flow rate

VA- ECMO:

- V-A ECMO weaning trials can be performed by clamping both the drainage and return lines.
- Ventricular fuction is assessed simultaneously with ECHO and Hemodynamics are monitored .
- V-A ECMO weaning trials are generally shorter in duration than V-V ECMO
- weaning trials because of the higher risk of thrombus formation.9

WEANING OF VA ECMO
F Decrease pump flow to minimum while assessing ventricular function by TEE
Clamp both arterial & venous line for 3-5 min and check TEE
If O2 is good and CO2 is managed by ventilation, consider decannulation

Removal of ECMO cannula:

- Removal of arterial ECMO cannulae should always be performed as an 'open' surgical procedure (CUT-DOWN) and be accompanied by vessel wall repair.
- Venous cannula can be removed and pressure applied to the site for 20 minutes.

TROUBLE SHOOTING:
CAUSE AND MANAGEMENT:

1. Air in Circuit

a) Air in venous line or pump head only.

1. Air infused into right atrium through I.V. lines.
2. Venous cannula position.

Management :

Small amounts of air entering the venous side of the oxygenator will be vented across the membrane at the top of the venous side of the oxygenator.

2. Gross venous air:

Management:

1. Clamp off the ECMO cannulae and shunts.
2. Turn the pump off.
3. Ventilate the patient ,maintain cardiac output and increase supports if required
4. Ask for help.Notify senior immediately.
5. Find and fix the site if the leak.
6. Attach a 50 ml Luer lock syringe to the tap on the Luer connector on the venous line.
7. Take the pump head out of the external drive unit.
8. Hold the pump head lower than the venous cannula, shake and tap the circuit to move
the air up towards the syringe.
9. Aspirate with the syringe until all the air is removed.
10. Put the pump head back in the external drive unit.
11. Re-institute ECMO. Remove the venous clamp, increase pump speed to 1500 RPM,
remove the arterial clamp and increase pump speed to required flows.
12. Re-establish the correct flows through the tubings.

b) Air in oxygenator

Causes :

1. Improper priming procedure.
2. Membrane rupture.

3. High gas flow with low pump flow.

4. From pump head or venous line.
5. From sample port.

Management :
Small amounts of air entering the venous side of the oxygenator will be vented across the membrane at the top of the venous side of the oxygenator.

For gross air or air in the arterial side:

1. Clamp ECMO lines between the pump head and the oxygenator and any shunts.
2. Turn the pump off.
3. Ventilate the patient and maintain cardiac output. Find and fix the leak site. 4. Connect a
50 ml Luer lock syringe to a tap on the arterial side of the oxygenator and tilt the
oxygenator so that the tap with the syringe is higher than the air in the circuit.
5. Tap and shake the oxygenator to move the air upwards and aspirate the air into the 50
ml syringe until all the air is removed.
6. Re-institute ECMO.

If you suspect that the oxygenator membrane has ruptured the patient must be supported by conventional methods until a new oxygenator is used to replace the ruptured one.

c) Air in the arterial line and patient.

Causes:

1. Oxygenator rupture (Gas port obstructed).
2. Loose connector at cannula.
3. Venous line port left open and circuit filled with air via venous line if on low flow.

Management:

1. Clamp arterial and venous line. Turn pump off.
2. Increase ventilator and maintain cardiac output. Find and fix the leak.
4. Have plenty of volume available to give and a person to give it.

Clamp the arterial line before the arterial cannula port .
5. Attach a 50 ml Luer lock syringe to the three way stopcock on the connector on the
arterial cannula and open the port.
6. If air is seen in the cannula aspirate blood from the arterial cannula to remove the air
seen in it. Clamp the cannula once the air has been removed.
7. Remove the clamp from the arterial line and tap the line to move the air to the syringe
and aspirate it. Give volume as required.
8. Check the rest of the circuit for air. Tap the oxygenator, if any air appears at the top of
the membrane do not re-institute ECMO as the membrane has been ruptured and the
oxygenator needs to be replaced.
9. If no more air is seen re-institute ECMO.

2. OXYGENATOR FAILURE :
a) Air in the top of the oxygenator.

Cause: Membrane rupture.
Management: Change the oxygenator.

b) Clots in the oxygenator.

1. Inadequate anticoagulation.
Management :
Increase anticoagulation.

2. Less than rated blood flow for the oxygenator.
Management:
Increase flow to patient .

3.Decreasing post oxygenator pO2.
Management:
Repeat pre and post oxygenator gases, increase FiO2 if possible.

4.Increasing pCO2
Management:

Increase sweep gas if not at maximum.

5. Blood leaking from gas exhaust port.

Management:

Ruptured membrane. Change oxygenator.

6. Decreased blood flows with increased negative pressures.

The low flow alarm should sound, the venous pressure will become more negative and as
the flow decreases so will the saturation. Venous line chattering should be present.

Decreased blood return to the pump may be caused by:

- 1. Change in patient head position.
- 2. Change in venous cannula position.
- 3. Patient hypovolaemia due to increased diuresis or bleeding.

Management:

- Hypovolemia- check CVP and transfuse volume as per doctor's instruction.
- Venous cannula position- notify doctor and cannula to be repositioned.

5. Decreasing Blood Flow (no Increasing Negative Venous Pressure).

The low flow alarm should sound and the arterial cannula pressure will increase, The patient saturation may fall as the flow decreases.

Increased resistance to flow can be caused by:

- Increased arterial pressure.
- Change in patient head position.
- Change in arterial cannula position.
- Clots in: - oxygenator/arterial cannula / arterial tubing

6. Patient bleeding.

- High ACT values / APTT Values.
  -Reduce heparin infusion rate and check ACT value.
  -Stop heparin infusion if required.
- Decreased Hb, visible bleeding.
  -Due to pre-ECMO procedure. Investigate wound site.
- Internal bleeding.
  -Pneumothorax etc.

-Check with X-ray &ultrasound.

- Platelet count low.
  -Destruction of platelets by circuit.-Transfuse platelets.
  -DIC.-Check APTT Transfuse Platelets, FFP etc
  -Infection/Sepsis - Culture and treat with appropriate antibiotic.

7.Hematuria

- Red serum noted. Check plasma Hb.
- Plasma Hb > 1.0 g/L.
- Pump failure, clots in circuit or pump -Change pump head or circuit.
- Renal Dysfunction. - renal ultrasound.
- Pump speed too high -Reduce pump speed.
-
- Patient has sepsis/DIC. Low platelet count, prolonged PT & APTT. Elevated FDPs.
- Culture blood, check PT, APTT & FDPs.

8. LOW P02:

- 1. Inadequate flows.
- 2. Inadequate gas flow to oxygenator.
- 3. Oxygenator clots / failure.
- 4. Sepsis.

9. HIGH PCO2:

- May be due to inadequate gas flow- increase gas flow

TRANSPORTATION OF ECMO :

Transport of ECMO patients requires coordination and careful considerations of potential risks and benefits of transport and is typically accomplished *via* ground or air.

- Documentation of clinical information should be performed in an efficient and timely manner.
- Consider the use of electronic medical record tools and standardized formats.
- Consider the use of a standardized referral form
- Mobile ECMO team should be self-sufficient in terms of medication, equipment, monitoring, and diagnostic devices. An equipment checklist should be completed by the mobile ECMO team before departure.

Equipments :

1. ECMO machine console
2. Centrimag/ Rotaflow
3. Motor arm / Driveline
4. Flow probe
5. ETO blood pump
6. PLS/HLS set
7. Maquet insertion kit
8. Medtronic insertion kit
9. Free life insertion kit
10. Ventilator (portable)
11. Cardiac monitor
12. Transport monitor
13. Act machine
14. Monitor modules
15. Standard accessories
16. Power cords
17. Ventilator circuits
18. Extention board
19. Double monitoring kit
20. Heparin coated tubing
21. 3/8 tubing
22. ¼ tubing
23. Ipex stand
24. ECG leads
25. ETO & new dilators
26. Spictra jar
27. Spictra stand
28. Quick priming set
29. Kabilyte
30. Connectors
31. 3 way stopcock
32. 3 way 10cm
33. 22 blade
34. 2ml syringe
35. 10ml syringe
36. Gloves
37. PPE kit
38. N95 mask
39. Gown
40. Aluminium foil
41. Arrow jel
42. Camera cover
43. Intranule 16g
44. 14g single lumen catheter

45. Sterile clamps
46. Unsterile clamps
47. Plastic clamps
48. Bloodset
49. ETO guide wires
50. ACT tubes
51. Suture 216
52. Centi silk
53. Heparin
54. Pressure bag
55. Albumin 5%
56. Metfix
57. NS 500ml
58. Cannula
    1. femoral venous
    (a) 19fr
    (b) 21fr
    (c) 23fr
    (d) 25fr
    (e) 27fr
    (f) 29fr

    2. femoral arterial

    (a) 13fr
    (b) 15fr
    (c) 17fr
    (d) 19fr
    (e) 21fr
    (f) 23fr
59. Dual lumen 27f