EXTRA CORPOREAL MEMBRANE OXYGENATION (ECMO)

<table>
<thead>
<tr>
<th>Cross references (including NSW Health/ SESIAHS policy directives)</th>
<th>Extracorporeal Life Support Organisation (ELSO)</th>
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1. **What it is**
This document describes a standardized guide to the management of patients receiving Extracorporeal Membrane Oxygenation (ECMO) at the St. George Hospital ICU.

2. **Employees it applies to**
This policy describes the roles and responsibilities of doctors, nurses and perfusionists/cardiac anaesthetists in regards to the management of ECMO within the ICU.

3. **When to use it**
When a patient requires ECMO

4. **Why the rule is necessary**
Patients in the ICU who require ECMO shall receive this treatment in an optimal and safe manner.

5. **Who is responsible**
All medical staff, Nursing, Physiotherapists, and Perfusionists

6. **Process**

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1.0 INTRODUCTION

1.1 DEFINITION:
ECMO is a life support device similar to a heart-lung machine. It is capable of providing both gas exchange and circulatory support for patients who have lung and/or heart failure refractory to conventional methods of ventilatory and cardiovascular support.

1.2 TYPES:
- **Venous-Venous (V-V) ECMO** is used to provide gas exchange support for patients with lung failure refractory to conventional ventilatory support. Venous blood is removed from the patient and pumped through an oxygenator (adding oxygen and removing carbon dioxide). The oxygenated blood is returned to the patient’s venous circulation, providing gas exchange support only. It does not provide cardiac support. The primary aim is to provide adequate gas exchange to support life and thereby facilitating a significant reduction in mechanical ventilation, reducing ventilator-associated injury and allowing the best chance of lung recovery.

High flow V-V ECMO allows higher circuit flow and uses 2 access cannulae to draw patient blood from the great veins. It is required when a single cannula circuit flow is inadequate to maintain safe oxygenation in more severe cases of respiratory failure.

- **Venous-Arterial (V-A) ECMO** is used to provide both circulatory and gas exchange support for patients with heart or heart and lung failure refractory to inotropes, intra-aortic balloon counterpulsation and ventilation. The blood is removed in the same way as V-V ECMO but the oxygenated blood is returned to the patient’s arterial circulation. Therefore in addition to gas exchange support the blood pump flows contribute to effective cardiac output and provides circulatory support. Depending on the flow rates, low flow 2-3L/min will provide partial assistance, while high flow 4-6L/min will replace the native cardiac output.

1.3 CANNULATION:
There are 3 ways of accessing the major vessels for ECMO
- **Percutaneous cannulation** - performed using the Seldinger technique which involves serial dilation of peripheral vessels over a guide wire access. It does not involve any cutting of skin at insertion. The skin should form a tight seal around the cannulae.
- **Surgical peripheral cannulation** - involves the surgeon accessing a peripheral artery or vein via a surgical incision. The surgeon may then directly cannulate the vessel under view. This is required in cases of prior vascular injury and often for placement of an arterial backflow cannula.
- **Surgical central cannulation** - involves the surgeon attaching the cannulae to the major vessels and securing them with sutures. The cannulae leave the patient through surgical incisions. In the case of arterial cannulae – this means the cannulae is attached to the ascending aorta.
2.0 **INDICATIONS:**
ECMO is indicated for potentially reversible, life-threatening respiratory and/or cardiac failure which is unresponsive to conventional therapy.

### Indications for V-V ECMO:
**Common:**
- Acute lung (graft) failure following transplant
- Severe pneumonia
- ARDS

**Other:**
- Alveolar proteinosis (to facilitate whole lung lavage)
- Status asthmaticus
- Smoke inhalation
- Pulmonary contusion
- Airway obstruction
- Aspiration syndromes

### Indications for V-A ECMO:
**Common:**
- Primary graft failure: post heart/heart-lung transplant
- Non-ischaemic cardiogenic shock (includes):
  - Acute fulminant myocarditis
  - Acutely de-compensated dilated cardiomyopathy
- Ischaemic cardiogenic shock: AMI and complications including wall rupture, papillary muscle rupture, refractory VT/VF.
- Post cardiac surgery: unable to wean from cardiopulmonary bypass using conventional supports.
- Cardiomyopathy: as a “bridge” to longer term ventricular assist device
- Drug overdose with profound cardiac depression
- Sepsis with profound cardiac depression

**Other:**
- Pulmonary embolism
- Cardiac or major vessel trauma
- Massive haemoptysis/pulmonary haemorrhage
- Pulmonary trauma
- Severe anaphylaxis
3.0 CONTRAINDICATIONS:

Absolute contraindications for all forms of ECMO:
- Progressive and non-recoverable cardiac disease (and not suitable for cardiac transplant)
- Progressive and non-recoverable respiratory disease (irrespective of transplant status)
- Malignancy
- Graft versus host disease
- Body wt < 20kg or > 120kg
- Unwitnessed cardiac arrest
- Central nervous system injury
- Contraindication to systemic anticoagulation

Absolute contraindications for V-A ECMO
- Aortic dissection
- Severe aortic regurgitation

Absolute contraindications for V-V ECMO
- Severe cardiac failure
- Severe pulmonary hypertension (mean PAP approaching systemic pressure)
- Cardiac arrest

Relative contraindications for ECMO
- Age > 70 yrs
- Multiple trauma with multiple bleeding sites
- Immunosupression
- CPR > 60mins
- Multiple organ failure
- Severe peripheral vascular disease (favour central cannulation)
- Severe hypothermia (femoral artery constriction - difficult cannulation)

4.0 EQUIPMENT

ICU does not store the equipment for the initiation and maintenance of ECMO (cannulae, pump, circuit etc). Perfusion Services are responsible for providing an ECMO pump and a primed circuit when ECMO is initiated in ICU. They should be contacted as early as possible after the decision to commence ECMO is made. Out of hours, the on – call perfusionist can be contacted through the hospital switchboard or directly if “on-call” perfusionist is known.

Related equipment is kept in theatre and is accessed by Perfusion Services.

- ECMO circuit PLS 2051
- Holder for Quardrox Oxygeneator x 1
- 1 L Hartmanns Solution x 1
- Heparin 5000U/5ml x1
- 500ml 0.9% Saline x 1
- Pressure infusion bag x1
- Pressure Transducer Set Double set
- O2 Cylinder x1
- Cable ties to all connections
- Ultrasonic Gel Rotaflow x 1
- Clamps medium x 4 lable with Perfusion
- Oxygen Tubing for x 1
- Sterile tubing scissors
- Jostra Rotaflow Console x 1
- Rotaflow Drive Unit x 1
- Emergency Hand crank x 1
- ACT machine (order supply of ACT cartridges)
- Heat exchanger x 1
- Record keeping
5.0 PREPARATION

Percutaneous cannulation
This may be performed only by cardiothoracic surgeons and intensive care specialists practiced in the insertion of these cannulae.

Preparation of Patient:
- Consider Transoesophageal Echocardiography (TOE) to aid positioning of cannula in inferior vena cava.
- Clip hair from appropriate area.
- Definitive lines inserted prior to anticoagulation.
- Arterial line (preferably right radial for peripheral veno-arterial ECMO).
- Long term Subclavian or Left Internal Jugular CVC and / or pulmonary artery catheter (Edward’s CCO with SvO2).
- Right Jugular vein cannulation should be avoided if possible as it may be a required site for ECMO cannulation.
- Inotropes and vasopressor infusions made up and connected to patient as required.
- Order red blood cells to ensure an adequate "post connection to circuit" Hb of 100 to 120 g/L.
- Adequate sedation and paralysis if required.
- Cannulae selection may be made with the assistance of the cannulae blood flow table.

Cannulae Blood Flow Table

Percutaneous Cannulae Dimensions and Flows

<table>
<thead>
<tr>
<th>Diameter (Fr)</th>
<th>Arterial cannula</th>
<th>Venous cannula</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>2.3</td>
<td>1.5</td>
</tr>
<tr>
<td>17</td>
<td>3.05</td>
<td>2.0</td>
</tr>
<tr>
<td>19</td>
<td>3.9</td>
<td>2.7</td>
</tr>
<tr>
<td>21</td>
<td>5.0</td>
<td>3.5</td>
</tr>
<tr>
<td>23</td>
<td>6.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Flow (L/min) through single cannula at pressure drop of 60 mmHg.
Flow (L/min) through any two access cannulae combined with a pressure drop of 60 mmHg.
Bi Cavall dual lumen catheter
The single site, double lumen catheter (27 and 31 Fr) can maintain flows and adequate gas exchange at mean flows of 4.25 – 5.5 L/min\(^1\). See figure 1.

- One lumen drains deoxygenated blood from the superior and inferior vena cava (SVC and IVC) by openings in the proximal and distal catheter, respectively, whereas the second lumen delivers oxygenated blood to the right atrium (RA).
- The catheter should be inserted under image guidance with its tip confirmed to be in IVC.
- Inadequate flows or oxygenation may indicate re-circulation. Check the position and orientation of the catheter if this is suspected.
Cannulation

- Decide on cannulation sites (femoral is preferable to jugular). Subclavian cannulation (for ECMO) is not performed.
- Wash cannulation site with a Chlorhexidine based preparation and wait until dry.
- Prepare heparin solution (for heparin locking of cannulae): 10,000 units in one litre of saline. Sterile 1 litre jug kept on cannulation trolley
- Drapes must be aseptically applied and extensive because of guide-wire length.
- Medtronic cannulae kits and cannulation trolley contain all equipment required for insertion of cannulae.
- After successful guide-wire insertion for ECMO cannulae, 5000-10000(U) bolus of heparin should be given to maintain an ACT of 180-200 seconds.
- Skin incisions are to be avoided with dilation attempts as this weakens the tightness of the fit around the cannulae once inserted
- **In veno-arterial ECMO**: the arterial (short) cannula should be fully inserted (to the length of the cannula)
- **In veno-arterial ECMO with a femoral arterial return cannula in situ**: a backflow cannula may be required to protect the leg distally from arterial insufficiency. Ideally it should be inserted close to the time of femoral artery ECMO cannulation.
- **In veno-venous ECMO**: the return cannula should be proximal to the right atrium (TOE is desirable)
- **In veno-venous ECMO**: the access cannula may be around the level of the diaphragm (femoral insertion) or in the SVC (internal jugular insertion). Final position will be determined by degree of recirculation and TOE data.
- Heparin lock cannulae immediately after insertion and clamp.
- Sterility of the operator must be maintained until final position of the cannulae are established and then covered with transparent dressings.
- All cannulae must be firmly secured by the cannulator and the responsibility for securing cannulae cannot be delegated.
- Abdominopelvic and chest Xrays should be performed as indicated to verify the position of both cannulae. (In V-V ECMO if the cannulae are too close together there is danger of recirculation with oxygenated blood re-entering the access cannula. This can be assessed on pre-oxygenator ABGs. (Preoxygenator saturation > 75% and PO2 > 45 mmHg suggest recirculation)

6.0 COMMENCEMENT OF ECMO

- Check ACT and ensure 180 - 210 seconds if there is no contraindication to full dose heparin.
- Ensure fresh gas flow is connected to oxygenator. Gas flow of 100% O2 should be commenced at 3 L/min and then titrated.
- Clean loop is opened and handed to the cannulating physician.
- Circuit is connected to cannulae ensuring no air is introduced by using the bulb irrigation syringe, jug and heparin solution.
- Clamps are removed as circuit flows are gradually increased.
- For veno-venous ECMO target flows must provide adequate arterial oxygen and carbon dioxide tensions. Arterial O2 will be proportional to ECMO pump flows. Commonly, commence the ECMO pump flows at 3-4L/min and then adjust flows as required based on resultant arterial PO2. (In circumstances where the patient’s cardiac output is high, the pump flow may need to approach the patient’s cardiac output to achieve adequate arterial PO2, or else consider lowering the patient’s cardiac output.)
- For veno-arterial ECMO target flows must provide adequate cardiac output and oxygen delivery. ECMO pump flows + native cardiac output = effective cardiac output. That is, increasing pump flows increases effective cardiac output.
- Check patient and circuit arterial blood gases.
- Establish baseline anticoagulation sampling times.
7.0 MANAGEMENT OF A PATIENT ON ECMO

The management of a patient on ECMO is performed and guided by the multidisciplinary team approach. The ECMO Team includes Perfusionists, medical and nursing staff trained in ECMO.

The Medical Team includes:
- Intensivists
- Cardio-thoracic surgeons
- Cardiac anesthetists

7.1 The medical team is responsible for:
- Selection or exclusion of patients referred to ICU for ECMO
- All critical decision making (e.g. weaning, withdrawal of support, bleeding management).
- Change of circuit in collaboration with other stake holders.
- Change of circuit: Medical staff are responsible for the decision to change the ECMO circuit.
- Intensivists, Cardiothoracic Surgeon, Scrub team and Perfusionist must be notified.
- Circuit is primed by Perfusionist and a clean loop is handed to the surgeon circuit is cut and new circuit reconnected insuring no air is introduced by using the bulb irrigation syringe, jug and heparin solution.
- Ensuring the following routine investigations (and others as indicated):
  - Daily CXR
  - Daily Routine blood tests:
    - U, E & C, Ca, Mg, Phos
    - FBC
    - LFT
    - Plasma Free Hb, APTT, PT, INR
  - Monday, Wednesday and Friday blood tests:
    - D Dimer, Fibrinogen, TT
    - Blood cultures (Taken from existing lines)
  - Routine Swabs on Monday, Wednesday and Friday.
    - Include urine, sputum, wound, nose and groin (and rectal on Monday)
  - 6 hourly APTT.
  - Other cultures as indicated.
- Anticoagulation management (see below).
- Ventilatory management (see below)
- Ensure appropriate monitoring (see below).
- Aim for Hb 10-12 g/dL to maximize oxygen delivery.
- Aim for albumin ~ 30 g/L to ensure plasma volume is maintained.
- Carefully monitor therapeutic levels or effects of medications, as appropriate, since drug sequestration and altered distribution may occur on ECMO with particular emphasis upon morphine, fentanyl, antimicrobials (vancomycin), voriconazole, heparin etc.
- Antibiotics to prevent line sepsis are considered with the start of ECMO. Other antibiotics are used as indicated.
- Standard stress ulcer prophylaxis is prescribed.
- Calf compressors unless contraindicated due to critical ischemia of distal limb.
7.1.1 Anticoagulation Management
Prevention of bleeding is a primary objective in ECMO. All preventative steps should be taken to avert bleeding where this is possible. Anticoagulation practices are based on patient bleeding risk profiles. The patient’s Hb should ideally be maintained at 10 – 12 mg/dL. Infused packed cells should be as fresh as possible.
- Avoid surgical and invasive procedures.
- Routine blood tests for ECMO patients include:
  - 2 hourly ACTs on Day 0.
  - Continue checking ACTs 2 hourly on day 1 until stable (180-210 sec or within ordered range). ACT is considered to be stable if 4 consecutive 2 hourly tests are within therapeutic range.
  - The usual target for the ACT in the non bleeding patient with Platelets >80,000 is 180 -210 seconds
  - 6 hourly APTTS (Commencing Day 0 concurrently with ACTs)
  - Daily FBC
  - Mondays, Wednesdays and Fridays: D Dimer, Fibrinogen, TT (and additionally as required)
  - Additional tests as indicated, e.g. Thromboelastogram (TEG).
- Systemic anticoagulation with heparin should be provided for all patients on ECMO provided there is no bleeding and there is no anticipated or recent surgery.
- APTTs are preferred and must be ordered, obtained and reviewed by Medical Officer 6 hourly.
- Following the first day, on day 2 if stable, APTTs guide heparin therapy with the usual target range for the non-bleeding patient with platelets > 80,000 of 60 - 80 seconds.

Heparin infusion titration guide for APTT from day 1 onwards when ACTs are stable:

<table>
<thead>
<tr>
<th>APTT</th>
<th>Response</th>
</tr>
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<tbody>
<tr>
<td>&lt; 37</td>
<td>Bolus 60 units/kg and increase infusion by 4 units/kg/hr</td>
</tr>
<tr>
<td>37 - 44</td>
<td>Bolus 40 units/kg and increase infusion by 3 units/kg/hr</td>
</tr>
<tr>
<td>45 - 60</td>
<td>Bolus 20 units/kg and increase infusion by 2 units/kg/hr</td>
</tr>
<tr>
<td>61 - 80</td>
<td>No change</td>
</tr>
<tr>
<td>81 - 100</td>
<td>Decrease infusion rate by 2 units/kg/hr</td>
</tr>
<tr>
<td>&gt; 100</td>
<td>Decrease infusion rate by 3 units/kg/hr</td>
</tr>
</tbody>
</table>

7.1.2 Heparin Infusion
Add 10000 units of heparin to a 100 mL flask of 5% dextrose.
Concentration is 100 units per mL.
The starting rate is to be determined by the Intensivist. (10mLs /hr will deliver 1000 units of heparin per hour).
Connect to the patient.
Aim for an APTT of 60 – 80 seconds (ACT 180 -210) or as directed.
- If heparin is adjusted, repeat ACT and/or aPTT in 2 hours.

Heparin infusion titration guide for ACT 1/24 - 2/24 in first 24 hours until stable.

<table>
<thead>
<tr>
<th>ACT</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;130</td>
<td>Bolus 1000units and increase infusion by 300unit/hr</td>
</tr>
<tr>
<td>130 - 150</td>
<td>Increase infusion 200units/hr</td>
</tr>
<tr>
<td>150 – 180</td>
<td>Increase infusion 100units/hr</td>
</tr>
<tr>
<td>180 -210</td>
<td>No change</td>
</tr>
<tr>
<td>210 - 250</td>
<td>Decrease infusion 200unit/hr</td>
</tr>
<tr>
<td>&gt;250</td>
<td>Cease infusion for 1 hr. Check ACT hourly and recommence when ACT &lt;210 at 300units/hr less than original rate</td>
</tr>
</tbody>
</table>
NOTE: From day 2 onwards ACT may need to be used as a quick bedside reference if there are concerns of clotting or bleeding and increase fibrin deposits on oxygenator (see mapping of oxygenator - 7.3.8).

- If ACT demonstrates clotting time outside reference prescribed by Medical team repeat test and at same time repeat aPTT. Discuss with Senior Registrar/ICU Consultant to determine whether the ACT and response table above be used to manipulate heparin therapy.
- If heparin is adjusted, repeat ACT and/or aPTT in 2 hours.
- Inform Senior Registrar and ICU Consultant if there is a large discrepancy between ACT and aPTT.
- Continue Heparin therapy as per ICU Senior Registrar/ICU Consultant; consider additional tests.

7.1.3 Clinical handover and documentation

- **At each ICU round, the senior medical staff (advanced trainee or consultant) should review confirm and document**
  - ECMO orders including:
  - latest coagulation results
  - overnight plan for ECMO pump and gas flows,
  - coagulation strategy.
- **They should ensure that the overnight staff are aware of these plans.**

- **The medical team is responsible for all medical decisions involving ECMO whilst the patient is in ICU. Any necessary changes that occur must be notified to the appropriate consultants. They are contactable 24 hours a day.**

- **All changes to anticoagulation must be relayed to the medical team.**

**Ventilation Strategy for V V ECMO**

- Aim for prevention of barotrauma/volutrauma by implementing lung rest strategies (PIP < 35 cmH2O, P Plat < 30 cm H2O, TV < 6 mL/Kg IBW, rate ~ 6 breaths/min, PEEP 10-15 cm H2O)
- Provide adequate oxygenation to avoid hypoxaemia (e.g. PaO2 of > 50 mmHg and saturation of > 85% may be adequate for some individuals). FiO2 between 40 - 90 % (aim for ≤ 50% when able). Ensure adequate oxygenator function. Avoid re-circulation through ECMO circuit (Check pre-oxygenator ABG. Preoxygenator saturation > 75% and PO2 > 45mmHg suggest recirculation)
- Aim for normal (or acceptable) systemic pCO2 and pH using the Fresh Gas Flow settings
- After the acute inflammatory phase has passed, daily recruitment maneuvers may be performed by Intensivist or their delegate, aiming for optimal static compliance in conjunction with best achievable oxygen saturation and establishment of best PEEP.
- Transition from lung rest strategies towards efforts to ventilate lung tissue as soon as appropriate (as assessed by increasing tidal volume or during recruitment manoeuvres) and generally between day 7 to day 21, or earlier.

**Ventilation Strategy for V A ECMO**

- Select settings to provide adequate aeration, maintenance of normal FRC and prevention of atelectasis. (Usual settings include: FiO2 always ≥50%, rate of 6 – 12, TV 6 – 9 mLs / Kg IBW and best PEEP). Aim for normal PaCO2. Oxygenation parameters will usually be high when delivered by the ECMO circuit.
- Prevent over ventilation of the lungs, keeping in mind that when there is minimal flow through the
cardiopulmonary system there may be little or no native gas exchange even in the setting of “normal” lungs.

- See strategies for VV ECMO in circumstances of severe lung dysfunction, in conjunction with strategies to prevent cerebral and coronary hypoxaemia related to differential circulation (e.g., if the heart is ejecting hypoxaemic blood it will be necessary to ensure adequate native gas exchange [V/Q match] and when this is not achievable, it may be necessary to consider central cannulation or to decrease native cardiac output to ensure oxygenated ECMO blood is delivered to cerebral and coronary tissues). FiO₂ always ≥50%.

- Prevent preferential delivery of native hypoxaemic blood to cerebral and coronary tissues as described above.

### MONITORING

#### For V-V ECMO:
- **Arterial catheter:**
  - The arterial waveform will display a normal pulsatile waveform since it is generated by the patient’s heart function and haemodynamics.
- **Pulmonary artery catheter (PAC):**
  - SvO₂ may be helpful. It will reflect the true mix of ECMO oxygenated blood and the residual cardiac output of the patient not flowing through the ECMO circuit. However, it probably adds little to the SpO₂ and long term PAC insertion for this purpose is impractical.
  - Thermodilution measurements of cardiac output may be inaccurate because of the effects of the ECMO flow.
  - Measurement of cardiac output using TOE is a reliable alternative.

#### For V-A ECMO
- Peripheral V-A ECMO requires right arm arterial catheter (where possible), ETCO₂ and oximetry either from right finger, forehead or ear lobe.
- **Arterial Catheter:**
  - The arterial waveform will display a combination of the ECMO pump (which is non-pulsatile) and the patient’s intrinsic output across the aortic valve.
  - In most cases using full pump flows there will be little pulsatility to the arterial waveform, because there is little or no flow across the aortic valve.
  - The waveform should become more pulsatile as the ECMO pump flows are reduced.
- **PAC:**
  - SvO₂ will not be helpful while running full flows because there will not be much flow through the pulmonary arteries.
  - Thermodilution (cold or warm) measurement of cardiac output is a reasonable estimate of intrinsic cardiac output. It is particularly useful while weaning V-A ECMO.

### 7.2 PERFUSIONIST SERVICES

Perfusion Services provide twenty-four hour cover for:

- Assistance in initiation of ECMO
- Priming of circuits
- ECMO circuit maintenance and technical support required for all phases of ECMO (including ensuring lines are changed as indicated)
- Nursing support

Perfusion Services provide regular review of ECMO patients once daily and additionally as required. Circuit blood gases pre and post oxygenator are taken when indicated and additionally as required, by a
Clinical Business Rule SGSHHS CLINXXX

Perfusionist or trained ICU Clinical Nurse Educator or Clinical Nurse Consultant. Transports out of ICU are supervised by a perfusionist. All non-urgent transports are performed during regular working hours.

Regular nursing education is provided at scheduled daily visits, which includes review of observations and addressing nursing concerns related to ECMO.

Perfusion Services should be contacted regarding all circuit issues related to ECMO.

Contact information for the Perfusionist-On-Call is provided at the bedside.

7.3 NURSING MANAGEMENT

7.3.1 Staff Requirements

- Only nurses who have attended an ECMO education course may be the primary carer for a patient on ECMO. If staffing requires, a nurse who has previously been the primary carer may care for the patient.

- Patients on ECMO must be nursed in a 2:1 ratio for the first 48 hours and then until stable. Patients requiring transport throughout the hospital eg CT Scan or have CRRT running also require 2:1 nursing. In all other instances a decision of nursing ratios will be based on acuity and safety of the patient at the discretion of the Intensivist or Senior Registrar on duty.

- The Nursing team is responsible for care directed toward the patient. Technical maintenance of the ECMO circuit lies with the Perfusionist and ICU medical team.

7.3.2 General

- Any changes in circuit fresh gas and blood flows must be reported to the ICU medical team
- No alcohol based solutions are to be used on the patient or ECMO circuit as they crack and disintegrate the polycarbonate components of the circuit.
- Nursing staff may change flush bags as necessary.
- The oxygenator must be positioned below the level of the patient
- Cannula dressings may be performed by nursing staff following consultation with the ICU medical team. Standard invasive line dressing procedure should be used, without the use of alcohol based solutions. The site should be cleaned with Betadine and covered with an occlusive, transparent dressing.
- No procedures are to be performed without consent of the ICU consultant

7.3.3 Cardiac Arrest Management

- V-V ECMO
  - Commence CPR, defibrillate as standard protocol
  - May require reduction of flow settings to prevent “suck down”
  - Flows will be limited by venous return achieved

- V-A ECMO
  - May lose pulsatility
  - Turn flows up (if previously on partial support)
### 7.3.4 Nursing Observations

<table>
<thead>
<tr>
<th>Risks</th>
<th>Nursing Interventions</th>
</tr>
</thead>
</table>
| **Neurological** | - Thrombo-embolic event  
- Bleeding  
- Cerebral Hypoperfusion  
- Prolonged hypoxia | - Hourly neurological observations  
- Adequate sedation and paralysis  
- Hourly limb obs |
| **Cardiovascular** | - Vasodilation due to inflammatory response  
- Heat loss  
- Regulation of temperature masks febrile patient  
- Infection | - Hourly haemodynamic monitoring  
- Hourly Temperature  
- Maintain temperature 36.5-37°C via heat exchanger (+/- warming blanket)  
- Monday, Wednesday, Friday:  
  - Routine swabs/screen (urine, sputum, wound, nose & groin, rectal on Monday only)  
  - Blood cultures |
| **Respiratory** | - Predisposition to fluid overload due to leaky capillaries from inflammatory response | - See 7.3.6 for ventilation directions  
- Daily supine CXR  
- Regular suctioning  
- ABG & SpO2 site of analysis is important |
| **Gastrointestinal** | - Stress Ulcer development | - Ulcer prophylaxis  
- Minimises NGT changes  
- Enteral feeding as tolerated  
- 4<sup>th</sup> hourly aspirate, daily NGT aspirate testing for blood  
- Aim to detect and treat abdominal distension early |
| **Renal** | - Renal failure due to hypoperfusion, haemolysis, antibiotics | - Monitor urine output  
- Daily Creatinine & Urea |
| **Haematology** | - Bleeding  
- Haemolysis | - Daily FBC  
- Monday, Wednesday, Friday:  
  - D Dimer, Fibrinogen, TT  
  - 2<sup>nd</sup> hourly ACT (aim 180-210) day 0 – 1 until stable. Stable = 4 consecutive 2/24 samples in range)  
  - 6<sup>th</sup> hourly APTT  
  - Administer heparin to maintain target APTT 60-75sec  
  - Maintain platelet level >80,000  
  - Report bleeding sites early  
  - Report oxygenator mapping changes  
  - If ACT is required after 2 days and is out of range return to 1 - 2/24 ACT tests until stable utilizing the ACT protocol as directed by Senior Registrar/ICU Consultant |
7.3.5 Pressure Area Care

- Turning an ECMO patient require 3-4 staff depending on the position of cannulae and stability of the patient. One person is required for the body, one person for monitoring ECMO cannulae and tension, one person monitoring flows and if a neck cannula is insitu, one person holding the head.
- Patients with an open sternum must not be rolled, they require Jordan frame for PAC.
- All patients should be placed on a pressure relieving air mattress as soon as practicable.
- Fourth hourly turns should be maintained if the patient is stable to do so. The ICU medical team should be notified prior to turning and be present in the unit.
- Due to limitations in pressure area care, special attention should be paid to high risk areas of pressure such as the back of the head and heels. The use of gel pads may be required.

7.3.6 Ventilation

- Aim for prevention of barotrauma/volutrauma by implementing lung rest strategies (see section 7.0).
- Provide adequate oxygenation to avoid hypoxemia (see section 7.0).
- Changes to ventilator settings should only be attended on medical orders.
- Aim for normal (or acceptable) pCO2 levels and pH using the Fresh Gas Flow settings.
- After the acute inflammatory phase has passed, daily recruitment manoeuvres may be perform with direction from the Intensivist.

7.3.7 CRRT

- Currently CRRT will run via a separate access cannula. As per direction from the perfusion team, CRRT is not to be run via the ECMO circuit.

7.3.8 Mapping of oxygenator

- Use a separate transparency for side 1 and side 2 of the oxygenator
- Side 1 will be the oxygen inlet side
- Trace any fibrin or clotting observed on oxygenator after testing 1 hourly with torch.
- Document on ECMO check list
- Inform Medical team immediately if any clotting or change in existing fibrin sheath on oxygenator.

7.3.9 Documentation

- Documentation consists of two CIS screens under the RESP tab and then ECMO tab.
- The ECMO tab will lead to a double screen of both ECMO observations and ECMO orders.
- The entries above the resistance (highlighted in yellow) on the observations screen need to be entered by the nurse.
- ACT also needs to be manually entered.
- ABG and haematology results will automatically download into the chart.
- The ICU medical team and/or perfusionist should fill in the ECMO orders daily and as required.
- Please fill in paper ECMO chart as well as CIS for the first 48 hours until aPTT has stabilised
- Perfusionist to gain access to CIS and view trends of aPTT, pre and post membrane pressures etc.
### ECMO Observations

<table>
<thead>
<tr>
<th>24/04/10</th>
<th>19:00</th>
<th>20:00</th>
<th>20:52</th>
<th>21:05</th>
<th>22:06</th>
<th>22:11</th>
<th>22:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Membrane Pressure</td>
<td>133</td>
<td>132</td>
<td>130</td>
<td>132</td>
<td>133</td>
<td>131</td>
<td>130</td>
</tr>
<tr>
<td>Post Membrane Pressure</td>
<td>107</td>
<td>106</td>
<td>107</td>
<td>109</td>
<td>110</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>RPM</td>
<td>5950</td>
<td>5950</td>
<td>5950</td>
<td>5950</td>
<td>5910</td>
<td>5910</td>
<td>5910</td>
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<tr>
<td>Flow</td>
<td>3.54</td>
<td>3.49</td>
<td>3.39</td>
<td>3.10</td>
<td>3.57</td>
<td>3.57</td>
<td>3.57</td>
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<tr>
<td>Oxygen</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Resistance</td>
<td>6.9</td>
<td>6.9</td>
<td>6.9</td>
<td>6.4</td>
<td>6.4</td>
<td>6.4</td>
<td>6.4</td>
</tr>
<tr>
<td>ACT</td>
<td>166</td>
<td>170</td>
<td>166</td>
<td>154</td>
<td>154</td>
<td>154</td>
<td>154</td>
</tr>
<tr>
<td>Heparin 10,000 units/10DmL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heparin Bolus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other anticoagulants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APTT</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
</tr>
</tbody>
</table>

### ECMO Orders

<table>
<thead>
<tr>
<th>24/04/10</th>
<th>26/04/10</th>
</tr>
</thead>
<tbody>
<tr>
<td>04:56</td>
<td>17:45</td>
</tr>
<tr>
<td>RPM</td>
<td>3110</td>
</tr>
<tr>
<td>Flow</td>
<td>3.50</td>
</tr>
<tr>
<td>Oxygen</td>
<td>4.00</td>
</tr>
<tr>
<td>Heparin Rate</td>
<td>4</td>
</tr>
<tr>
<td>Heparin Bolus</td>
<td></td>
</tr>
</tbody>
</table>

**ECMO Target / Acceptable Values**

- Pre Membrane Press
- Post Membrane Press

---

**Note:**

- 2010 Arterial Cath: SBO at 01/05/10

---

**Dosage:**

- Heparin 10,000 units/10DmL
- Other anticoagulants

---

**Values:**

- Resp
- Fluids
- Meds
- Pathology
- Graphs
- Medical Docs
- Pathology
- DEXA
- Acsc Charts
- Research
- ECU Policies
- Literature
- Templates

---

**Ventilation Chart:**

- ECMO
- UWSD
- Physiotherapy

---

**Other:**

- “ECMO”
- “WAND”
- “Physiotherapy”
### 7.3.9 Equipment Check

**ECMO Pump & Shift Checklist**

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME</th>
<th>AM</th>
<th>PM</th>
<th>ND</th>
<th>AM</th>
<th>PM</th>
<th>ND</th>
</tr>
</thead>
</table>

#### Power & Battery
- Connected to AC (red power point)
- LED light ON indicating mains operation
- LED light indicates battery operation (notify perfusionist)
- LED light indicates battery charging (notify perfusionist)

#### Emergency
- Hand crank available
- Flow sensor grease & plastic wrap available
- Clamps available for each access/return line (minimum 4 clamps, specialised perfusionist clamps)
- Spare O₂ tubing for oxygenator

#### Circuit Assessment
- Label & zero pre/post membrane pressure transducers
- Transducer’s positioned at level of heart?
- FiO₂ connected to oxygenator
- Inspect Oxygenator for visible clots (1/24)
  (Strict mapping of clots on plastic sheet see instructions)
- Pump Access line (still/kicking/moving)
- 9V torch available
- Ensure water heater level >1/2 full (use sterile H₂O)
- Ensure yellow cap on oxygenator

#### Cannula Assessment
- CXR position confirmed
- All cannula’s secure (Dressings secure?)
- Skin length (cm’s) of cannula (access/return)
- Skin length (cm’s) of high flow VV cannula

#### Console Settings
- Revs (RPM)
- Flow (LPM)

#### Gas Flow Settings
- Fresh Gas Flow (O₂ connected to wall LPM)

#### Nurse Initials

#### Perfusionist
- Name
- Tel No’s
8.0 WEANING ECMO

The decision to wean ECMO is made by the medical team.

The principals of V-A ECMO weaning:

- Circuit flows must be reduced to assess native heart function. This requires changes to the ventilator and oxygenator gas flow settings and increases the risk of stasis and clotting within the circuit. ECMO pump flows should not be less than 1L/min. Flows less than 1L/min may precipitate rapid clotting of the ECMO circuit.
- TOE is very helpful in assessing cardiac function when weaning from ECMO.
- Transthoracic ECHO, SvO$_2$, pulmonary artery catheter with continuous cardiac output and arterial waveform are also helpful.

Principals of V-V ECMO weaning:

- Mechanical Ventilation is increased and fresh gas flow to the ECMO Oxygenator is turned off when appropriate for a trial with no ECMO gas exchange support. It is not necessary to reduce ECMO blood pump flow rates during this process, since ECMO pump flow is generally set throughout the run at the lowest flow that provides adequate support (ELSO Guidelines, 2009). (NB: ECMO pump flow is never less than 1L/min due to the increased risk of circuit clotting).
- TOE is not required.

9.0 REMOVAL OF CANNULAE

The heparin infusion should be reviewed by the medical team prior to cannulae removal. (NB. Care should be taken if heparin is ceased since there is increased likelihood of clotting within the ECMO circuit).

The technique for removal of peripheral ECMO cannulae depends on the route of insertion.

- All peripheral arterial cannulae removal must be performed by an open surgical approach.
- All peripheral cannulae inserted via surgical cut down approach must be performed by an open surgical approach.
- Percutaneous venous cannulae may be simply removed and the site compressed for 30 minutes without surgical repair. A cardiothoracic (or vascular) surgeon should be notified of the intention to remove peripheral venous cannulae within the ICU.
10.0  **COMPLICATIONS:**

10.1  **Bleeding and Inappropriate Clotting**

**Bleeding Patient**
- This includes: post surgical; post procedural and spontaneously bleeding patients.
- Cease all heparin (NB: Heparin coated ECMO circuits may run without problems for several days without anticoagulation in some circumstances). Avoid the use of protamine as it will destroy the heparin bonds within the circuit.
- Heparin may not be recommenced until all bleeding has stopped for 12 to 24 hours. This could be longer or shorter depending upon the circumstances.
- Investigate all potential causes of bleeding and manage accordingly:
  - Cryoprecipitate to maintain fibrinogen > 1.5
  - Platelets to maintain count >80,000
  - FFP to maintain INR <1.3 (prothrombinex requires haematology approval and is generally reserved for overwarfarinized patients)
  - Consider Tranexamic acid
- If circuit clotting occurs in this context the circuit can be changed and this requires notification to the following Intensivists Cardiac surgeon, scrub team and Perfusionists.
- Obtain surgical review
- Provide local tamponade
- Factor VIIa may be considered if other options fail to arrest bleeding and prepare blood bank for potential massive transfusion requirements.
- Contact the Haematologist on call.
- Consider late options:
  - Protamine (ALERT: protamine will affect heparin bonded circuits)
  - Palliation

**Anticipated Surgery (Not yet bleeding)**
- Avoid surgery and invasive procedures where at all possible
- Replace deficits as stated above
- Cease heparin as directed by surgeon (May be 4 hours prior or not at all)

**Post surgical management:**
Do not commence heparin infusion until APTT and ACT are within target range and bleeding is < 30 mLs per hour for four hours or as directed by the responsible team.
Bleeding patients are managed as per, “The bleeding patient” (above).

**Inappropriate clotting**
Prevention of inappropriate clotting is another primary objective in ECMO. All preventative steps should be taken to avert inappropriate clotting where this is possible. (Please refer to heparin and bleeding patient protocol above).
Anticoagulation practices are based on patient bleeding and clotting risk profiles.
Any person with an identified thrombotic issue (e.g. occlusion of minor vessels, embolism in femoral artery, cerebral event, pulmonary embolism and or extensive visible clotting within the ECMO circuit) may require:
- Haematology review
- Surgical review and intervention
- Investigation of coagulation abnormalities
- Review of anticoagulant therapy. Increase in APTT target may be appropriate, however HITTS should also be considered and alternatives to Heparin (e.g. Bivalirudin or Lepirudin) may need consideration.
## 10.2 Haemolysis

Haemolysis is suspected when plasma free haemoglobin (Hb) concentration and serum bilirubin are rising.

### Plasma free-haemoglobin:
- Performed soon after establishment of ECMO and daily thereafter. Normal operating plasma free-haemoglobin level is <45 mg/dL. The sample must be handled and taken very carefully and slowly to avoid sampling error.
- A (confirmed) plasma free-haemoglobin >45 or any high reading associated with clinical evidence of intravascular haemolysis or circuit malfunction demands a rapid response and must be communicated to the medical team urgently (see below for signs of haemolysis and access insufficiency).

### Causes of elevated plasma free-haemoglobin readings:
- High pump speed settings resulting in high negative pressure on the drainage side of the pump head.
- Inadequate venous drainage, leading to frequent intermittent “suckdown”.
- Clot within the circuit, pump head, oxygenator or near the cannulae orifices.
- Inappropriate sampling (any elevated readings should be re-checked immediately with a repeat sample taken carefully and slowly from a venous port (NOT a venipuncture) and handled meticulously. Repeatedly high readings are confirmation of intravascular haemolysis).

### Signs of haemolysis:
- Red (or dark brown in extreme cases) urine
- High potassium
- Renal failure
- Jaundice (late sign)

### Signs of access insufficiency:
- Occurs when flow into the circuit from the patient is inadequate for the pump speed settings. This may occur if the venous return is insufficient or there is obstruction near the inlet of the cannulae.
- Blood flow into the circuit becomes episodic and pressure swings can be very large resulting in damage to red blood cells.
- The access line tubing may visibly shake or have a palpable “kick”.
- Continuous, hourly observation of the access line is part of routine nursing care of a patient on ECMO.
- If access insufficiency occurs repeatedly, it is a sign that adequate circuit flow cannot be achieved through one access cannula and prompt consideration of an additional cannula for high flow ECMO is required.

### Response to confirmed intravascular haemolysis:
- Ensure optimal volume state
- Review pump settings (if signs of access insufficiency present). Decrease speed if appropriate.
- Echocardiography to ensure all cannulae are not obstructed. Look for clots at all cannulae access sites.
- Carefully review all of system for signs of clotting and fibrin deposits, particularly the pump head.
- Consider changing the circuit.
- Reset anticoagulation targets. Aim for APTT 60 – 70 where appropriate and continue APTT six hourly.
- Repeat Plasma Hb at least daily.
- Repeat coagulation studies daily until settled and then Mondays and Thursdays (include APTT, PT, INR, TT, D Dimer, Fibrinogen, FBC)
- Obtain haematological review for related complex haematological issues.
10.3 Low ECMO Pump Flow and Loss of Flow

Decreased or loss of flow into the circuit from the patient may occur if the venous return is insufficient for the pump speed settings or if there is obstruction to the blood flow. Other causes of decreased or loss of flow include kinking of the cannulae, pump head disengagement, large circuit air embolism, clotting of the circuit, cannulae dislodgement and pump failure (Please refer to relevant sections of ECMO Emergency Complications Management). In addition, patient variables such as preload, cardiac contractility, afterload, heart rate and rhythm may impact on the patient’s volume status and the level of flow able to be generated by the ECMO pump.

When blood flow into the circuit is insufficient, the flow becomes episodic and pressure swings can be very large resulting in damage to red blood cells. The access line tubing may visibly shake or have a palpable “kick”, or stop moving if there is complete obstruction to flow (eg “suck down”). Pressure traces pre and post oxygenator will display large dips, (or drop to baseline and remain there if complete obstruction occurs)

If access insufficiency occurs repeatedly, it is a sign that the patient may be hypovolaemic or the pump speed settings are inappropriate or the cannulae or patient are not positioned correctly.

Interventions:

- Optimize volume status of patient (If additional fluid volume required, consider packed cells or albumin)
- Review pump speed settings
- Review cannulae position (obtain ultrasound of flow through entry and exit sites to assist assessment) and optimize if able
- Ensure patient is in optimal position
- Exclude obstructions, including kinks, clots and compression of tubing
- Optimize haemodynamic influences including preload, afterload and contractility
- Consider optimal sedation and analgesia for patients who experience decreased flow during health care activities such as re-positioning or hygiene measures
- Consider TOE to review flows for the right and left sides of the heart (especially in circumstances where V-PA pump flow may be too low to provide for adequate LVAD flow)

Where complete “suck down” has occurred, the loss of flow may result in rapid hypoxaemic arrest for VV ECMO patients or haemodynamic collapse for VA ECMO patients. Decrease the pump speed to reduce suction on the catheter and then restore flow settings towards “normal” as smoothly and as quickly as able.

If adequate circuit flow cannot be achieved through one venous drainage cannula then prompt consideration of an additional venous drainage cannula is required to facilitate draining both SVC and IVC.

10.4 Hypoxaemia

VV ECMO

The ECMO blood post oxygenator that is delivered to the patient generally has a high PaO₂ (around 400 – 500 mmHg) and saturation (~ 100%) which then returns to the patient near the right atrium, is mixed with the patient’s blood flow (cardiac output), then traverses the pulmonary capillary tree, through the left side of the heart and on to the body tissues, resulting in a peripheral arterial blood sample that often has a borderline PaO₂ (55-90 mmHg) and saturation (~ 85-95%) or less.

Determination of hypoxaemia includes clinical assessment in conjunction with blood gas analyses:

- Increasing lactate (in the absence of other causes)
- Worsening acidosis
- Worsening organ function
Signs of cyanosis

Response:
- Ensuring adequate delivery of oxygen via sufficient cardiac output, Hb 10 -12 g/dL and appropriate volume state
- Ensuring adequate ECMO pump flow (Consider increasing flow if appropriate, re-assess cannulae position to ensure optimal flow and prevention of recirculation, insert additional drainage cannula to allow increased flow and decreased re-circulation)
- Decreasing the patient’s oxygen demand where appropriate (Ensure adequate sedation and analgesia, consider neuromuscular blockade, consider mild hypothermia if appropriate, consider negative inotropic medications if appropriate)
- Ensure sufficient oxygenator function

If refractory hypoxaemia despite all of the above then consider various methods to increase oxygenation via the pulmonary system such as: Best PEEP, recruitment maneuvers if appropriate, increase FiO₂ to maximum acceptable, ventilation techniques to provide aeration but avoid baro/volutrauma (e.g. permissive hypercapnea, prolonged inspiratory time), other adjuncts e.g. inhaled NO

For **peripheral VA ECMO**, hypoxaemia usually occurs in the context of decreased lung function in combination with increased native cardiac ejection such that the left heart ejects hypoxaemic blood which then preferentially perfuses the coronary and cerebral circulations.

Response: Ensure appropriate ventilation, including FiO₂ ≥50%

Where there is severe impairment of lung function and unresolved delivery of hypoxaemic blood to the cerebral and coronary circulations, consideration may need to be given to:
- Central VA ECMO
- Suppressing native cardiac ejection if appropriate (consider adequate sedation and analgesia, consider increasing ECMO pump flow which may decrease preload to the heart, increase afterload and decrease native ejection)

### 10.5 Inadequate oxygenator function

Oxygenator dysfunction and ultimate failure usually occurs slowly over time and when significant will require change of the oxygenator or entire circuit.

Oxygenator change may be considered in the following circumstances:

i. Significant decrease in post-oxygenator PaO₂ in conjunction with significant impact on the patient’s oxygenation +/- pH balance i.e:
   - Post oxygenator gas with PaO₂ less than 200 mmHg or > 50 % drop from original and or failure to adequately remove CO₂, and /or;
   - Patient’s PaO₂ <60mmHg with signs of hypoxaemia such as increasing lactate or worsening organ function or bluish peripheries, and/or;
   - Detrimental increase in PaCO₂ and/or unacceptable acidosis.

ii. Presence of substantial blood clots and fibrin deposits with significant impact on gas exchange as indicated above.

iii. Significant haemolysis (e.g. haemolysis related to bleeding/clotting abnormalities, liver dysfunction, inadequate oxygenation), following investigation and exclusion of other potential causes of haemolysis.
10.6 Infection

Approximately 20% of adult patients receiving ECMO experience infectious complications. Possible infection sites include: blood, urinary, surgical site, wound, respiratory and others.

Techniques to avoid hospital acquired infections are:

- Heightened surveillance (since signs of infection may be masked by the extracorporeal circuit): including blood cultures taken from existing lines, and routine samples of urine, sputum, wound, nose and groin swabs on Mondays, Wednesdays and Fridays. Additional cultures as indicated.
- Carefully monitoring of therapeutic levels of antimicrobials as appropriate, since drug sequestration and altered distribution may occur on ECMO
- Appropriate antibiotics for identified organisms
- Prophylactic antibiotics as indicated
- Daily liaison with Microbiology as indicated

In addition, particular emphasis is placed upon achieving otherwise routine infection prevention techniques, including:

- Dressings and monitoring of cannulae sites
- Dressings and monitoring of surgical sites and wounds (including invasive catheters and lines)
- Pulmonary toilet (with regular bronchoscopy when appropriate)
- Mouth care
- Head of bed elevation
- Frequent patient re-positioning

11.0 ECMO EMERGENCY COMPLICATIONS

Emergency complications are dramatic, life threatening events involving the ECMO circuit that demand immediate responses. They are largely preventable.

Possible complications are:

- Cardiac arrest
- Decannulation
- Circuit rupture
- Air embolism
- Pump failure
- Oxygenator failure

General guidelines for their management are:

- Emergency Call for help (intensivist, cardiothoracic surgeons, perfusionist & others as appropriate)
- Clamp (only if appropriate)
- Manage Oxygenate (ventilation) and cardiac output (haemodynamic support).
- Eliminate Cause Manage Outcomes.
11.1 Cardiac Arrest

This is the cessation of native cardiac function resulting in pulseless circulation from any of the usual causes.

**Effects:**

<table>
<thead>
<tr>
<th>V-A ECMO</th>
<th>V-V ECMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Little haemodynamic effect if circuit flow is above 4 L/min</td>
<td>- This is the cessation of patient’s circulation.</td>
</tr>
<tr>
<td></td>
<td>- ECMO flow will diminish accordingly.</td>
</tr>
<tr>
<td></td>
<td>- Patient will be in cardiac arrest with no output.</td>
</tr>
</tbody>
</table>

**Response:**

- Establish adequate circuit flow.
- Notify ICU consultant and Perfusionists.
- Address reversible factors.
- Defibrillation may be considered.
- CPR should NOT be necessary unless ECMO pump flow is significantly compromised.
- CPR may be contraindicated in central cannulation with an open chest, where chest opening should be prepared for.

**Response:**

- Call for help.
- Notify ICU consultant and Perfusionists.
- CPR / Defibrillation as indicated.
- Address reversible factors.
- Establish adequate circuit flow as able (This may NOT be achievable if the patient has inadequate circulation).

11.2 Decannulation

This is the removal of either the access or return cannula caused by extreme tension being placed on tubing and hence cannulae and cannulation sites.

**Effect:**

<table>
<thead>
<tr>
<th>V-A ECMO</th>
<th>V-V ECMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haemodynamic collapse and hypoxaemia of varying severity (depending on underlying cardiac and respiratory reserve).</td>
<td></td>
</tr>
<tr>
<td>1. In centrally cannulated, immediate loss of ECMO support and ;</td>
<td>Hypoxaemia leading to haemodynamic collapse of varying severity (depending on underlying respiratory and cardiac reserve)</td>
</tr>
<tr>
<td>- if arterial, cannula would be pulled out of or torn off Aorta resulting in catastrophic blood loss</td>
<td>- Massive blood loss from cannulation site</td>
</tr>
<tr>
<td>- if venous, cannula would be pulled out of Right Atrium.</td>
<td></td>
</tr>
<tr>
<td>2. In peripherally cannulated, massive blood loss from cannulation site (maybe controllable)</td>
<td></td>
</tr>
<tr>
<td>- Possible introduction of air into ECMO circuit and patient</td>
<td></td>
</tr>
</tbody>
</table>
Response:

- Clamp the circuit and turn pump off.
- Call for help. Contact ICU Consultant, Surgeons and Perfusionist.
- Provide ventilation and haemodynamic support (including CPR as indicated).
- Give volume to replace blood loss.
  - If peripheral cannulation, apply pressure to the cannula site.
  - If central cannulation, prepare for chest opening.

11.3 Circuit Rupture

This is the disruption of any part of the circuit due to fracture, breakdown, cutting or puncturing of any of the components including the circuit, 3 ways taps and pump head. (NB: Significant force is required to break parts of the circuit. Careful prevention of causing damage is required.)

Effects:

<table>
<thead>
<tr>
<th>V-A ECMO</th>
<th>V-V ECMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haemodynamic collapse and hypoxaemia of varying severity (depending on extent of rupture and underlying cardiac and respiratory reserve).</td>
<td>Hypoxaemia leading to haemodynamic collapse of varying severity (depending on extent of rupture and underlying respiratory and cardiac reserve).</td>
</tr>
<tr>
<td>Possible introduction of air into ECMO circuit.</td>
<td>Possible air embolus.</td>
</tr>
</tbody>
</table>

Response:

- Clamp the circuit on either side of the circuit disruption.
- Call for help.
- Contact medical team.
- Increase the ventilator settings and inotropes to compensate for loss of support.
- Give volume to replace blood loss.
- In the event of cardiorespiratory arrest, CPR should be commenced.

Circuit Management

- If possible, manage disruption, e.g, if fractured three way tap: place sterile gloved finger over leak.
- Prepare for change of disrupted component or circuit.
11.4 **Circuit Air Embolism**

This is the introduction of air into the ECMO circuit through any of the connectors or cannulation sites.

**Effects:**

<table>
<thead>
<tr>
<th>V-A ECMO</th>
<th>V-V ECMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Massive air embolus into the pump head will de-prime the pump and stop it pumping leading to haemodynamic collapse and hypoxaemia of varying severity (depending on underlying cardiac and respiratory reserve).</td>
<td>• Massive air embolus into the pump head will de-prime the pump and stop it pumping leading to severe hypoxaemia.</td>
</tr>
<tr>
<td>• Possible introduction of arterial air embolus into the patient.</td>
<td>• Hypoxaemia leading to haemodynamic collapse of varying severity (depending on underlying cardiac and respiratory reserve).</td>
</tr>
<tr>
<td></td>
<td>• Possible introduction of venous air embolus into the patient.</td>
</tr>
</tbody>
</table>

(NB: Massive air will de-prime the pump so air should not enter the patient. Small amounts of air may collect in the top corner of the oxygenator and may require aspiration by the perfusionist)

**Response to large air embolism:**

- Clamp the circuit (anywhere on circuit) and switch off pump to prevent potential introduction of air into the patient.
- Call for help. Contact the medical team (including the responsible perfusionist).
- Provide ventilation and haemodynamic support (including CPR as indicated).

**Patient Management**

- Position patient head down.
- Volume load.
- If air embolism has entered patient's arterial system (eg VA ECMO), consider hypothermia to 34°, barbiturates, steroids, mannitol, lignocaine, as appropriate.
- If air embolism has entered venous system (eg VV ECMO), consider aspiration of right heart using PAC.

**Circuit Management (removal of air)**

- Clamp the circuit (anywhere on circuit) and switch off pump to prevent further introduction of air into the patient.
- Examine for site of air introduction and seal if possible or replace.
- Examine for extent of air bubbles and clamp (second clamp) beyond the distal extent. Remove first clamp.

**If air limited to around pump head:**

Attach a 60 ml luer lock syringe to circuit access port (distal to air) and aspirate air. Use gravity to assist movement of air to aspiration site. (Small amounts of air may be removed via the venting port of the oxygenator. Remove yellow cap from venting port if patent, ensure pump head is full of blood (not air embolism) and rotate pump head outlet to 12 o’clock and turn on pump: air should be pumped into oxygenator and removed there via the open air vent.)

**If air on the outlet of oxygenator:** clamp circuit (second clamp) at the return cannula beyond the luer port. Remove first clamp. Attach a 60 ml luer lock syringe to luer lock connector on patient return cannula and aspirate air and blood.
Once all air is removed from the circuit, return pump head and resume support. Replace the cap on the oxygenator vent.

**11.5 Oxygenator failure: Gas Transfer Disruption**

Gas transfer failure of oxygen and carbon dioxide is a gradual process that is identified through routine observation of clots and other deposits in the oxygenator, routine blood gas analysis, routine monitoring of pre and post oxygenator pressure gradient and requires elective responses by perfusion services to change the oxygenator and circuit up to the cannulae. Refer to: 10.5 Indications for change of Oxygenator.

**Oxygenator failure: Heat exchange rupture / water to blood leak.**

Oxygenator failure may also be caused by heat exchanger rupture that may involve water to blood leak. It is caused by excessive water pressure in the heat exchanger (from obstructing or rolling over the heater / cooler hoses) or by manufacturing defect.

**Effects:**

<table>
<thead>
<tr>
<th>Heat Exchanger Rupture</th>
<th>Water to Blood Leak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water spraying everywhere, loss of ability to control blood temperature through oxygenator</td>
<td>Massive haemolysis and sepsis</td>
</tr>
</tbody>
</table>

**Response:**

- Turn off Heater Cooler.
- Contact medical team.
- Use warming blanket to control patient temperature.

Water to Blood leak requires circuit replacement and treatment of haemolysis and sepsis as indicated.

**11.6 Pump failure: Electrical motor failure and pump head disengagement**

1. Pump failure is a no flow state due to failure of the electrical pump to drive the pump head. It is caused by motor failure or battery failure (no AC power connected).

2. Pump head disengagement may be a no flow state due to failure of the electrical pump to drive the pump head because the pump head is not sitting properly within the pump. This is marked by an unusual grinding noise and vibration of the pump head, and an error message on the flow sensor. The extent of “no flow” will depend upon the extent of disengagement whereby it may be possible that a small amount of flow is maintained. (NB. This is the only real practical mechanical hazard requiring circuit replacement since only this mechanism can break the rota.)
Effect:

<table>
<thead>
<tr>
<th>V-A ECMO</th>
<th>V-V ECMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>If effective cardiac output is predominantly derived from the ECMO circuit, pump failure is associated with haemodynamic collapse manifested as shock akin to cardiac arrest.</td>
<td>Hypoxaemia</td>
</tr>
<tr>
<td>If a significant native circulation is present: this is associated with significant aorto-venous (L→R) shunt i.e. blood flows passively from the aorta to the central veins reducing effective cardiac output and putting load on the heart. The extent of hypotension and hypoxia will depend on the underlying cardiac function.</td>
<td>Hypoxaemia may quickly precipitate cardiac failure and cardiovascular collapse.</td>
</tr>
</tbody>
</table>

Response
- Call for help.
- Contact medical team.
- Provide ventilation and haemodynamic support.

Pump head disengagement: Re-seat pump head properly.
- Clamp line and turn down pump speed.
- Re-engage pump head, ensuring the pump head is housed securely beneath the lip.
- Turn pump on to 1000 rpm and remove clamp.
- Gradually increase revs to previous setting.
  (If the rota has been terminally damaged, prepare for circuit change.)

Electrical motor failure
- Clamp line and turn off pump.
- Use manual hand pump whilst obtaining new ECMO blood pump console.
- Re-engage pump head in new ECMO blood pump, ensuring the pump head is housed securely beneath the lip.
- Turn on blood pump to 1000 rpm and remove clamp.
- Gradually increase revs to previous settings.
  (If the rota has been terminally damaged, prepare for circuit change.)

Battery failure
- Re-establish AC power or commence manual cranking.

* If ECMO is off for any period of time, clotting in the circuit is a possibility.

* NB: Pump Flow SENSOR failure is NOT an emergency and is marked by unchanged patient haemodynamics and an error message on the flow sensor. It is a sensor problem that is usually rectified by applying additional lubricating cream to the ultrasonic flow sensor under controlled conditions. This is performed by a Perfusionist.
12.0 PREVENTATIVE RULES OF ECMO CARE

1. No procedures to be performed on patient *without prior consent of managing intensivist* who has considered the risks of bleeding and alternatives for management. This includes:
   a. Suturing
   b. Venipuncture (any type)*
   c. Exploration (“blunt”) of wounds
   d. Insertion of nasogastric tube
   e. Change of airway
   f. Percutaneous tracheostomy

2. *Note: Central line insertions carry additional risks in ECMO patients (bleeding, malposition and air embolism) and should only be performed when deemed mandatory by experienced staff. They should not be performed for prevention of line related sepsis.*

3. Intercostal catheters should not be inserted in patients requiring veno-venous ECMO unless there is an emergent indication (mediastinal tension).
   a. Thoracotomy and sternotomy can be safely performed if indicated.

4. Protamine and antifibrinolytics should only be given at the discretion of the Intensivist in accordance with the ECMO Protocol (see anticoagulation and bleeding management in protocol) and after notification of the perfusionist On Call. These therapies carry the risk of acute circuit thrombosis.

5. No alcohol containing (cleaning) solutions should come into contact with ECMO circuit as they will cause the material to weaken and crack. Perfusion services should be notified immediately in the event of this eventuality. Betadine solution should be the only antiseptic stored in the ECMO patient cubicle.

6. A designated staff member(s) must be present to secure ECMO circuit lines to prevent tension or torsion during patient moves or daily CXR.
   a. Note: patients with surgically placed cannulae via an “open sternum” should not be routinely moved out of hours. Medical and/or perfusion staff should be present during any required moves to ensure no change in flow or access pressures occur as a result of catheter displacement.

7. Perfusion staff must be present for all transports within or without the department. Whenever possible transports should be arranged “in hours”.

8. All percutaneous cannulae must be secured at 2 points with properly adherent Elastoplast. Cannulae should be secured at the time of insertion by the cannulator and responsibility for this cannot be delegated.

9. Cannulae position is checked daily on nursing check lists and by medical staff on CXR. In the event a cannula is noted to become displaced or partially withdrawn the ICU consultant and perfusion services must be notified immediately and a decision made as to whether the catheter should be removed and reinserted before being re-secured.
7. Compliance evaluation

Q1: What guide should be used to measure coagulation status of the patient in the first 24 hours until stable of commencement on ECMO and if bleeding or clotting is a concern
A: The Actual Clotting Time

Q2: What are the causes of low flow in V – V ECMO
A: Obstruction to blood flow, cannula dislodgement, kinking of catheter, large circuit air embolus, clotting of cannula and pump failure. Patient hemodynamic status, decreased preload, afterload, contractility causing low venous flows.

Q3: How often should plasma free hemoglobin be monitored and what does it indicate?
A: Daily and it can indicate intravascular hemolysis
Other: eg: Audit Plan

8. External references

9. Extracorporeal membrane oxygenation
The Alfred Hospital, Melbourne and ECMO team, St Vincent Hospital, Sydney who provided permission to extensively use their policy document

I, Dawn Fowler, Clinical Services Manager (Medicine and Critical Care) of St George / Sutherland Hospitals and Health Services attest that this business rule is not in contravention of any legislation, industrial award or policy directive.

Revision and approval history

<table>
<thead>
<tr>
<th>Date</th>
<th>Revision number</th>
<th>Contact Officer (Position)</th>
<th>Date for revision</th>
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<tbody>
<tr>
<td>Oct 2012</td>
<td>0</td>
<td>Dr Kush Desphande ICU Staff Specialist</td>
<td>Oct 2015</td>
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<tr>
<td></td>
<td></td>
<td>Sarah Jones ICU CNC</td>
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<td></td>
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<td>Erin Casey ICU CNS</td>
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