2016

EXTRA CORPOREAL OXYGENATION (ECMO) LEARNING PACKAGE

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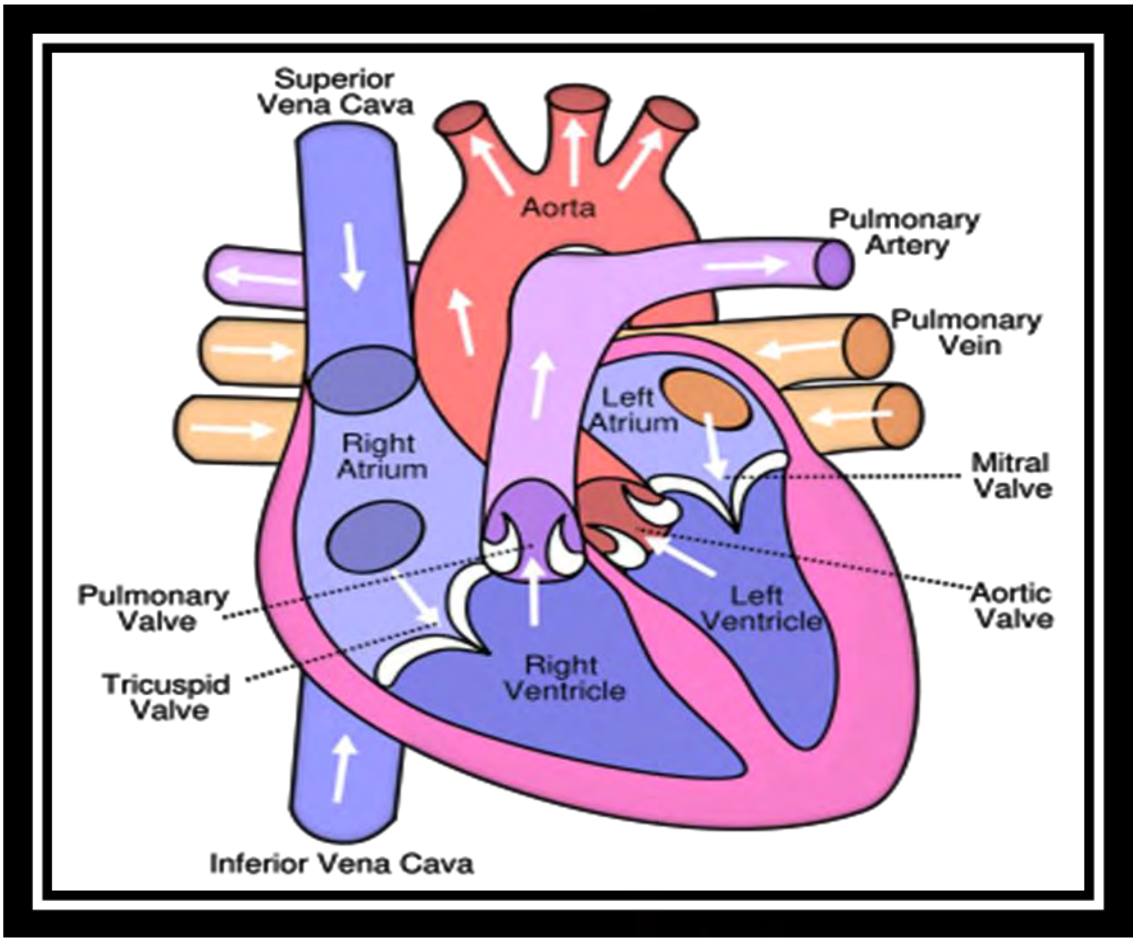
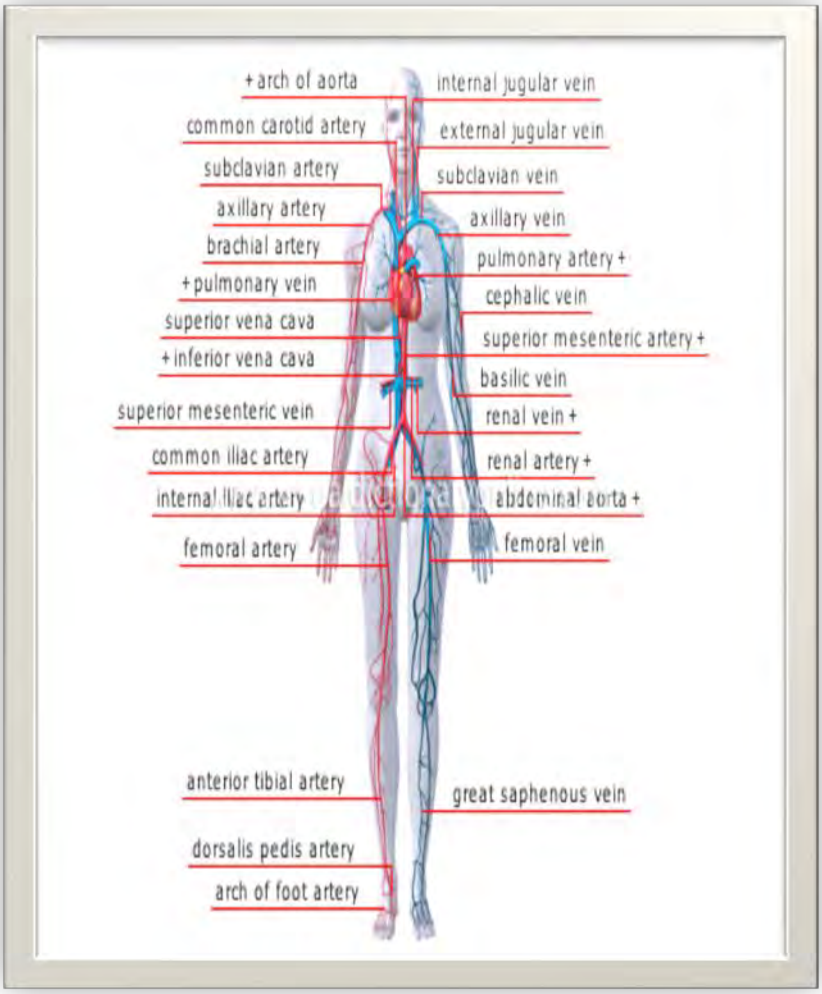
ANATOMY[5,8]



- Superior vena cava
  - Carries deoxygenated blood from the veins from the upper body then into right atrium
- Inferior vena cava
  - Carries deoxygenated blood from the lower body to right atrium
- Aorta
  - Carries oxygenated blood from the Left ventricle to the organs
- Pulmonary artery
  - Carries deoxygenated blood from the Right ventricle to the lungs

Principle veins and arteries



- Veins carry blood to heart
- Arteries carry blood away from heart to lungs to be oxygenated

EXTRA CORPOREAL MEMBRANE OXYGENATION (ECMO)

Definition:[1,7]

ECMO is a form of extracorpeal life support where an external artificial circulator carries venous blood from the patient to a gas exchange device (oxygenator) where blood becomes enriched with oxygen and has carbon dioxide removed. This blood then re-enters the patient's circulation.
Circuit flow is achieved using a pump either centrifugal or a roller pump.

ECMO evolved from cardiopulmonary by-pass.

Patients who are hypoxaemic despite maximal conventional ventilatory support, who have significant ventilator-induced lung injury or who are in cardiogenic shock may be considered for ECMO support. For respiratory failure, the basic premise is that ECMO will allow the level of ventilatory support to be reduced, which may allow time for recovery from the underlying pathology and recovery from ventilator-induced lung injury to occur.

There are two types of ECMO, veno-venous and veno- arterial.

Figure 1: ECMO Circuit

INDICATIONS[1,2,7]

ECMO is indicated for potentially reversible, life-threatening forms of respiratory and / or cardiac failure, which are unresponsive to conventional therapy and it, is always applied at the discretion of the managing intensivist or cardiac surgeon.

- Respiratory failure
  - ALI/ARDS
  - Aspiration
  - Pneumonia
  - Asthma
  - Post lung transplant
  - Lung contusion

- Cardiac Failure
  - Post cardiac arrest
  - Pulmonary embolus
  - Drug overdose
  - Post cardiac surgery
  - Bridge to transplant
  - Post heart transplant
  - Cardiogenic shock

CONTRAINDICATIONS

Absolute Contraindications[1,2,7]
- Severe irreversible neurological condition
- Encephalopathy
- Cirrhosis with ascites
- History of variceal bleeding
- Moderate-severe chronic lung disease
- Terminal malignancy
- HIV

Absolute Contraindications to Veno-Venous ECMO
- Severe left ventricular failure EF <25%
- Cardiac arrest

Absolute Contraindications to Veno-Arterial ECMO
- Aortic dissection
- Severe aortic regurgitation

Relative Contraindications[1,2,7]
- Age >65
- Multiple trauma with uncontrolled haemorrhage
- Multi-organ failure

Relative Contraindication to Veno-Venous ECMO
- High pressure / high FiO2 IPPV for >1 week

Relative Contraindication to Veno-Arterial ECMO
- Severe peripheral vascular disease

ECMO EQUIPMENT[1,2]

Perfusion Services are responsible for providing an ECMO pump and a primed circuit when ECMO is initiated in the ICU. They should be contacted as early as possible after the decision to commence ECMO is made. In and out of hours, the cardiothoracic team on call is brought in to establish ECMO (including the medical perfusionist), details of the on-call staff are kept in ICU, and with the hospital switchboard. A spare ECMO circuit for exchange in the event of pump failure is available in the theatre pump room.

- Circuit priming and preparation are performed exclusively by Perfusion Services and equipment for this function is stored in Theatre. Perfusion staff provides 24 hours emergency cover for this role.

ECMO Cannulae (stored in Theatre)
- Arterial Kits 50cm Medtronic Biomedicus cannulae: sizes: 19 and 21F
- Venous Kits 150 cm Medtronic Biomedicus cannulae: sizes: 19, 23 and 27

ECMO: initial set-up items:
- Centrifugal pump module
- Hand crank
- Brackets for Rotaflow oxygenator / pump

ECMO pack
- 1x 1L crystalloid
- 2x tubing clamps

Further items that should remain with the patient:

- Spare ECMO circuit
- 2x single transducer kits (Rotaflow)
- ECMO operating notes, trouble-shooting guide and observation chart
- Rota-flow / Cardiohelp manual
- 4 sterile tubing clamps
- Sterile heavy scissors
- Heparin-bonded 3/8 –3/8 connectors
- Silicon paste (for Rotaflow flow probe)
- ACT machine and tubes
- Heater-cooler
- Cable ties and gun
- 30cm monitoring extension lines for use with CVVHD

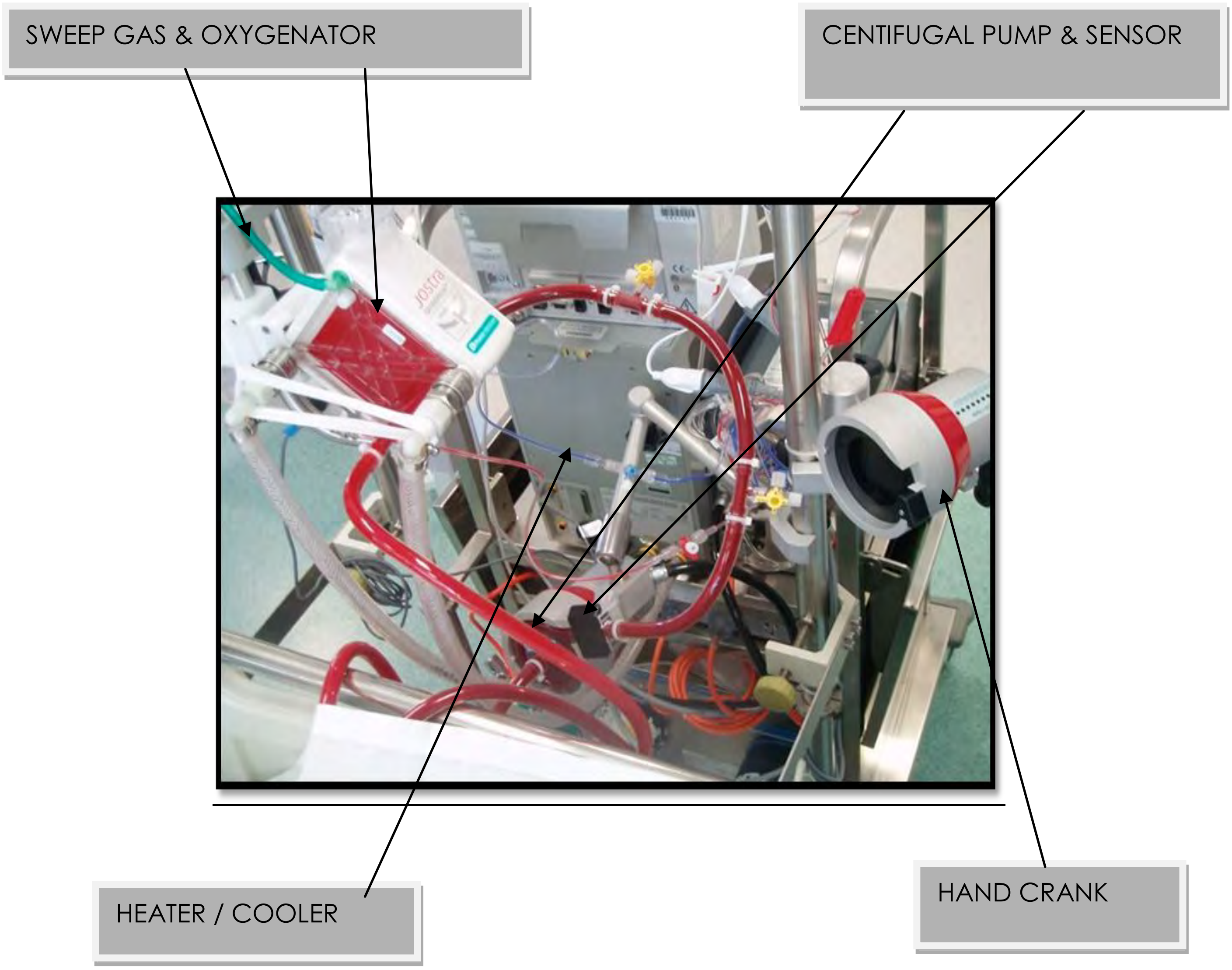


Figure 2: ECMO Equipment

Oxygenator

- The oxygenator has a semi permeable membrane
- Blood flows across one side while a "sweep" gas 100% O2 moves in opposite direction
- The higher the gas flow rate the more CO2 is removed

Sensor

- Measures the flow
- Needs cream applied to function. Wrap in cling –wrap

Centrifugal Pump

- The circuit flow is achieved using a pump: either centrifugal or a roller
- Centrifugal is used for ECMO at Liverpool
- The centrifugal pump has a priming volume of 32mls which reduces haemodilution

Figure 3: Centrifugal pump

Rotaflow drive

- The drive is what the pump sits in and the blood flow is measured in the pump outlet by ultrasonic sensor
- The sensor requires regular placement of cream to maintain function

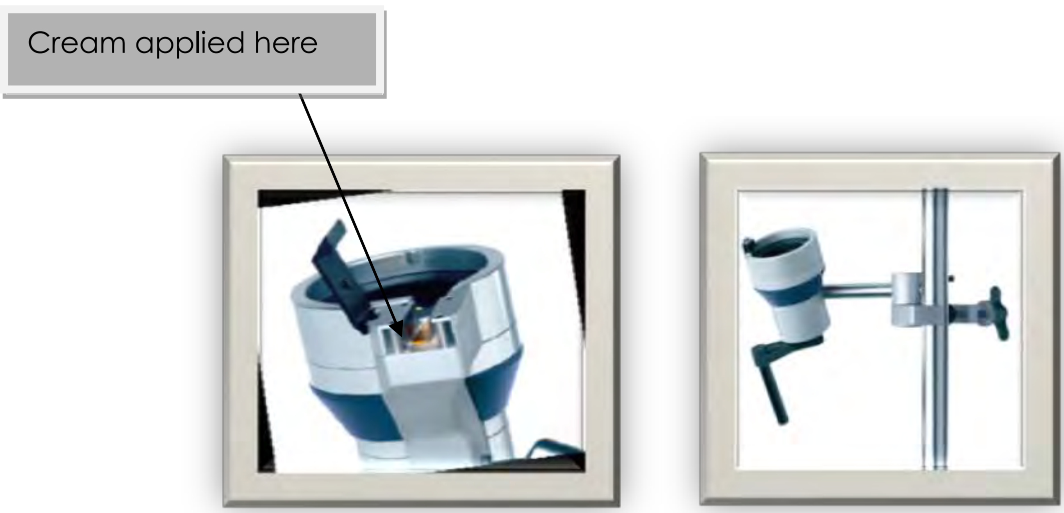


Figure 4: **Rotaflow drive** **Rotaflow emergency hand crank**

Rotaflow emergency hand crank

- This is utilised when there is a pump failure
- There is an LED display of the pump speed on the side of the drive

Pump Console

- Provides the controls for pump blood flow rate and speed
- Battery backup of 90 minutes
- It can be incorporated into the bypass machine or stand alone mode

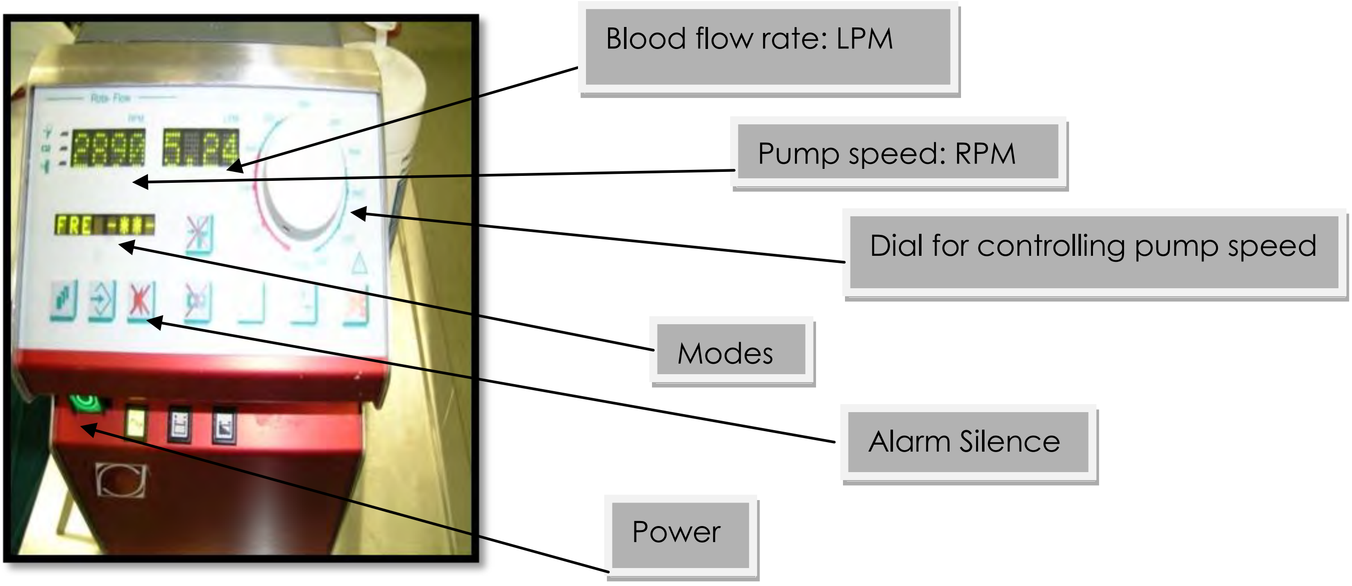


Figure 5: Pump console

Heater / Cooler Machine

- A heater cooler machine is attached to oxygenator to regulate patient temperature
- Aim to maintain normothermia

Figure 6: Heater/cooler

Pressure Monitoring[1,2]

Inflow and outflow pressures from the oxygenator reflect the performance of the oxygenator

The pre-membrane pressure is at a connector near the venous inlet of the oxygenator

The post membrane pressure is measured at the connector on the oxygenator's arterial outlet

These pressures are displayed on a separate monitor with the ECMO circuit

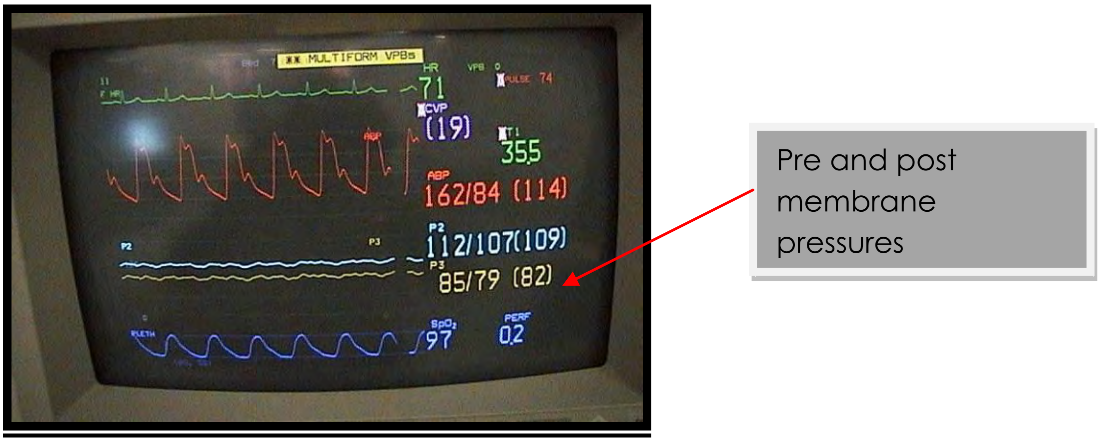


Figure 7: Pressure Monitoring

The difference between the pre and post membrane pressure gives you the trans-membrane pressure gradient.

The trans-membrane pressure gradient should be less than 50mmHg

An increase in the trans-membrane pressure gradient may indicate clot formation within the oxygenator

A steadily increasing trans-membrane pressure without a concomitant increase in the circuit flows may indicate that the oxygenator needs to be replaced

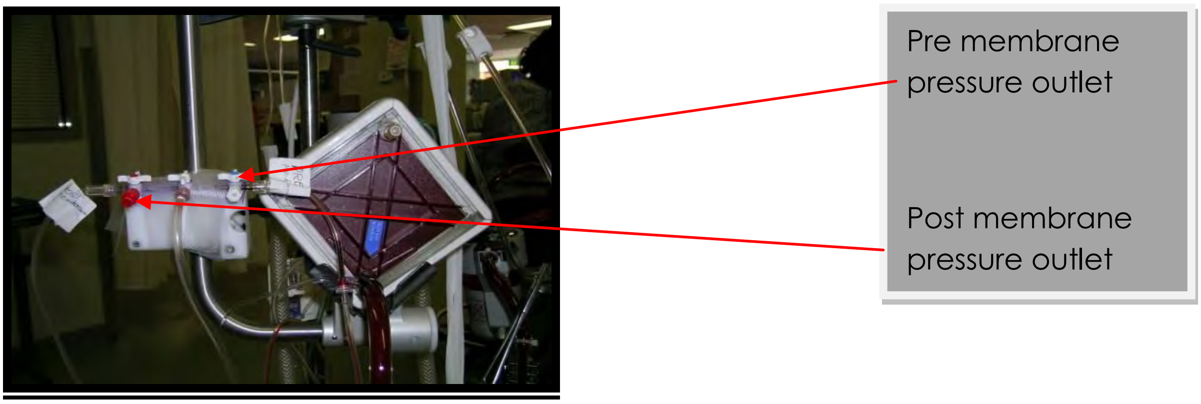


Figure 8: Pressure monitoring points post oxygenator

CANNULATION[4,6,7]

There are three ways of accessing the major vessels for ECMO:
- Surgical central cannulation
- Surgical peripheral cannulation
- Percutaneous cannulation

Sites

- Venous cannulation sites include the internal jugular veins, femoral veins and the right atrium.
- Arterial cannulation sites are the carotid arteries, femoral arteries and the aorta.

Sizes

Range in size from 16F -23F
Anti-coagulate patient prior to insertion
Percutaneous preferable to cut down to minimise bleeding
TOE utilised to confirm correct placement in IVC

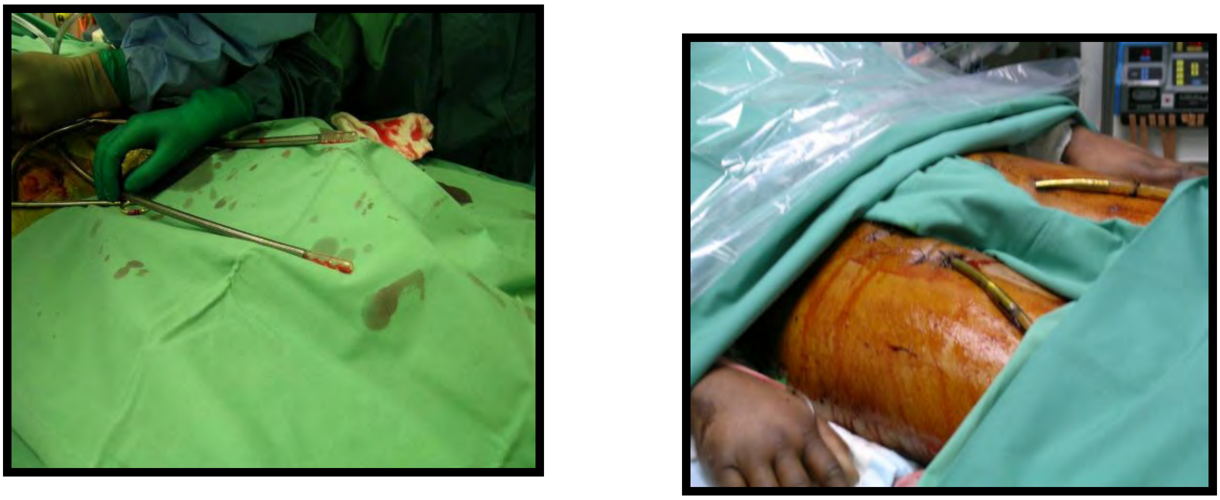


Figure 9: ECMO Cannulae

Positioning of Cannulae

V-V ECMO

Access cannula:
- For femoral insertion, use TOE (Trans Oesophageal ECHO) to confirm that the wire is in the IVC, position the cannula tip in the IVC below the level of the diaphragm; (~35-40 cm in an adult);
- Use the Avalon introducer kit to dilate the vessel to about 1 size below the cannula gauge; the tips of the femoral return and access lines should be separated by about 10cm to avoid recirculation
- If high flow rates are required, a second access line is inserted in the SVC, via the right internal jugular vein; use ultrasound to assess the diameter of the IJV and to confirm that the wire is in the IJV and SVC; insert the cannula ~15 cm

Return cannula:
- Use TOE to confirm that the wire is in the IVC and to position the cannula tip at the IVC/RA junction

Avalon cannula:
- Maximum flow from the largest (31F) catheter is 5 Lpm
- Consider for any patient up to 90 kg
- Ensure that the right IJV is patent

- Use the Avalon introducer kit, during serial dilation of the vein and during
- final cannula placement
- With TOE or TTE (Trans Thoracic ECHO), ensure that the guidewire remains well inside the IVC at all times, to minimise the risk of cardiac perforation
- The final position of the cannula should be at least 3cm into the IVC
- ensure that the return jet is directed towards the tricuspid valve before
- securing the cannula to the patient's neck

Figure 10: The Avalon Elite Multi-Port Venous Femoral Catheter

V-A ECMO

Access cannula:

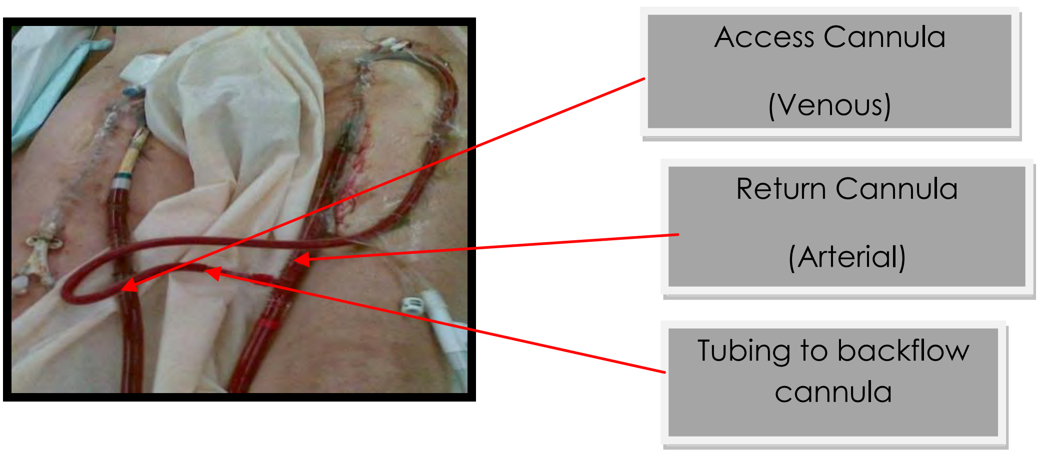
- Femoral insertion, use TOE to confirm that the wire is in the IVC and to position the cannula tip in the RA

Return cannula:

- The arterial (short) cannula should be fully inserted to the length of the cannula

Backflow cannula:

- Used to prevent ischemia occurring distally to the arterial cannulation site in peripheral V-A ECMO
- Inserted in the artery distal to the ECMO cannulation site
- Connected to the luer connector on the arterial cannula by a piece of extension tubing
- Should be inserted and connected at the time of cannulation, or as soon as practical later
- After arrival in ICU, the ultrasonic flow probe should be used to confirm that there is flow in the extension tubing



Doppler examination of the blood flow in the back-flow cannula is indicated if deteriorating leg perfusion is observed in the cannulated leg.

TYPES OF ECMO[4,6,7]

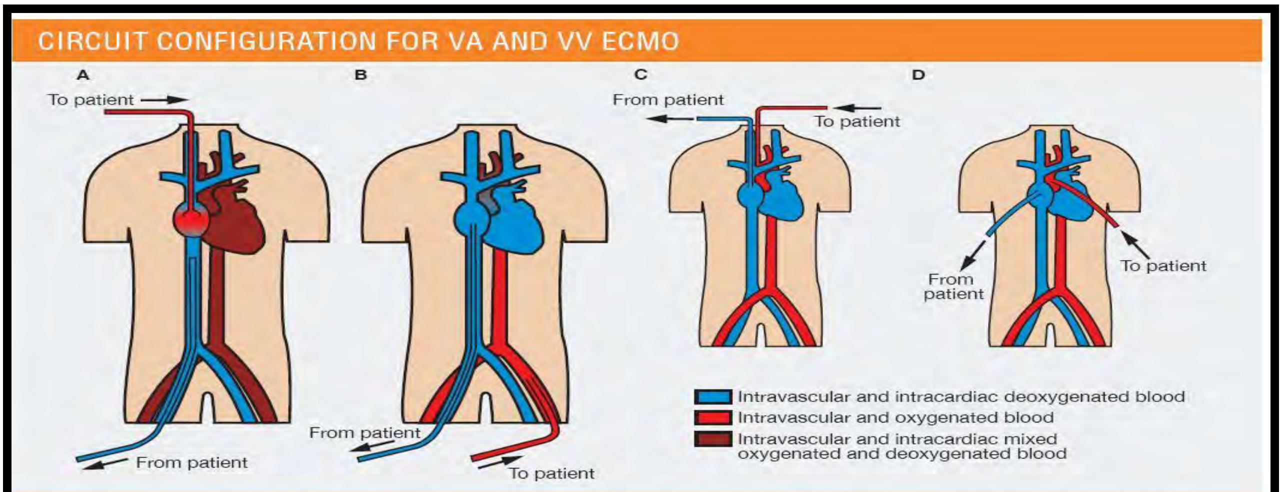
There are two basic types which are described by the site of drainage & where the blood returns

Veno-venous

- Deoxygenated blood is drained from venous circulation into the ECMO circuit
- Blood is oxygenated via the oxygenator and is returned to the right atrium
- Drains from major vein & returns to a major vein
- Supports only the lungs
- Adequate circulation is provided by the native cardiac output

Veno-arterial

- Deoxygenated blood is drained from venous circulation into the ECMO circuit
- Passes through the oxygenator and is returned directly to the arterial circulation
- Drains from major vein & returns to major artery
- Supports heart & lungs



A, VV ECMO; B, VA ECMO, femoral cannulation; C, VA ECMO, carotid cannulation; *D*, VA ECMO, thoracic cannulation. Reproduced from: Gaffney AM, Wildhirt SM, Griffin MJ, Annich GM, Randomski MW. Extracorporeal life support. BMJ. 2010;341:982-986.
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Figure 1.

Figure 11: ECMO Circuit

VENO VENOUS ECMO

Involves venous blood from the patient being accessed from the large central veins (via the “access line”) and returned to the *venous system* near the right atrium (via the “return line”) after it has passed through an oxygenator.

It provides support for severe respiratory failure when no major cardiac dysfunction exists. When flow through a single access cannula is insufficient to support the high ECMO flow rate that may be required in severe respiratory failure, a second venous access cannula may be required.

V–V ECMO improves the patient’s oxygenation by reducing the amount of blood that passes through the lung without being oxygenated and in addition removes CO_2 from the patient’s blood.

This allows the level of ventilatory support to be reduced, which reduces ventilator-induced lung injury.

The efficiency of oxygenation by the ECMO circuit depends on the pump flow relative to the patient's cardiac output.

The patient's oxygenation should increase with increasing ECMO flow rate, if this does not occur, recirculation of blood between the inflow and outflow cannulae should be suspected

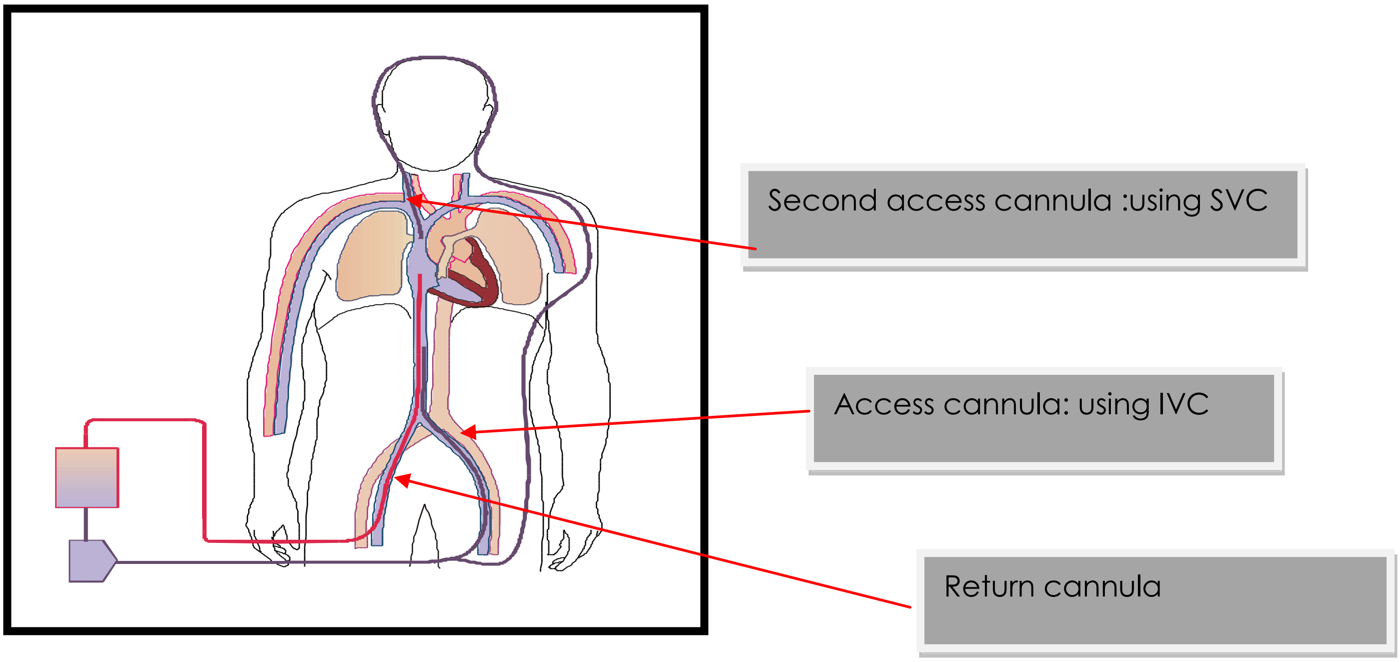

Figure 12: An example of Veno-venous ECMO

V-V ECMO and CO2:

V-V ECMO is more efficient at removing CO_2 from the blood than delivering oxygen. The amount of CO_2 removal depends on the ECMO flow rate relative to the patient's cardiac output and also depends on the oxygen flow rate (sweep gas) to the oxygenator. Increasing oxygen flow rate decreases the CO_2 in the blood leaving the oxygenator (analogous to the effect that increasing minute ventilation has on arterial PCO_2)

The oxygen flow rate (the sweep flow) to the oxygenator should be roughly twice the ECMO flow rate. Eg: if the ECMO Flow rate is 3L, the oxygen flow rate shoud be 6L. With an ECMO flow rate of approximately 2/3 the patient's cardiac output, and an oxygen flow rate of twice the pump flow, nearly all of the patient's CO_2 production can be removed by the oxygenator.

V-V ECMO and O_2:

Arterial O_2 is determined by the relationship between the ECMO pump flow and the patients cardiac output

If the ECMO pump flow is low compared to patients cardiac output the arterial O_2 will also be low

Increasing the ECMO pump flow will increase the O_2 in the mixed venous circulation & therefore increase the arterial O_2

Providing ECMO pump flows equal to 66% of the patients cardiac output will achieve a saturation of > 90% (Locker et al., 2003)
Common for patients on V-V ECMO to have PO_2 in range of 55-90mmHg

<u>In Summary</u>

- To remove CO_2 increase the O2 sweep gas
- To increase the $p0_2$ you increase the pump flow

VENO-ARTERIAL ECMO

Involves venous blood from the patient being accessed from the large central veins and returned to a major artery after it has passed through the oxygenator.

It provides support for severe cardiac failure, (usually with associated respiratory failure), most commonly after cardiac surgery

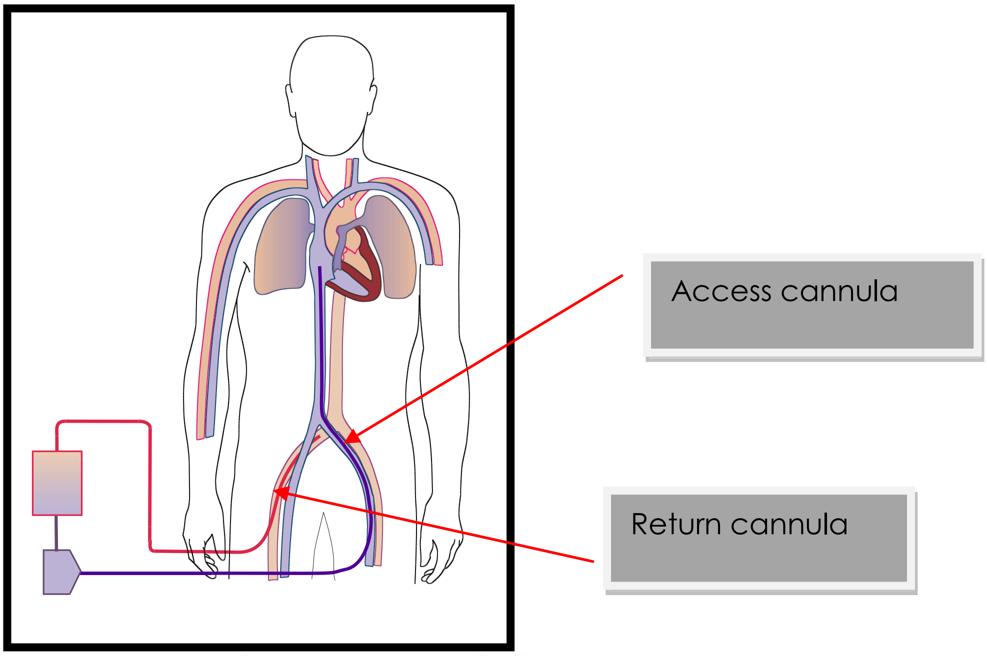

Figure 13: An example of Veno – Arterial ECMO

May be used at low rates (2-3L/min) to provide partial assistance or at high rate of 4-6L/min to totally replace the patients cardiac output

All gas exchange is delivered directly to arterial circulation so PO_2 levels 400-500mmHg can be achieved

Changing flow rates will not affect arterial PO_2 but will determine the patients cardiac output

ECMO circuit malfunctions will result in cardiac arrest as the ECMO flow rate is the patients cardiac output

V-A ECMO may be applied via central or peripheral cannulation

If peripheral cannulation is applied any residual native cardiac output passes through the lungs. If the lungs are affected by disease or mechanical ventilation is insufficient the blood of the residual cardiac output will remain hypoxic as it enters the systemic circulation

Anatomically there is potential for this hypoxic blood will be delivered to the head, neck and right arm.

Therefore any patient on peripheral V-A ECMO should have O_2 saturations measured on the forehead or right hand

Patients on V-A ECMO require adequate ventilation with FiO_2 of at least 50%to reduce the risk of coronary and cerebral hypoxia

Carbon dioxide removal is controlled by the sweep gas flow rates as in V-V ECMO, but if there is some native cardiac output and the lungs are ventilated normally some CO_2 will be removed by the lungs

V-V AND V-A ECMO

V-V

- Provides respiratory support
- Blood from and returned to venous circulation
- Less arterial injury
- Decreased likelihood air or clot emboli from the circuit
- Low pressure circuit therefore improving longevity of circuit
- Decreased hemodynamic instability as blood is returned and withdrawn from same side
- Achieves arterial p02 55-90mmHg
- Changing flow rates affects p02
- Increasing O2 sweep gas removes more CO2

V-A

- Provides complete respiratory & hemodynamic support
- Blood from venous circulation then returned to arterial circulation
- Bridge to recovery or for heart transplant
- Pump flow is the pt CO, any disruption to flow = cardiac arrest
- All gas exchange in oxygenator is delivered to arterial circulation = arterial p02 400-500mmHg
- Changing flow rates affects cardiac output

CONNECTING CVVHDF TO ECMO

The Prismaflex machine can be connected to the ECMO circuit. This should be done by the perfusionist. Once the ICU nurse has been trained in this procedure it may be done by the nurse. If the ICU nurse is unsure on how to make the connections the perfusionist must be called. The ECMO circuit is a high pressure circuit and opening taps and connections will result in air entering system or blood spills.

The access and return lines of the dialysis machine are attached to the ECMO circuit to the two three-way taps between the outlet of the pump head and the oxygenator.

ACCESS:

- Access line goes to the three way tap closet to the centrifugal pump
- If pressure within ECMO circuit causes high pressure alarm in Prismaflex change access pressure alarm in set up to positive. Always should select positive ACCESS Pressure for ECMO and CRRT.
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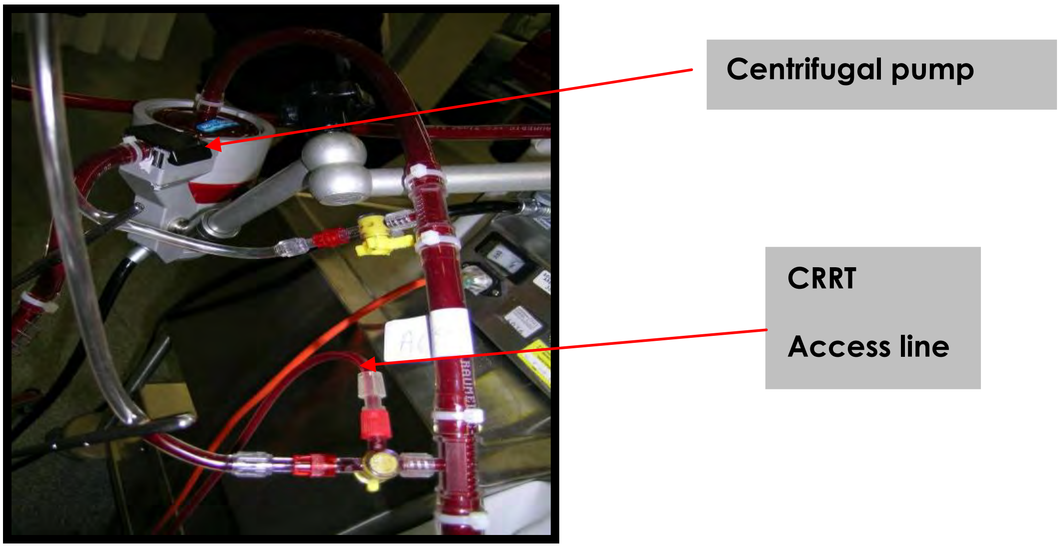


Figure 14: Access Line for CRRT connection to ECMO Circuit

RETURN:

- Return line is connected to three way tap closest to the oxygenator
- 3 way taps not to be flushed with any solution including sodium chloride
- Betadine to wipe connections when disconnecting from ECMO

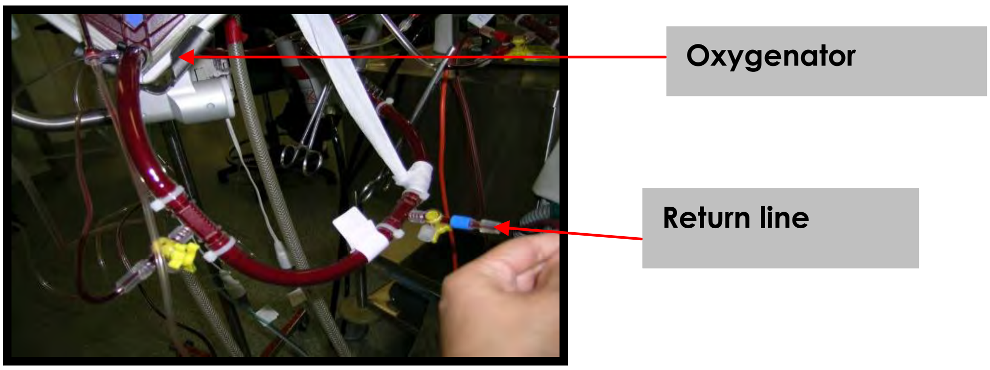


Figure 15: Return Line for CRRT connection to ECMO Circuit

MANAGEMENT[1,4,6,7]

Commencement of ECMO:

- Check ACT and ensure >200 seconds
- Ensure oxygen line is connected to oxygenator. Gas flow should be commenced at a rate equal to or greater than the anticipated circuit blood flow (usually 5-6L/min)
- Clean loop is opened and handed to the cannulating physician
- The circuit is cut between two clamps allowing sufficient length on the access line and return line to prevent any tension on the circuit. Note the pump trolley is best kept at the "feet" end of the patient's bed (picture)
- Circuit is connected to cannulae ensuring no air is introduced
- Clamps removed as circuit flows are gradually increased
- Target flow rates are determined by the cannulating Physician
- *For V-V ECMO* target flows must provide adequate arterial oxygenation
- *For V-A ECMO* target flows must provide adequate oxygen delivery
- Check patient and circuit arterial blood gases
- Reduce ventilator settings as indicated
- Establish baseline anticoagulation sampling times.

Securing Access and Return Lines

- Once the cannulae position has been confirmed femoral lines should be secured by suturing to patients leg and then using large opsite over the top of the cannulas. The internal jugular line is best stabilised by directing the tubing around the head before passage down the body to the oxygenator. The loop around the head is immobilised by strapping around the patient's forehead

Figure 16: Securing ECMO Lines

Care of Equipment:

- Ensure AC power alarm is turned on when using wall power
- Keep pump head in a position to minimise risk of accidental contact with other equipment e.g. X-ray machine
- Ensure heater cooler hoses & O2 flow tubing is not obstructed by feet, bed etc
- Don't allow any part of the circuit to come in contact with alcohol or organic solvents

Medical Staffing:

There is a medical perfusionist (a cardiac anaesthetist) and a pump technician available 24 hours for:

- Initiation of ECMO
- Priming of circuits
- ECMO circuit maintenance and nursing support

Out of hours (1800 to 0800 weekdays and weekends), the medical perfusionist may be contacted directly or via switchboard.

Their contact details should be left at the patient's bedside.
They should be contacted about all circuit and patient issues related to ECMO.

The ICU consultant is responsible for all medical decisions involving ECMO while the patient is in ICU and must also be notified of any changes. They can be contacted 24 hours.

Respiratory Management

Once adequate ECMO flows have been established and the patient's oxygenation has improved, the level of ventilatory support is reduced.

Typical ventilatory goals would be:

- FiO_2 <0.7,
- PIP < 35cmH_2O,
- PEEP < 15cmH2O
- respiratory rate < 10bpm (V-A)

Pump Flow rates:

- Flow rates: V-V
  - 2/3 of pts cardiac output, minimum 50% of patient's cardiac output
  - O2 flow rate twice ECMO flow rate
  - Avoid increasing fluids to maintain pump flow as this may decrease respiratory function
  - Lowest SaO2 85-90% or PaO2 of 55-60
- Flow rates V-A
  - Flow rate 2.1- 2.4l/min/m2

- ECMO flows less than 2litres for long periods should be avoided to prevent clots in circuit

Figure 17: Pump flow rates

Line pressures:
- Pre-membrane pressure <300mmHg
- Trans membrane gradient normal <50mmHg if > 150mmhg consider circuit change

Temperature:
- Normothermia, set heater cooler at 37degrees
- The heater-cooler settings should only be altered by the perfusion staff unless the nurse has been trained to do this. Should the patient become unexpectedly hypo- or hyperthermic while on ECMO, the medical perfusionist on call must be contacted immediately.

Anticoagulation:
Although the ECMO circuit has an anticoagulant lining, low-dose heparin is usually administered to prevent clot formation

- The ACT is usually used to titrate heparin infusion rate in the first 24 hours and is measured 6 hourly over the first day. It is performed by the attending nurse, using 2 mls of arterial or venous blood.
- A usual target for ACT in the non-bleeding patient with platelet count > 80,000 is 140–160.
- Beyond 24 hours, the APTT performed in the Haematology lab is primarily used to guide heparin therapy. It is performed 4 times per day and is routinely labelled as urgent to ensure safe response times.
- A usual target for APTT in the non -bleeding patient with platelet count > 80,000 is 45-55sec.

Investigations required for patients on ECMO include:
- Daily CXR
- Daily bloods: FBE; Urea, Creatinine, Electrolytes; Mg; PO4; LFT
- Clotting: APTT, INR, Fibrinogen are performed daily (morning bloods)
- APTT is performed 6 hourly as determined by the ICU consultant while the patient is on ECMO.
- Plasma free Hb is performed when clinically indicated. The safe range for this is < 0.1g/L. Levels above this MUST be discussed with ICU Consultant and medical perfusionist.
- Daily d-Dimers should be preformed
- Blood cultures 3 times per week or as indicated. Unlike other patients, these samples should be taken from the circuit or through existing lines. Do NOT perform venipuncture for the collection of blood cultures. (Samples from circuit are obtained by a perfusionist)
- Other cultures as indicated

Figure 18: ECMO Cannula on X-ray

General management

- Doppler examination of the blood flow in the back-flow cannula is indicated if deteriorating leg perfusion is observed in the cannulated leg.
- Antibiotics (IV vancomycin) to prevent line sepsis are commenced at the start of ECMO. Other antibiotics are prescribed as indicated.
- Stress ulcer prophylaxis is standard.
- No procedure can be performed on a patient on ECMO without the consent of the ICU consultant.
- Protamine is contraindicated for patients on ECMO as it can cause serious circuit related thrombosis
- All changes to circuit flows, gas and blood, should be relayed to the medical perfusionist via ICU Senior Registrar
- All changes to circuit anticoagulation should be relayed to the medical perfusionist via ICU Senior Registrar

Nursing Management[1,4,6,7]

Nursing responsibilities are to patient care. Responsibility for technical maintenance of the ECMO circuit lies with the medical and technical perfusionists Liverpool Hospital.
Patient positioning and the safe performance of pressure area care are affected by ECMO support.

- Patients with ECMO support *with an "open sternum"* may not be rolled and require alternate means of preventing pressure area care eg: KCI mattress. Daily chest x-rays and other patient moves require a Jordan Frame and the presence of medical staff and/or perfusionist to ensure no change in circuit flow result as a consequence of movement.

- Other patients on ECMO support can be log-rolled and moved for chest x-rays. These moves can be safely performed but require a designated staff member to ensure no tension is transmitted to the cannulae and the circuit tubing is not kinked. This includes patients with surgical grafts for femoral artery access but extra care is required to prevent obstruction to ECMO flow at this site. Moves are scheduled between the hours of 0800 and 2000 and not during the night (unless there is an urgent patient need).

- All moves are to be performed with medical staff knowledgeable in ECMO, immediately available to assess any circuit changes that may occur.

- Patients nursed at 2:1 nursing ratio

The ECMO patient must NOT be left unattended at any time

- Relief for breaks should be arranged so that a suitably experienced member of staff is monitoring the patient and ECMO circuit at all times
- The ECMO patient is dependent on the circuit for maintenance of oxygenation +/- cardiac output
- Any disruption to ECMO flow will result in rapid deterioration, which if not rapidly rectified will result in death

Safety checks

- ECMO plugged into blue power point
- Hand crank near by
- Secure oxygen flow to oxygenator
- Check flow settings

- Check Pump access line for chattering
- Patient must not be left unattended at any time

Hourly observations

- Pump flow rate
- ECMO observation chart Nursing ECMO observation chart must be maintained and reviewed by the rostered medical perfusionist. Nursing staff can communicate any difficulties with observations with the rostered perfusionist. This data will form part of the medical record.
- Haemodynamic observations
  - Continuously monitor patient and ECMO set for drop in BP/ CVP

- Evidence of hypovolaemia in the form of fluctuating flow rates and 'shaking' of ECMO tubes
  - Hypovolaemia (relative or absolute) may result in disrupted blood flow through the circuit
  - Sucking down of the access cannula against the vessel wall may occur in hypovolaemia potentially causing trauma to vessel endothelium and haemolysis
  - Blood flow through the ECMO circuit is essential for maintenance of gaseous exchange, and also to maintaining haemodynamic stability

- Pre & post membrane pressure

- Oxygen flow to oxygenator
  - Ensure oxygen tubing is secured to floor
  - Check flow on oxygen outlet

- Patient temperature
  - Temperature measurement should be initiated and continuously monitored throughout ECMO therapy via either blood thermister in the presence of a PiCCO/ PA catheter
  - To promote homeostasis, normal body temperature must be maintained, unless mild hyperthermia is clinically desired
  - Continuous monitoring allows for early detection and therefore management of temperature changes

- Access & return cannula for bleeding
  - Observe for oozing of blood, and maintain secure dressings
  - Secure dressings are required to maintain cleanliness of cannulae sites, and also to help stabilise the cannulae

- Circulation observations lower limbs
  - Limb temperature
  - Limb colour
  - Pedal pulses
  - Capillary refill
  - Due to the large bore cannulae distal arterial perfusion may be compromised in A-V ECMO, while the venous cannulae may lead to DVT formation

- Input & output, haematuria
  - Haematuria is often present when there is haemolysis, and therefore should be reported and investigated appropriately

- Ventilation observations should be attended: mode, $Fi0_2$, Tidal volume, respiratory rate, PEEP, pressure support, inspiratory time, plateau pressure.

- Patient should be nursed in the supine position
- Head of bed should be elevated 30 degrees
- Pressure relieving mattress should be insitu (because of decreased mobility and perfusion sate these patient often high risk for pressure areas).
- Heel pressure should be offloaded.

- If patient needs to be moved a designated person must watch cannulae, tubing & flow rates
- Patient need to be Jordan framed. They can be log rolled if not contra- indicated.

- Neurological and pupillary assessment must be attended hourly (they are at increased risk of intracranial bleed).
- Pain scores with CPOT (Critical Pain Observation Tool) and sedation scores with RASS (Richmond Agitation Sedation Score) should be attended 2nd hourly. Daily sedation vacations are attended to assess underlying neurological assessment.

ECMO OBSERVATION CHART (example)
DATE:- ________________ (Record observations hourly)

TYPE:- ____________ COMMENCED:- _____________ FILTER CHANGED:-____________

TIME	PUMP FLOW RATE	PUMP RPM	INFLOW LINE PRESSURE (PRE)	OUTFLOW LINE PRESSURE (POST)	PO2 IN OUTFLOW LINE
0100					
0200					
0300					
0400					
0500					
0600					
0700					
0800					
0900					
1000					
1100					
1200					
1300					
1400					

Circuit Management:[1,2,4]

The Jostra Quadrox D oxygenator is remarkably robust and is capable of several weeks of continuous function.

Figure 18: Membrane Oxygenator

The oxygenator should be positioned in the oxygenator arm
The oxygenator's performance must be monitored by:

- Recording the trans-membrane pressure gradient (the difference in pressure between the inflow and outflow side of the oxygenator)
- Blood gas analysis of the oxygenator outflow
- Trans-membrane pressure should be recorded hourly
- Blood gases from the oxygenator outflow ("post- membrane") should be performed every 12 hours (Rotaflow only).

Circuit change is indicated if :

- There is a trend towards increasing transmembrane pressures and / or worsening oxygenator function (oxygenator outflow PaO_2 < 150mmHg).
- A normal transmembrane pressure gradient is <50mmHg.
- The decision to change the oxygenator will be based on the trend of transmembrane pressures and oxygenator performance and should also be considered if the ECMO circuit is thought to be a source of sepsis.

The Jostra Rotaflow pump is capable of several weeks of continuous operation.

The pump head is kept with the outlet at 6 o clock

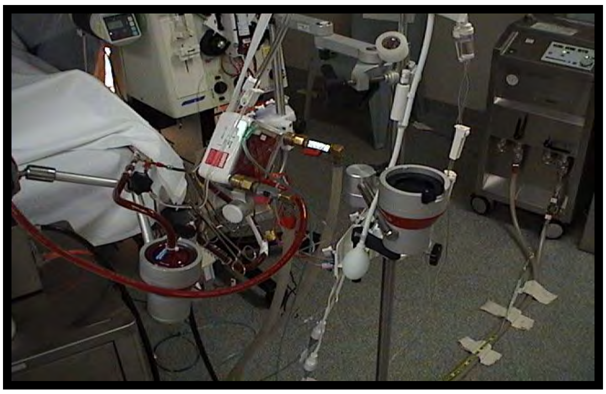


Figure 19: Oxygenator and Pump

It is important to ensure that the pump RPM rate is not too high for the maximum flow that can be delivered ("over-spinning" the pump).
When the maximum pump flow rate has been attained (which is determined by the rate of venous drainage in the access line), increasing the RPM further will increase the negative pressure in the access line, producing 'line-shake' and increasing the risk of haemolysis.

"Over-spinning" of the pump is corrected by dropping the pump RPM until the flow rate starts to drop.
Because the rate of venous drainage in the access line is variable, if the pump RPM is constant and the venous drainage falls (eg. due to decreased preload), the pump will over-spin and access flow limitation will start to occur.

Increased noise from the pump head may indicate that it is starting to fail. The other indications for changing the pump head are the development of haemolysis (producing haematuria and an increased plasma free haemoglobin) and large thrombus formation within the pump head.

COMPLICATIONS / TROUBLESHOOTING[1,2,4,7]

VENO- VENOUS ECMO

- **Hypoxia**

Check

- Pump flow is > 2/3 pt cardiac output (e.g. CO 6l = 4l pump flow)
- 100% 0_2 to oxygenator
- Check Oxygenator :outflow pO_2>150mmHg

Management

- Increase pump flow
- Increase ventilation
- Cool pt to 35deg
- Muscle relaxants
- Correct anaemia
- Second access line to reduce shunt

- **Hypercarbia**

Check

- Pump flow is > 2/3 cardiac output
- Oxygen flow to oxygenator twice pump flow rate(e.g. if pump flow 4l, O_2 flow 8l)

Management

- Increase pump flow rate otherwise consider that recirculation may be occurring
- Increase ventilation
- Cool patient to 35°C
- Administer muscle relaxants

- **Shunting/ Recirculation**

Access & return cannulae too close may cause recirculation of blood, so Pump flow may not improve oxygenation

Check

- Pre membrane (venous) pO_2 < 50mmHg

Management

- Reposition access line

VENO- ARTERIAL ECMO

- **Differential hypoxaemia**
  - Lower $p0_2$ in upper body compared to lower body
  - Can occur when there is severe respiratory failure with a high cardiac output
  - Heart supplies upper body with de-oxygenated blood & ECMO supplies lower body with oxygenated blood

Check

- Patient ABG sample from right radial arterial line (close to heart)
- O_2 saturation measured on right hand or forehead

Management

- Ensure proper functioning of oxygenator return line $p0_2$ >150mmhg
- Pump flow as high as possible
- Increase ventilation/ PEEP / $Fi0_2$
- Resite return line from femoral to right subclavian artery

- **Hypercarbia**

Check

- Adequate pump flow > 2/3 CO
- O_2 to oxygenator is twice pump flow rate

Management

- Increase pump flow rate
- Increase ventilation
- Cool pt
- Paralysis pt

BLEEDING

- Prevention is primary objective
- ACT's day 0; APTT 6hrly
- Daily FBC, d-Dimer, fibrinogen
- Anticoagulation management with heparin APTT 50-75 sec
- If patient bleeding
  - Cease heparin. Heparin coated circuits can run for couple days without heparin
  - Investigate cause
  - Platelets, Cryoprecipitate, FFP, packed cells

HAEMOLYSIS

- Breakdown of RBC

Causes

- Clot in the circuit or near cannulae orifice
- Access & return insufficiency or obstruction
- “over spinning” of pump speed

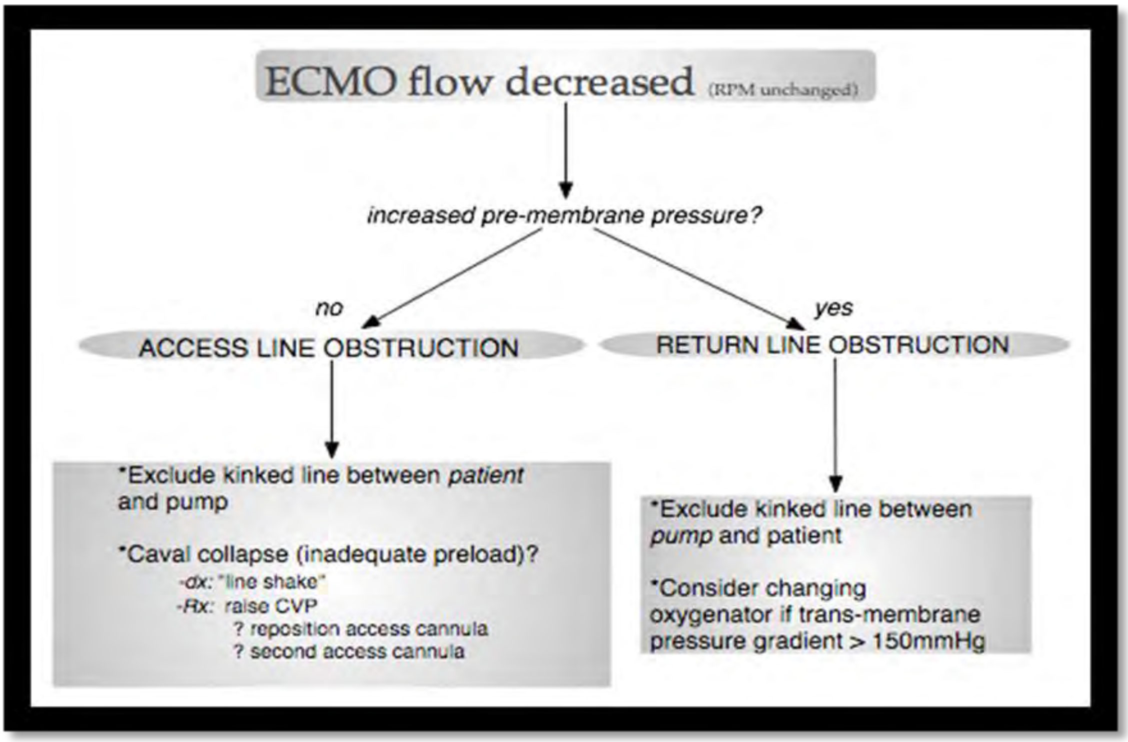
Signs

- Red or dark brown urine
- High K+
- Renal failure
- Jaundice (late sign)
- Access line shaking due to changes in pressure

Management

- Plasma free haemoglobin measured
- Increase volume
- Review pump flow settings
- TOE to ensure cannulae not obstructed
- Consider changing circuit

ECMO FLOW DECREASED RPM UNCHANGED

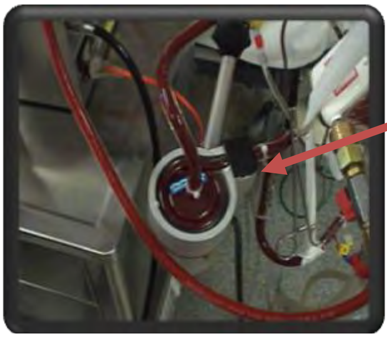


Ecmo policy and guideline: RPAH. P.Forrest. 2007

- Management
  - Optimise fluid status
  - Optimise preload afterload & contractility
  - Sedation & analgesia before pressure care etc
  - If complete "suck down" occurs decrease pump speed to reduce suction on catheter & then turn up as to normal as smoothly & quickly as possible
  - Consider extra venous drainage cannulae

"SIG" ALARM ON PUMP CONSOLE

- Flow rate indicator on pump says "SIG" while the pump is still functioning normally. RPM is unchanged
- Occurs as cream under the flow sensor has dried out
- Management
  - Contact perfusionist
  - Re- establish full ventilation
  - Stop pump slowly & clamp inflow & outflow lines to pump head
  - Unclip black clip & remove pump head
  - Apply silicone cream
  - Reinsert head & close clip
  - Unclamp lines & slowly restart flow
  - Wrap sensor in cling wrap to prevent drying out



Sensor

EMERGENCY COMPLICATIONS[1,2,4,7]

- Dramatic and life threatening that require immediate action
- General rules
  - Call for help, Intensivist, CT surgeon, Perfusionist
  - Clamp
  - Ventilate, haemodynamic support

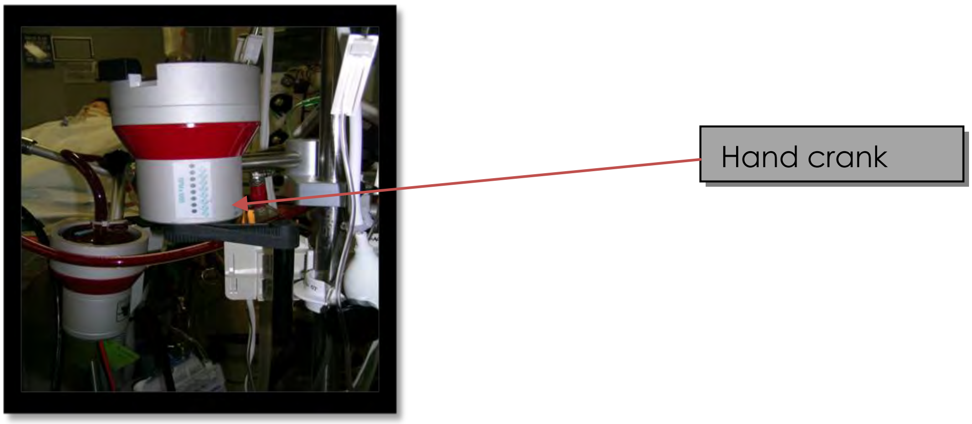
PUMP FAILURE

- No flow due to electrical failure or pump head disengagement
- If circuit stopped for any period clotting is possible
- Prevention:
  - Always maintain the pump head in a position to minimise the risk of contact especially with devices such as portable x-ray, haemofilter and TOE
  - Minimise time on battery
  - Ensure AC "Power Off" alarm is turned on when using wall power
  - Console not in use, needs to be plugged into AC power and "on Switch" turned on in order to recharge battery

V-V	V-A
▪ **Hypoxaemia / hypercarbia which may lead to cardiac arrest**	▪ **Cardiac arrest if circuit providing full C.O** ▪ **If some native C.O extent of hypotension & hypoxia depends on cardiac function**

- ***Management***
  - Call for help
  - Ventilate & haemodynamic support
  - *Electrical motor failure*
    - Clamp line & turn off pump
    - If the cause is not immediately rectified, commence hand cranking till new console arrives
    - Re insert pump head
    - Turn on pump to 1000 rpm & remove clamp
    - Gradually increase rpm's
  - *Pump head disengaged*
    - Clamp line & decrease pump speed
    - Re-insert pump head
    - Turn on pump to 1000rpm & remove clamp
    - Gradually increase rpm's

Note on HAND CRANKING the pump
- Clamp lines.
- Disconnect the pressure sensor and venous oximeter cables
- Open the safety bar
- Press on both locks on the joints of the safety bar and fold it upwards..
- Take the disposable PUMP out of the CARDIOHELP:
- Fix the disposable to the CARDIOHELP Emergency Drive hand crank
- Fit the disposable under the locating lug from below.
- Open the lower locking device. Swing the disposable right up to the pump drive and release the lower locking device so that it fixes the disposable
- Unfold the hand crank handle.
- Open the clamp on the venous side and turn the hand crank clockwise
- When RPM is > 1500, unclamp lines and increase RPM



CARDIAC ARREST

- Cessation of native cardiac function

V-V	V-A
▪ No patient circulation ▪ ECMO flow decreases ▪ Patient in cardiac arrest with no output Mx ▪ Call for help ▪ CPR ▪ Reversible causes	▪ Little hemodynamic effect if flow > 4l/min Mx ▪ Establish adequate flow ▪ Call for help ▪ Reversible causes ▪ CPR may not be needed unless pump compromised

DECANNULATION

- Accidental removal of access or return cannula

V-V	V-A
▪ Hypoxaemia ▪ Cardiac arrest depending on cardiac & respiratory reserve ▪ Massive bleeding	▪ Cardiac arrest ▪ Catastrophic if central cannula torn off aorta ▪ Venous pulled out of atrium ▪ Peripheral blood loss from site controllable

Prevention:

- Anchoring the cannulae to the patient
- Use of a spotter to ensure that lines remain free during patient manoeuvres

Management

- Call for help
- Clamp circuit
- Turn off pump
- CPR
- Establish ventilation & inotropic support
- Volume
- Peripheral: apply pressure
- Central: prepare chest opening

AIR EMBOLISM

- Introduction of air into circuit through connections or cannulation sites
- Massive embolus into the pump head will de-prime the pump with loss of ECMO support

Management

- Clamp arterial return line
- Stop pump
- Patient head down
- Increase ventilation & inotropes
- Volume
- If embolus entered patient arterial system (VA)
  - hypothermia'
  - Barbiturates, steroids, mannitol, lignocaine
- If embolus entered venous system (VV)
  - Aspiration of right heart using existing lines
- Circuit Management
  - Clamp circuit
  - Turn off pump
  - Ensure pump head outlet is at 12 o'clock position
  - Examine site for air & seal if possible
  - Further management requires perfusionist

CIRCUIT RUPTURE

- This is the disruption of any part of the circuit
- Massive blood loss
- Haemodynamic collapse and hypoxaemia of varying severity (depending on underlying cardiac and respiratory reserve)
- Possible introduction of air into ECMO circuit
- Fracture and breakdown of polycarbonate components after being cleaned with alcohol
- Broken three way tap
- Accidental cutting or puncturing of circuit tubing

Prevention:

- Do not allow any part of the circuit to come into contact with alcohol or other organic solvent such as volatile anaesthetic
- Allocated person to act as "spotter" to ensure that three way taps are not snagged on anything during patient manoeuvres
- Care with needles and instruments near tubing

Management:

- Clamp the circuit on either side of the circuit disruption
- Call for help. Contact perfusion services and ICU consultant
- Assign roles for concurrent patient and circuit management
- Increase the ventilator settings and inotropes to compensate for loss of support.
- Give volume to replace blood loss
- If fractured three way tap: if possible place sterile gloved finger over leak
- Connection change

WEANING ECMO[1,2,4,7]

- Decision made by consultants & CT surgeons

V-V	V-A
▪ Maintain ECMO flow rate ▪ Re-establish pt full ventilation ▪ Turn off 02 to oxygenator ▪ 6hr stability then decannulation	▪ Heparin so ACT >400 to decrease risk clotting ▪ Decrease pump flow 1litre while ventricular function assess by TOE ▪ Period of low flow ECMO before decannulation • Respiratory function is a concern: turn off gas flow (Only at circuit flows ≤1.5L/min) and assess oxygenation achieved using the ventilator exclusively. Note: in this situation the circuit flow acts as a right-to-left shunt. If adequate oxygenation and CO_2 removal can be maintained in the presence of this shunt it is likely that respiratory failure can be managed without ECMO. ▪ If 02 good & C02 managed by ventilation consider decannulation

Removal of cannulae:

- Removal of arterial ECMO cannulae should always be removed as an “open” surgical procedure and be accompanied with the vessel wall repair.
- Venous cannula can be removed and pressure applied to the site for 20 minutes.

Post-decannulation Doppler:

- Lower limb venous Doppler studies should be performed following decannulation- as prolonged femoral venous cannulation promotes distal DVT formation.

LEARNING ACTIVITIES

1. Define ECMO
2. Describe the two types of ECMO
3. What are the indications for ECMO?
4. What is the purpose of the oxygenator?
5. What is the function of the pump?
6. What is V-V ECMO more efficient at doing and how does it remove C02?
7. How much oxygen should be delivered to the oxygenator and what should it be set at in relation to the ECMO flow rate for V-V ECMO?
8. What should the ECMO flow rate be set at for V-V ECMO?
9. Where are the access and return lines for CVVHDF connected on the ECMO circuit?
10. What are the safety checks that need to be performed for a patient on ECMO?
11. Why are the pre and post membrane pressures continuously monitored?
12. What is the management for “shaking” or “chattering” of the circuit?
13. Why are vascular observations important?
14. Why should oxygen saturation be measured on the patient’s right hand or forehead for V- A ECMO?
15. What does the “SIG” alarm on the pump console signify and how do you rectify the alarm?
16. What is the management for cardiac arrest for V-A and V-V ECMO?
17. Describe the process for weaning V-V and V-A ECMO.

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