Extracorporeal Membrane Oxygenation (ECMO)

TARGET AUDIENCE
Staff involved in management of patients receiving Extracorporeal Membrane Oxygenation (ECMO) in ICU

PURPOSE
This document describes the standardised management of patients receiving ECMO in ICU.

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This document describes the standardised management of patients receiving ECMO in ICU.

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GUIDELINE Extracorporeal Membrane Oxygenation (ECMO)

GUIDELINE

1. Application of this Protocol and Related Documents

This protocol provides guidelines for the safe practice of ECMO at The Alfred ICU. It contains references to current equipment and staffing practices. Educational resources covering relevant physiology and equipment function are located within ICU Net (ICU Intranet) under Equipment and Education. Related documents for the safe performance of ECMO include:

- ECMO Circuit Priming Guideline
- Guideline for Peripheral ECMO Cannulation
- Adult Retrieval Victoria: Introduction to Retrieval Systems For ECMO Clinical Escort Staff
- ECMO Competency Course Material
- ECMO Equipment Stock List

An overview of the staffing roles, responsibilities and training requirements are contained in the
- ECMO Clinical Service Structure and Scope of Practice

2. Equipment referred to in this Protocol

This protocol is written for the use with two Maquet ECMO Systems
- The PLS 2050 circuit and Rotaflow® Blood Pump
- HLS Advanced 7.0 circuit and Cardiohelp®

At The Alfred, ECMO always involves a centrifugal pump to drive circuit flow.

3. ECMO Definitions

ECMO or Extra Corporeal Membrane Oxygenation is a form of extracorporeal life support where an external artificial circuit 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 circulation. ECMO circuit blood flow is optimised to provide adequate patient support in the absence of native lung or heart function.

Partial Extra Corporeal Life Support incorporates a membrane oxygenator, but cannot support patients with minimal native organ function. ECLS support systems which predominately remove CO₂ (Extracorporeal CO₂ Removal – ECCO₂R) are not specifically covered in this protocol and are not in use at The Alfred. This includes the Arterio-venous partial support systems (Novalung).

The Mode of ECMO is defined by the position of the access and return cannulae. There are three modes of ECMO: Veno-Venous (VV), Veno-Arterial (VA) and Veno-Pulmonary Artery (V-PA).

VV and VA modes of ECMO have a number of configurations to best suit patient needs.

The Configuration of ECMO refers to the cannula insertion site, type, tip position and size used in a particular mode.

Cannulae Definitions:

- Access Cannulae: drain blood from the venous system into the ECMO circuit. (See Figure 1)
  i. Single-stage access cannulae drain blood via a short region near the tip only
ii. Multi-stage access cannulae drain blood through side holes over a long length of the cannula in addition to the tip.
b. **Return Cannulae**: deliver blood back to the patient from the ECMO circuit and only ever expel blood at the cannula tip (single stage).

c. **Distal Perfusion Cannula**: Deliver blood antegradely into the femoral artery distal to the ECMO return cannula to maintain perfusion to the leg. This cannula is a straight reinforced 9F cannula (or similar). (See section 14c. Prevention of lower limb arterial insufficiency, page 29)
d. **Double-lumen Cannulae** single cannula partitioned into two lumens with both access blood flow and return blood flow, similar to vascular access cannulae used in renal replacement therapy.

e. **Cannula Length**
   
   i. Long cannulae (55 cm) are labelled by manufacturers as “venous” and are designed for use in the venous system.
   
   ii. Short cannulae (15-25cm) are labelled by manufacturers as “arterial”. They are used to return blood in both VA ECMO and some VV ECMO configurations (femoro-jugular) and to access venous blood via the jugular vein in high flow (VV and VA) ECMO configurations. These cannulae also have side ports that can be connected to distal perfusion cannulae (in peripheral VA configurations).

4. **ECMO Modes**

Three Modes of ECMO are currently practiced at The Alfred:

- **Veno-venous ECMO (VV ECMO)**: support for respiratory failure
- **Veno-arterial ECMO (VA ECMO)**: support for cardiac failure
- **Veno-pulmonary artery ECMO (V-PA ECMO)**: support for right ventricular function post left ventricular assist device (LVAD) insertion
Some patients require more than one mode of ECMO support over the duration of their illness, but patients only receive one mode of ECMO at a time.

a. **Veno-Venous ECMO**: Venous blood is accessed from the large central veins, pumped through the oxygenator and returned to the venous system near the right atrium. It provides support for severe respiratory failure where the circulation is powered entirely by native cardiac function. There are 4 configurations of VV ECMO used at The Alfred.
   i. Femoro-Femoral (Fem/Fem)
   ii. High-Flow
   iii. Femoro-Jugular
   iv. Dual lumen/Two stage single cannula (Avalon)
   In all cases, ECMO blood flow travels from the vena cavae to the atria (**Cavo-Atrial Flow**) to minimise recirculation\(^1\).

b. **Veno-Arterial ECMO**: Venous blood is accessed from the large central veins, pumped through the oxygenator and returned to the systemic arterial system in the aorta. Recirculation cannot occur in V-A ECMO. It provides support for severe cardiac failure (with or without associated respiratory failure). There are 5 configurations of VA ECMO used at The Alfred
   i. Standard Femoro-Femoral
   ii. Emergency Femoro-Femoral
   iii. High-Flow
   iv. Central: Specialised cannula
   v. Central: Bypass cannula

c. **Veno-Pulmonary Artery ECMO**: Venous blood is accessed from a large central vein, pumped through the oxygenator and returned to the pulmonary arterial system. It provides short-term right ventricular and respiratory support following LVAD insertion. The oxygenator does not necessarily need to be included in the circuit when respiratory function is adequate; in these circumstances the extracorporeal circuit is a temporary RVAD. Decannulation can occur without the need for re-sternotomy.
5. **VV ECMO Configurations**

   **a. Femoro-Femoral:**
   
   i. Two long "venous" cannulae are used
   
   ii. Direction of flow is cavo-atrial to minimise recirculation
   
   iii. Access cannula (single stage, or multistage) is inserted via the femoral vein with the tip sited within the hepatic IVC. Usual sizes 21-25 F
   
   iv. Return cannula (single stage) is inserted via the contralateral femoral vein with the tip sited within the right atrium. If the tip is advanced too far it will impinge on the inter-atrial septum. Usual sizes 21-25 F
   
   v. The tip of the access cannula is positioned 10-15cm lower than the tip of the return cannula to minimise recirculation.
   
   vi. Advantages: Quick and safe to insert; easy to secure cannulae; circuit pressures will allow connection to CRRT (Prismaflex)
   
   vii. Disadvantages: Limited maximum flow rates so often requires conversion to a high-flow configuration. Patient remains bed bound.

   ![Diagram of VV ECMO Configuration](image)

   **b. High-flow:**
   
   i. Uses the same bi-femoral cannulation as femoro-femoral (see above)
   
   ii. An additional short access cannula ("arterial") is inserted via the right internal jugular vein with the tip sited in the superior vena cava. The optimal position of the tip is established after commencing full circuit blood flow. The tip is withdrawn sufficiently to prevent visible recirculation. Usual size 17-19 F
   
   iii. Direction of flow is bi-cavo-atrial to minimise recirculation
   
   iv. Advantages: Allows higher circuit blood flows as two access cannulae draw patient blood from the great veins (SVC & IVC). It is required when single access cannula circuit flow is inadequate to maintain sufficient levels of gas exchange in more severe cases of respiratory failure (ie where native cardiac output significantly exceeds circuit flow). Can
provide maximal oxygen delivery if configured correctly. Circuit pressures will allow connection to CRRT (Prismaflex).

v. See section 17 (page 35) for description of the technique for conversion from femoro-femoral to high-flow.

vi. Disadvantages: Occupies 3 veins. Relatively complex to secure and dress the jugular cannula. Patient remains bed bound. Side-port on the short ("arterial") cannula is a potential source of air embolism and must remain tightly sealed during use; it is also a potential source of pressure injury.
c. Femoro-Jugular:
   i. Direction of flow is cavo-atrial to minimise recirculation
   ii. Access cannula (multi-stage) is inserted via the femoral vein with the tip sited just below the inferior cavo-atrial junction. Usual size 21-25 F
   iii. Return short cannula (“arterial”) is inserted into the right internal jugular vein with the tip sited in the lower superior vena cava. Blood returning in this direction preferentially flows towards the tricuspid valve and right ventricle, which minimises recirculation. Usual sizes 19-23 F
   iv. Advantages: Nearly always can provide adequate support (5-7 L/min) without large recirculation, only two veins occupied. Circuit pressures will allow connection to CRRT (Prismaflex)
   v. Disadvantages: Relatively difficult to secure and dress the jugular return cannula. Requires two sterile fields to be during ECMO cannulation. Access insufficiency can be more difficult to identify in the early stages without negative pressure monitoring (Rotaflow/PLS). Patient remains bed bound.

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d. Dual lumen/Two stage single cannula (Avalon):
   i. Direction of flow is bi-cavo-atrial to minimise recirculation
   ii. Single cannula with two lumens for access and return inserted via the right internal jugular vein.
   iii. Two access stages (SVC and IVC)
   iv. Return port emerges between the two access ports and is positioned at the level of the tricuspid valve.
   v. Advantages: Single vein cannulation. Allows movement from bed and potentially ambulation
   vi. Disadvantages: Care on insertion to avoid right ventricular placement/rupture and hepatic vein cannulation. Large cannula to insert (27F or 31F for adults). Difficult to position return port towards the tricuspid valve. Difficult to run CRRT via the circuit due to high
circuit pressures. Must be carefully secured to accommodate the unsupported weight of the ECMO circuit, prevent catheter movement (or accidental decannulation) and pressure injury.
6. VA ECMO Configurations

a. Standard Femoro-Femoral
   i. Access Cannula (multistage) is inserted via the femoral vein with the tip sited within the right atrium without impinging on the interatrial septum. Usual size 21-25 F
   ii. Return cannula is a short "arterial" cannula inserted via the common femoral artery. This cannula is fully inserted to the taper, with the tip lying in the common iliac artery or lower aorta. Usual size 17-21 F
   iii. Additional distal perfusion 9F return cannula (“backflow cannula”) is inserted antegrade into the common femoral artery and directed into the superficial femoral artery. It is connected to the side port of the short "arterial" return cannula and adequately secured
   iv. Advantages: Provides full or partial cardiac support. Can support CRRT (Prismaflex) circuit connection
   v. Disadvantages: Risk of differential hypoxia - may need conversion to high-flow configuration if native cardiac function improves in the setting of significant respiratory failure (See section 17, page 17)
b. Emergency Femoro-Femoral
   i. Similar to standard femoro-femoral cannulation but uses **smaller** cannula, which are quicker to insert in an emergency. Usual size: 19-21F multistage venous and 15F arterial return.
   ii. Back-flow cannula is only inserted after ECMO is established
   iii. Advantages: Faster to insert. Used for ECMO-CPR or in peri-arrest patients.
   iv. Disadvantages: High circuit pressures (smaller return cannulae) may not support CRRT. Risk of differential hypoxia - may need conversion to high-flow configuration if native cardiac function improves in the setting of significant respiratory failure (See section 17, page 17)
c. High-Flow
   i. Uses the same bi-femoral cannulation as standard femoro-femoral configuration (see above) with an additional short access (“arterial”) cannula inserted via the right internal jugular vein with the tip sited in the superior vena cava. Usual size 17-19 F
   ii. Advantages: Used to minimise differential hypoxia when native cardiac function improves in the setting of significant respiratory failure.

![Diagram of ECMO setup]

**d. Central: Specialised cannulae**
   i. Uses specialised surgical cannulae. Access cannula is wire reinforced and malleable and is sited within the right atrium via the atrial appendage. Cannula is then tunnelled out of the chest and the sternum closed. Usual size >30 F
   ii. Return cannula is Dacron tipped and sewn directly onto the proximal aorta. Cannula is then tunnelled out of the chest and the sternum closed. Usual size >30 F
   iii. Advantages: Can provide full cardiac and respiratory support and is not associated with differential hypoxia in the setting of combined cardiac and respiratory failure. Optimal support for severe cardiac and respiratory failure in the immediate post cardiotomy setting. Allows sternum to be closed and facilitates standard patient pressure area care. Low circuit pressure easily supports CRRT connection. Can provide support for up to 2 weeks
   iv. Disadvantages: Requires sternotomy for institution and re-sternotomy for decannulation. Bleeding more common than in femoro-femoral configuration.
e. Central: Bypass cannulae
   i. Uses existing bypass aortic and venous cannula which emerge via the open sternum
   ii. Disadvantages: Increased bleeding. Cannot support the patient safely beyond 5 days. Open sternum prevents standard patient pressure area care.
7. Patient Selection

ECMO is indicated for life-threatening forms of respiratory and/or cardiac failure where the risks of less invasive support are considered greater than the risks of ECMO and there is a reasonable expectation of long-term survival without severe disability. It is always applied at the discretion of the managing Intensivist or Cardiac Surgeon. All ECMO admissions to ICU are at the discretion of the ICU ECMO Clinical Service.

a. Contraindications for all forms of ECMO (See Appendix 1, page 50)
   i. Presence of additional severe chronic organ failures (cirrhosis, COAD, end-stage renal or hepatic failure)
   ii. Severe brain injury
   iii. Malignancy
   iv. Age > 75

b. Conditions where ECMO should be considered and is commonly associated with favourable clinical outcomes
   i. Respiratory Failure (age < 65)
      a. ARDS with primary lung injury from infection, aspiration or direct trauma
      b. Primary graft dysfunction following lung transplantation (within 7 days)
      c. Pulmonary vasculitis (Goodpasture’s, ANCA-associated, Autoimmune)
   ii. Cardiac Failure (age < 65)
      a. Acute fulminant myocarditis
      b. Cardiomyopathy first presentation
      c. Primary graft failure: post heart / heart-lung transplant
      d. AMI-cardiogenic shock without multiple organ failure
      e. Drug overdose with profound cardiac depression or arrhythmia
      f. Pulmonary embolism with cardiogenic shock
      g. In-hospital cardiac arrest (with ECMO commenced within 60 min)
      h. Post cardiac surgery (failure to wean from CPB)

c. Conditions where ECMO is often considered, but outcome is variable. Acceptance of patients for ECMO support with these conditions depends on individual patient circumstances and must include discussion with experienced ECMO Clinical Services Staff
   i. Respiratory Failure
      a. ARDS from secondary lung injury (e.g. intra-abdominal sepsis or burns)
      b. Lung transplant recipients 7-30 days post transplant
      c. Lung transplant recipients > 30 days and suitable for re-transplantation from ECMO
      d. Age >65 (any cause)
   ii. Cardiac Failure
      a. Chronic cardiomyopathy (suitable for VAD and heart transplant) with acute severe heart failure or sepsis
      b. Ischaemic cardiogenic shock with multiple organ failure or sepsis
      c. Heart transplant recipient with chronic rejection and end stage heart failure and suitable for VAD and re-transplantation
      d. Age >65 (any cause)
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d. Conditions where ECMO should NOT be applied, as survival from ECMO is very low.
   Compassionate use of ECMO in these conditions would be associated with remarkable patient circumstances.

   i. Respiratory Failure
      a. Interstitial Lung Diseases/Pulmonary Fibrosis ("negative" biopsy is required to exclude this process for patients referred for ECMO at high clinical risk, such as known SLE, RA, scleroderma, sarcoidosis, dermatomyositis, methotrexate toxicity, etc)
      b. Lung transplant chronic rejection
      c. Cystic fibrosis (infrequent use as bridge to transplant)
      d. Severe acute restrictive lung disease with relatively clear CXR (early) is suggestive of cryptogenic organizing pneumonia (bronchiolitis obliterans with organizing pneumonia) and biopsy should be performed prior to instituting ECMO if this condition is suspected
      e. Long-term immuno-suppressed (heart, renal, bone marrow transplant recipients, HIV, Graft versus host lung disease)

   ii. Cardiac Failure
      a. Un-repaired moderate-severe aortic or mitral valve regurgitation

e. ECMO should not be applied in some conditions in the presence of multiple acute organ failures prior to the initiation of ECMO, as survival is very low.

   i. Respiratory failure with septic shock and 3 or more of the following features
      a. Lactate > 10
      b. Noradrenaline > 1.5µg/Kg/min
      c. Severe myocardial depression
      d. Advanced microcirculatory failure with severe mottling or established peripheral purpura

   ii. Cardiogenic shock and 3 or more of the following features
      a. Lactate >15
      b. Advanced microcirculatory failure with severe mottling or established peripheral purpura
      c. AST or ALT > 2000, or, INR >4.5
      d. Anuria >4 hours

8. Clinical Triggers for ECMO

a. Respiratory Failure: Clinical triggers and logistic factors to be considered when determining the need for and the timing of ECMO:

   i. The inability to maintain SaO2 >88 or pH > 7.20 with mechanical ventilation settings:
      Plateau Pressure ≤ 35 and Tidal Volume ≤ 6 ml/Kg (predicted body weight) despite
      • Diuretic therapy (where appropriate)
      • Trial of high PEEP (18 – 22)
      • Trial of recruitment maneuver (if not contraindicated)
      • Consideration of trial of HFO ventilatory support
      • 2-12 hour trial of iNO or alternative pulmonary vasodilator (if available)
      • Adequate cardiac support
      • Echo assessment
      • Inotropes

   ii. Rate of lung injury progression. Rapidly progressive (6-12 hours) lung infiltrates and increasing ventilator requirements particularly in the early stages of hospital admission
are often associated with a fulminant illness that reduces the time window when ECMO may be of benefit

iii. Onset of secondary organ failures (renal failure, circulatory failure) with primary lung processes. The development of early renal failure or need for high dose vasoactive support secondary to respiratory failure may support earlier ECMO commencement

iv. The need for inter-hospital patient transportation. ECMO is currently considered the safest mode of respiratory support for unstable patients with severe respiratory failure requiring inter-hospital transport

b. **Cardiogenic Shock:** Clinical triggers and logistic factors to be considered when determining the need for and the timing of ECMO:
   i. Pharmacological support of cardiac index and blood pressure are likely to exacerbate cardiac injury
   ii. Cardiac index and blood pressure refractory to pharmacological support:
      - Moderate or high dose inotropes (adrenaline > 0.3 µg/Kg/min equivalent) in combination with an IABP, vasopressors and positive pressure ventilation for predominately left ventricular failure
      - Moderate or high dose inotropes (adrenaline > 0.3 µg/Kg/min equivalent) in combination with pulmonary artery vasodilator and/or vasopressors for predominately right ventricular failure
   iii. Lactate > 5 mmol/L
   iv. Onset of hepatic or skin ischaemia tend to be late signs that may be indicative of a pre-terminal state

9. **ECMO Referral Pathway (including Inter- and Intra-Hospital Transport)**

Related documents:
- ECMO Clinical Service Structure and Scope of Practice
- Adult Retrieval Victoria: Introduction to Retrieval Systems For ECMO Clinical Escort Staff
See Appendix 2: External ECMO Referral Pathway, page 51
See Appendix 3: Retrieval Equipment Checklist, page 52
See Appendix 12: Referral Hospital Equipment List, page 63

a. **Internal (Alfred Hospital)**
   i. Referrals for ECMO support of patients within the Alfred Hospital, but **outside the ICU**, will be made through the ICU Consultant on for Referrals and External Wards. This clinician will be responsible for arranging for accredited ICU staff to perform cannulation under ultrasound and echocardiographic guidance and also facilitating ICU admission. Two ICU Consultants are always rostered on for ECMO cannulation. Cardiac failure patients will be admitted to Cardiac ICU and respiratory failure patients will be admitted to General ICU
   ii. The ICU consultant managing the patient will arrange ECMO cannulation for patients **within the Alfred ICU**.

b. **External**
   i. External referrals for ECMO support for patients **outside the Alfred Hospital** will be made through the ICU Consultant on for Referrals and External Wards. This clinician will be responsible for arranging for accredited ICU staff to perform cannulation under ultrasound and echocardiographic guidance and also facilitating ICU admission at the Alfred Hospital. In the event that the referred patient has a condition other than one for which ECMO is routinely used, an experienced ECMO Clinical Services Consultant should be contacted prior to accepting the patient for ECMO retrieval.
a. Two ICU Consultants are always rostered on for ECMO cannulation at referring hospitals. Staffing to perform ECMO cannulation and retrieval is limited to 09:00 – 20:00 hours weekdays
b. ECMO retrievals are performed in conjunction with Adult Retrieval Victoria (ARV) in accordance with the Memorandum of Understanding 2010
c. Retrieval of stable patients already on peripheral ECMO support from other hospitals may be performed by one ICU accredited consultant and an ECLS Co-ordinator or ARV Accredited Perfusion Staff

10. Circuit Priming of PLS and HLS circuits

See Related Document:
- ECMO Circuit Priming Guideline

a. **Staffing:** An ECLS Co-ordinator, accredited ICU Consultant, or a member of the Perfusion Department perform and/or supervise ECMO circuit priming.

b. **Pre-primed PLS circuits:**
   i. A PLS ECMO circuit pre-primed with 0.9% sodium chloride should be available at all times within the ICU. Pre-primed circuits may be used up to 30 days from priming date
   ii. Pre primed PLS circuits are initially primed with CO₂ prior to fluid priming to reduce incidence of air emboli on initiation.
   iii. Normal Saline primed PLS circuits are “albumin-coated” with 100mls of 20% Albumin immediately prior to commencement of ECMO

c. **Protein Coating:** HLS circuits are to be primed and albumin coated just prior to ECMO initiation. Albumin coated circuits cannot be stored.

d. **Pressure zeroing (HLS only):** Prior to priming of HLS circuit ensure that empty circuit is mounted to Cardiohelp machine and all circuit pressure monitoring are zeroed at this stage. Once primed zeroing cannot be carried out and the ability to monitor circuit pressure parameters will be unavailable.

e. **Pre pump access ports (PLS only):** All ECMO circuits primed at The Alfred have no access ports on the negative pressure (access) side of the circuit to reduce the incidence of air entrainment. PLS circuits do come with two ports on the negative pressure (access) side of circuit when removed from box. These ports are cut out of circuit during priming process by accredited staff. ECMO circuits that arrive from other centres may have access ports on the negative pressure side of the circuit. These should be immediately secured with sleek, and consideration given to changing out the circuit within 24 hours of admission to the Alfred ICU for operational and patient safety concerns, especially where CRRT is required.

11. ECMO Initiation

Related Documents
- Guideline for Peripheral ECMO Cannulation with Ultrasound Guidance
- ECMO Circuit Priming Guideline

See Appendix 4: Bedside ECMO Trolley Equipment List, page 54
See Appendix 5: Rotaflow/PLS Start of shift Checklist, page 56
See Appendix 6: Cardiohelp/HLS Start of shift Checklist, page Error! Bookmark not defined.

a. **Percutaneous Cannulation:** Percutaneous peripheral cannulation with ultrasound guidance is the first line technique for establishing ECMO support in the majority of patients provided the presence of adequate femoral and jugular vessels. This is performed by accredited ICU medical staff and surgeons.

b. **Trolley setup**

i. ECMO trolley is situated at the foot of the bed with the pump head and oxygenator facing toward the patient. The gas and blood flow controls face away from the patient. Power cords and gas tubing must be not tangled with the ECMO circuit and must not protrude onto the floor space around the patient bed. Torsion on the ECMO circuit is to be avoided.

ii. Note that for:
   d. double lumen jugular catheter (Avalon®) configuration for VV ECMO and
   e. femoro-jugular configuration for VV ECMO
   the standard circuit tubing length will be insufficient to reach an ECMO trolley situated at the foot of the bed. In this case, the trolley is positioned at the patient’s left.

iii. An emergency drive unit (“hand crank”) must be sited on the trolley in a position where-by the centrifugal pump can be transferred immediately in the case of either console or pump head failure.

iv. The pressurised fluid bag for transducing the pre and post oxygenator pressure in the PLS circuit must be located below the level of the ECMO drive console and not above the external drive unit. This will ensure that no fluid spills into the console or the external drive unit in the event of fluid bag rupture.

v. ECMO trolley equipment list (See Appendix 4, page 54)
c. Pump head orientation and Oxygenator position

i. Cardiohelp/HLS®: Pump head position is fixed within the Cardiohelp.
ii. Rotaflow/PLS®: Pump head orientation is set using a mechanical arm. The pump head should be sited slightly higher than the oxygenator with the pump outlet pointing down (“six o’clock”). The pump head inlet should also be positioned at approximately 30˚ to the vertical.
iii. Oxygenator should be lower than the patient in the PLS platform
iv. Gas outlet of the oxygenator must not be occluded in any way
v. In the Cardiohelp/HLS® the oxygenator position is fixed within the Cardiohelp Unit

d. Gas and Power connections: These connections must be established and tested prior to patient connection.
   i. The AC power indicator must be lit. This confirms AC power connection
ii. The AC Power Isolation Switch at rear of console must be "on". If the Power Isolation Switch is accidently switched to off, the AC power indicator will not light up after more than 15 seconds of AC power connection.

iii. Air and oxygen “wall” connections are established and the blender alarm is tested during connection (audible alarm).

iv. The fresh gas flow meter should be set to the desired gas flow. On initiation the fresh gas flow and ECMO blood flow should be commenced at a 1:1 ratio, and assessed via ABG post initiation. The reading should be made from the centre of the “ball” on the flow meter.

v. The outlet tubing from the fresh gas flow meter (before the oxygenator connection) is briefly occluded as the “ball” in the flow meter is observed. Shifting of the “ball” in the flow meter in response to the occlusion indicates a functioning fresh gas flow meter.

vi. Fresh gas tubing is connected to the oxygenator inlet.

vii. Ensure only selected high or low flow side of fresh gas flow meter is on and not both.

e. Starting Circuit Blood Flow

i. The PLS system blood flow signal is obtained prior to patient connection via application of ultrasonic paste to flow sensor in pump head.

ii. The HLS system blood flow signal is obtained via the magnetic flow sensor that is clamped securely over the return (post oxygenator) line with flow indicator arrow facing direction of blood flow in circuit (away from the oxygenator).

iii. The circuit is clamped distal to the oxygenator (and distal to the flow sensor on the HLS) during cannulae connection. This clamp is the last clamp to be removed and is the responsibility of the person controlling the pump.
iv. After patient connection, all other clamps are removed and only the post oxygenator clamp is left on

v. Pump speed is set to approximately 1000RPM and the post oxygenator clamp is released over approximately 3-5 seconds as RPM is gradually increased and correct direction of blood flow confirmed.

vi. After unclamping, the speed setting (“RPM”) is increased to achieve the desired blood flow.

vii. Colour change across the oxygenator confirms gas delivery and function

f. Flow Signal
The flow signal from the circuit needs to be re-zeroed once ECMO has been established (due to the different ultrasonographic properties of blood when compared to the crystalloid prime) to improve the accuracy of the flow readings.

i. Zeroing Rotaflow/PLS platform
   a. Circuit is clamped post oxygenator and the speed setting (RPM) is returned rapidly to zero
   b. Zeroing is performed by holding down the “0” button and confirmed when the flow reading indicates zero flow.
   c. Pump speed is set to approximately 1000 revs/min and the clamp is released over approximately 3-5 seconds whilst simultaneously increasing RPM until desired flow is reached

ii. Flow Signal Zeroing Cardiohelp/HLS platform is performed soon after establishing ECMO support
   a. Clamp circuit below and upstream of flow sensor on return line (ensure direction of flow arrow of flow sensor pointing in correct direction)
   b. Turn speed setting (RPM) to zero
   c. Select the flow monitoring screen on the touch screen panel and then press the zero indicator button once until zero flow is confirmed on the flow panel
   d. Pump speed is set to approximately 1000 RPM and the clamps are released over approximately 3-5 seconds whilst gradually increasing RPM until desired flow is reached

g. Transmembrane (transoxygenator) Pressure Monitoring: (PLS system only)
   i. Once ECMO support is established, pre- and post-oxygenator pressure monitoring can be established.
      a. Connect a pre-primed and pressurised transducer and bag to the J-loops immediately pre- and post-oxygeator. Aspirate via the 3-way tap and then open the tap to the circuit.
      b. Ensure bag is pressurised to 300mmHg and hung below drive console and away from the external drive unit
      c. Connect transducers to pressure modules, select appropriate monitor labels and zero.
      d. Record the transmembrane pressure gradient hourly (the difference between the pre- and post-oxygenator pressures)
      e. A normal gradient should be between 20 to 40mmHg. Higher readings may be related to clot formation within oxygenator, return cannula size or excessive flow rates. (See troubleshooting 16 f, page 34)
   ii. Cardiohelp/HLS utilises internal pressure monitoring characteristics and does not require external pressure monitoring (see HLS priming section)
12. ECMO Related Clinical Duties (Commencement to Weaning)

Related Documents:
- ECMO Clinical Service Structure and Scope of Practice

See Appendix 5: Rotaflow/PLS Start of Shift Nursing Checklist, page 56
See Appendix 6: Cardiohelp/HLS Start of Shift Nursing Checklist, page Error! Bookmark not defined.
See Appendix 7: ECMO Observations, Daily Targets and Daily Checklist, page 58
See Appendix 8: VV Clinical Pathway, page 59
See Appendix 9: VA Clinical Pathway, page 60

a. ECMO-specific roles for ICU Nursing and Medical staff from ECMO initiation to weaning are listed below: Section 13-14

b. The Alfred Perfusion Department provide a consultative service to ICU for the care of ECMO patients. They may be consulted to assist with
   i. Troubleshooting
   ii. Emergency responses
   iii. Transports to Operating Theatre: If a patient supported on ECMO within the Alfred ICU is required to go theatre at any stage, the treating ICU Consultant or Senior registrar must contact the Perfusion department within a reasonable time frame to arrange transport from ICU to theatre and back to ICU. A Perfusionist will receive a handover at the bedside prior to leaving the ICU and thus assume responsibility for the ECMO circuit until the patient is returned to ICU. The Perfusionist will give a handover once they return the patient to ICU
   iv. Training: Provide accreditation assessment for ICU staff
   v. Thromboelastogram (TEG) studies

13. ECMO Specific Routine Nursing Care

a. Start of Shift Nursing Checklists must be performed after admission, at the start of each shift and on return from intra-hospital transport
   i. Rotaflow/PLS Start of Shift Nursing Checklist (Appendix 5, page 56)
   ii. Cardiohelp/HLS Start of Shift Nursing Checklist (Appendix 6, page Error! Bookmark not defined.)

b. ECMO Console Settings:
   i. Alarm Settings
      a. Low ECMO Blood Flow Alarm is set 0.5L/min below target flow
      b. Speed setting Alarm: High and Low Speed Setting Limits are set 500 RPM above and below the current RPM. This is to alert beside staff to manual pump speed settings changes
   ii. Speed setting: The pump speed RPM is selected to deliver desired circuit blood flow. The pump speed setting required to achieve a given circuit blood flow is dependent on the resistance to flow in the circuit and the load across the circuit. Speed settings are chosen by ECMO accredited ICU bedside staff only.
   iii. Mode setting
      a. Rotaflow/PLS System: defaults to the “FRE” mode when started. This indicates that the device is not connected to any external peripheral device such as a roller pump used during bypass, bubble detectors, or reservoirs. The MODE option should never be selected or changed in the menu options as this will shut down the pump.
b. Cardiohelp/HLS System defaults to “ICU” mode on start up. Two other mode options are available: OR (operating room) or TM (transport mode) in the main menu. Changing the mode will not affect the running of the pump, but will alter the display and monitored variables. Only the ICU mode is to be used at the Alfred ICU.

iv. LPM Function (Litres per minute) Both the Rotaflow and Cardiohelp consoles offer the LPM function which, when set, will run the pump speed automatically to achieve a selected blood flow target. This function is unsafe during episodes of Access Insufficiency (see Section 16e, page 33). This function should never be used at The Alfred

v. “Interventions” setting (Cardiohelp/HLS only) The Cardiohelp HLS system has the added functionality of setting “Interventions” around certain clinical parameters such as circuit pressures and blood flow. When “Interventions” are enabled, the device automatically controls interventions in response to bubble, circuit blood flow, or pressure alarms. WE DO NOT SUPPORT THE USE OF INTERVENTIONAL SETTINGS WITH THE CARDIOHELP ECMO DEVICE IN THE ALFRED ICU due to the risk of unintentional alterations to (including discontinuation of) ECMO support.

c. ECMO Observations and Documentation: Required Hourly ECMO Observations for bedside charting are listed on a sticker for the bedside chart (see Appendix 7, page 58)

i. Distal Perfusion (“Backflow”) cannula and leg vascular observations must also be performed each hour for patients on peripheral VA ECMO. In the event that blood flow through the distal perfusion circuit is occluded, blood within the back-flow tubing will separate into plasma and cells, which is obvious on inspection. Normal blood flow can be seen under torchlight. Medical staff must be contacted immediately if the distal perfusion circuit blood flow stops or if there are any concerns about the adequacy of perfusion to the leg.

d. Routine Plasma free haemoglobin sampling: Performed 6 hourly whilst on ECMO (routinely with the APTT samples) according to clinical need/ECMO clinician direction. Samples are taken by passively filling a 10ml syringe carefully. Do not connect to a negative pressure “vacutainer” for sampling. The plasma-free Hb collection tube is filled from the syringe after removing the lid, gently injecting blood from the syringe and then replacing the lid. No needles are required. Samples must be hand delivered to the lab to avoid shaking, which will falsely raise the plasma free-haemoglobin. Normal operating plasma-free-haemoglobin level is <0.10 g/dL.

i. In the event of Plasma free-haemoglobin reading above 0.10 g/dL

- Patient should be assessed immediately for evidence of intravascular haemolysis: dark/red urine or CRRT effluent with high K+
- Circuit should be assessed for signs of malfunction: “noisy” pump head (pump head thrombosis), visible access insufficiency, or high transmembrane pressure gradient (oxygenator thrombosis)
- A high reading associated with clinical evidence of haemolysis or circuit malfunction demands a rapid response and must be communicated to the ICU Consultant immediately
- If the circuit is functioning and there are no clinical signs of haemolysis then a repeat sample should be taken and meticulously handled
- Repeat readings above 0.10 g/dL indicate likely low level haemolysis.
- Causes of low level haemolysis include: access insufficiency without visible kicking (may require echocardiography to detect venous “suck-down” with a multistage cannulae); vessel-cannula impingement due to pericardial collection or retroperitoneal haematoma; or excessive speed settings with small cannulae (greater than 4000 RPM).

e. CRRT (Prismaflex) Connections: For most ECMO configurations, the ECMO circuit provides the optimal access for continuous renal replacement therapy (CRRT) and a separate vascular access catheter (vascath) is not required. ECMO configurations that may not support CRRT due to excessive circuit pressures are: double lumen bi-caval (Avalon Elite) configuration in VV ECMO.
and any VA ECMO configuration with a small return cannulae (≤17 Fr). In these settings, a vascath may be required. The process of connection of the CRRT (Prismaflex) circuit is described below.

i. ECMO trained bedside ICU nurse carries out connection and disconnection of CRRT from the ECMO circuit.

ii. CRRT connection must always be sited on the positive pressure (post pump) part of the circuit. No ports exist for connection pre-pump (access) side of an Alfred Hospital ECMO circuit.

iii. The CRRT machine (Prismaflex) will access highly positive pressure blood flow when connected to an ECMO circuit. Current Prismaflex software will accept this pressure range after standard start up.

iv. ECMO Circuit ports for CRRT connection

   a. PLS Circuit connections: the access and return lines for CRRT are connected to the two Luer lock connectors between the outlet of the pump head (post pump) and the oxygenator. The access line for CRRT is attached to the "proximal" (closer to the pump head) connector and the return line for the CRRT circuit is connected to the "distal" (closer to the oxygenator) connector.

   b. HLS Circuit connections: Oxygenator inlet and outlet Luer taps with wide bore extensions are used for CRRT connection. The CRRT access line is connected to the oxygenator inlet port and the return line for CRRT is connected to the post oxygenator connector.

v. Blood from CRRT circuit must never be returned to patient via ECMO circuit.

f. ECMO dressings and line position monitoring: Initial cannulae dressings and ECMO line securing must be performed by the cannulator (medical) and cannot be delegated. The bedside nurse is responsible for maintaining cannula dressings and re-dressing soiled or inadequate dressings (in consultation with the medical team).

i. Line position monitoring is performed at least once per shift for patients with peripheral cannulae. Skin markings (with indelible marker) adjacent to the wire-plastic junction of the
cannula allow quick detection of cannula movement. Migrating ECMO cannulae must be immediately reported. These are also recorded on ECMO daily checklist. ECMO lines are secured with specialised adhesive dressings to prevent movement. Two dressings per line.

g. **Pressure area care:** Safe pressure area care is essential during ECMO support and should be performed at usual frequencies in all ECMO patients. Patients on peripheral and V-PA ECMO can be rolled. An additional person is required to hold the ECMO lines during turns. Rotating beds are desirable for all ECMO patients. Patients supported on peripheral ECMO can be elevated head up to 30 degrees. Patients with ECMO support with an “open sternum” may not be rolled and require alternate means of preventing pressure area injury e.g.: KCl mattress and Jordan Frame moves. Owing to the potential for cannula dislodgement, any pressure area care, turns, Jordan framing, dressings or manipulation of the circuit require an ECMO trained consultant / senior registrar to be available in the intensive care unit. Where essential these procedures can occur out of hours.

h. **Patient Arterial Blood Gas (ABG) sampling and Fresh Gas Flow (FGF) adjustments:** Routine ABG sampling is performed by bedside nursing staff. Changing FGF in response to patient ABG by bedside nursing staff is also permitted, but adjustments should be discussed with ECLS coordinator and/or medical staff. Changes to lung ventilation should be discussed with medical staff. Objectives of lung ventilation strategies are given in Section 14e: Lung Ventilation Management, page 30.

i. **Fresh Gas Flow Settings (VV ECMO for Respiratory Failure).** Fresh Gas flow adjustment are made on the basis of the patient’s arterial PCO₂.
   - In response to high arterial PCO₂: FGF should be increased. If oxygenator ventilation/perfusion ratio is > 2 (i.e. FGF is more than twice the ECMO blood flow), or FGF is already at 11L/min, medical staff should be notified and the possibility of oxygenator malfunction considered.
   - In response to low arterial PCO₂: FGF should be decreased. Once the FGF is zero, the patient is no longer supported by ECMO.
ii. Fresh Gas Flow Settings (VA ECMO for Cardiac Failure). Lung ventilation is reduced in VA ECMO due to reduced pulmonary artery blood flow. In general, minute ventilation to the lung is adjusted to achieved end-tidal CO₂ (ETCO₂) levels between 20 to 35mmHg (depending on dead space)
   • In response to an ETCO₂ < 20mmHg, lung ventilation should be reduced
   • In response to a high arterial PCO₂, FGF should be increased
   • In response to a low arterial PCO₂, FGF may be reduced provided V/Q is greater than 0.5 (i.e. the FGF is more than half of the ECMO blood flow). V/Q ratios below 0.5 may result in hypoxic post oxygenator blood. Most commonly, low PCO₂/elevated pH are due to excessive patient driven lung ventilation.
   • Never turn off the FGF in VA ECMO for a low PCO₂ as this will result in hypoxic blood being delivered to the regions of the body supplied by the ECMO circuit (frequently the lower limbs and abdominal viscera where oxygen saturations are not monitored)

i. **Blender Settings:** FGF blender setting is routinely set to 100% O₂ and should not need to be changed during weaning. This is to prevent un-intentional inadequate O₂ delivery when oxygenator V/Q is less than 1. This practice may be reconsidered as evidence emerges about the role of hyperoxia in the setting of ischaemia/reperfusion.

j. **Heater unit management:**
   i. Ensure that heater water level is approximately 75-80% full via water level on front of heater. If low, top up with tap water via a large syringe.
   ii. Ensure bridging device connected between heater hose ends to aid recirculation
   iii. Turn on unit and recirculate water until desired temperature attained (usually 37 degrees)
   iv. Turn off heater unit prior to attaching hoses to oxygenator
   v. Turn on heater unit once hoses are attached to oxygenator

14. **ECMO Specific Routine Medical Care**

Related Documents:
   • ECMO Clinical Service Structure and Scope of Practice
   • Guideline for Peripheral ECMO Cannulation with Ultrasound Guidance

See Appendix 7: ECMO Observations, Daily Targets and Daily Checklist, page 58
See Appendix 8: VV Clinical Pathway, page 59
See Appendix 9: VA Clinical Pathway, page 60

a. **Routine Investigations**
   i. Daily CXR
   ii. Daily bloods: FBE; UEC; Mg; PO₄; LFT; APTT, INR, Fibrinogen and D-dimers
iii. APTT is measured 6 hourly while the patient is on ECMO if they are receiving systemic anticoagulation. For patients not on heparin, APTT is only measured in the morning.

iv. Plasma free Hb is measured 6 hourly (with the APTT). The safe range for this is < 0.1g/dL. Sampling rate may be reduced in stable patients.

v. Blood cultures are taken only as clinically indicated. Unlike other patients, these samples should be taken from the circuit or through existing lines. Do NOT perform venepuncture for the collection of blood cultures.

vi. Peripheral VA ECMO patients require vascular ultrasound studies to be performed on lower limbs on day 1 and additionally as clinically indicated. These are performed by the Vascular Ultrasound Department.

b. Assess adequacy of ECMO support and target setting (See Appendices 8 and 9, pages 60-61)

i. For VV ECMO target blood flows must provide adequate arterial oxygenation while allowing non-injurious lung ventilation

ii. For VA ECMO target blood flows in combination with native cardiac function must provide adequate systemic oxygen delivery. VA ECMO support must also allow some native cardiac and pulmonary artery blood flow (to prevent clot formation within the heart/pulmonary vasculature) and adequate decompression of the left and right heart chambers

c. Prevention of lower limb arterial insufficiency (VA ECMO)

i. All patients with peripheral VA ECMO should have a backflow cannula inserted at the time of cannulation. If a patient is commenced on VA ECMO at another centre without a back flow cannula, this should be inserted as soon as possible after admission to The Alfred. The presence of normal lower limb perfusion should not falsely reassure the clinician.

ii. Bleeding and Post-operative ECMO Patients: This includes: post surgical; post procedural and spontaneously bleeding patients

   a. Heparin should not be recommenced until all bleeding has stopped for 12 to 24 hours (assessed on an individual case basis).

   b. Aggressively replace all clotting element deficiencies

   c. Give cryoprecipitate to target fibrinogen > 1.5

   d. Give platelets to target count > 80,000 or normal MA (maximum amplitude) on TEG

   e. Give Prothombinex and FFP to target INR < 1.3 or normal R time on TEG

- **Bleeding and Post-operative ECMO Patients**

<table>
<thead>
<tr>
<th>Initial Therapy</th>
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<tr>
<td>Reverse acidosis,</td>
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<td>Attain and maintain normothermia</td>
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<tr>
<td>Cease all heparin</td>
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<tr>
<td>Correct abnormal coagulation tests and platelet count</td>
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<tr>
<td>Cease anti-fibrinolytics (2-4 hours)</td>
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<tr>
<td>Correct abnormal coagulation tests, TEG and platelet count</td>
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iii. Ongoing severe bleeding (despite above) should be managed by an experienced ECMO Specialist in consultation with Haematology and relevant Surgical Specialists. Options to consider include:
   a. Protamine: May be used on the direction of an ECMO specialist if unreversed heparin is definitively implicated in bleeding (TCT and reptilase tests may support a clinical diagnosis). Protamine may promote circuit thrombosis in Bioline coated components (particularly HLS or PLS Oxygenators). Where protamine is to be administered a pre-primed circuit and capability for emergent circuit change must be arranged. Protamine should not be used to treat bleeding not temporally related to heparin.
   b. Factor VIIa In consultation with Haematologist
   c. Surgery or Interventional Radiology
   d. Palliation

iv. Scheduled essential surgery or procedure (not yet bleeding) not including scheduled VA decannulation
   a. Cease heparin for 4 hours prior
   b. Replace deficits as stated above
   c. Start tranexamic acid (anti-fibrinolytic) prior to surgery or procedure

v. Tranexamic Acid Dosing
   a. Prepare 50 ml syringe with “neat” TXA solution (5g). i.e. 10 ampoules of TXA 500 mg in 5 ml
   b. Loading dose of 12.5 mg/kg given over 30 minutes provided no other clotting factors being given concurrently
   c. Maintenance infusion of 6.5 mg/kg/hour started immediately after loading dose and continuing until syringe empty (approx. 10 hours) or bleeding has ceased for 2 hours
   d. Reduce maintenance infusion to 3 mg/kg/hour if administration is continuing beyond 5 grams.
   e. Maintenance infusion rate to be reduced if renal or hepatic dysfunction present. Loading dose should remain unchanged
   f. The main risk with this therapy is acute thrombotic events including circuit thrombosis.

vi. Heparin Induced Thrombocytopenia on ECMO is rare. Heparin should be ceased and platelet counts should not be treated. Circuit components are Bioline coated which contains heparin. Patients who have confirmed HITS on ECMO have been successfully managed on existing circuits despite the presence of heparin bonding. In these cases systemic anticoagulation is maintained with parenteral direct thrombin inhibitors (Lepirudin, Bivalirudin, and Argatroban) in close consultation with Haematology

e. Lung ventilation management is at the discretion of the managing ICU consultant. Non-injurious lung ventilation is a primary goal of ECMO and a number of lung ventilation strategies are used during the different phases of ECMO support. It is important that the lung ventilation strategy is changed only in consultation with the ICU medical staff
i. **Lung Ventilation strategies for patients on VV ECMO**: Various approaches to lung ventilation are currently used. Whilst the purpose of ECMO in respiratory failure is to minimise ventilator induced lung injury, there are likely to be costs to high levels of sedation and associated immobility and lack of spontaneous breathing over a prolonged period. Most commonly, in the severe stages of respiratory failure (TV < 2ml/Kg) we use relatively high PEEP (10-15cmH₂O) and low-level pressure control (Peak airway pressure < 25cmH₂O). FiO₂ should be ≤ 0.6 with adequate VV ECMO support. Once TV starts to improve (TV>2ml/Kg) trials of de-sedation and spontaneous breathing occur.

ii. **Lung Ventilation strategies for patients on VA ECMO**: Ventilator settings are chosen to provide the following outcomes:

   a. Maintain adequate lung aeration i.e. prevention of atelectasis and maintenance of normal FRC. This is achieved through adequate levels of PEEP and providing some ventilation to the lung.

   b. Prevent gross over-ventilation of the lung in cases of low native pulmonary artery blood flow. Lung ventilation should be titrated to indices of pulmonary artery blood flow. In general, we aim for ETCO₂ levels (depending on dead space and native cardiac function) of 20 to 30mmHg

   c. In the presence of predominately right ventricular dysfunction, minimising RV afterload is desirable and a careful balance between hypercapnoea and increased mean airway pressures must be sought.

f. **Percutaneous Tracheostomy**: Many patients have been successfully extubated without the need for a tracheostomy following prolonged VV ECMO support. Percutaneous tracheostomy may be indicated during ECMO support in younger patients with particularly high sedation requirements and prolonged ECMO. Percutaneous tracheostomy is virtually never indicated for patients supported with VA ECMO. In each case the risk:benefit ratio must be very carefully assessed, particularly as it relates to anticoagulation.

g. **Red Blood Cell Transfusion**: Specific transfusion triggers for RBC are not used. In the case of refractory hypoxaemia (SaO₂ < 88%) despite optimised VV ECMO support, higher transfusion thresholds (Hb > 10 g/dL) may be considered to optimise DO₂.

h. **Antibiotics**: Antibiotics are not specifically prescribed for ECMO

i. **Stress Ulcer Prophylaxis**: with H₂ receptor antagonists or proton pump inhibitors is routine on ECMO

j. **Nutrition**: Standard nutritional care is provided on ECMO. Friction-based post pyloric feeding tubes are contraindicated due to the additional bleeding risks. Parenteral lipid feeds are not contraindicated.

15. **Prevention of complications**

   Prevention of complications is fundamental to successful ECMO care. Many interventions during ECMO carry additional risks. The follow is a summary of important precautions to prevent common severe complications.

a. **Securing Cannulae**: All ECMO lines must be secured at 2 points with properly adherent skin dressings (Grip locks with skin preparation). Initial securing is the responsibility of the cannulator and cannot be delegated. All ECMO line dressings are maintained by bedside nursing staff.
b. Cannulae Positions: Checked each shift (as part of nursing checklist). Medical staff must also check cannulae positions radiologically when reviewing images. Any change in the position of a cannula must be referred to the ICU Consultant immediately for management.

c. ECMO Cannulae dressings: Sterility must be maintained and insertion sites kept unsoiled. Special attention must be given to jugular vein cannulae in particular to prevent contamination. All cannula dressings are maintained by bedside nursing staff (See Section 13f, page 26)

d. Patient moves and turns: A designated staff member must secure ECMO circuit lines to prevent tension or torsion during patient moves. ECMO accredited staff must be present and available to manage changes in ECMO circuit blood flow during patient turns and moves

i. Patients on central ECMO support with surgically placed by-pass cannulae via an open sternum should not be turned for pressure care (see Section 13g, page 27)

e. Electrical Safety: Do not allow water to enter the ECMO drive unit

i. Rotaflow external drive should always face “up” to prevent water entering in the event of a spill.

ii. Pressurised fluid bags should be sited below the console and drive units

f. Intra-hospital transports: Whenever possible these should be arranged in-hours. Two ECMO accredited staff must go on all transports. A designated staff member must secure all ECMO lines during transport and patient moves

g. Alcohol Containing Cleaning solutions (including triclosan) should not come in to contact with the ECMO circuit as they may cause cracking of some circuit components (See Emergency Response: Circuit Rupture, pages 40 and 46). Betadine should be the only antiseptic solution stored in the ECMO patient cubicle. ICU Consultant should be notified immediately if alcohol solutions come into contact with the circuit. Alcohol and chlorhexidine body wash wipes should not be used on ECMO patients.

h. Procedures: No procedures are to be performed on ECMO patients without the prior consent of the managing Intensivist who has considered the risks of bleeding and alternatives for management. This includes

i. Suturing

ii. Venepuncture

iii. Exploration of wounds

iv. Insertion of naso-gastric tubes

v. Percutaneous tracheostomy (see Section 14f, page 31)

i. Frictional Post pyloric feeding tubes should not be used in ECMO

j. Intercostal catheters should not be inserted in patients supported with veno-venous ECMO unless there is mediastinal tension manifest as haemodynamic instability. Small or asymptomatic pneumothoraces may be managed by a reduction in lung ventilation. Pleural effusions should not be drained during ECMO. Thoracotomy may be safer. (See Section 16i, page 34)

k. Echocardiography: Trans-oesophageal echocardiography should only be performed if transthoracic echo windows are inadequate.

16. Troubleshooting

a. SIG Alarm (loss of flow signal) Rotaflow/PLS platform: This is due to the loss of the ultrasonic flow signal on the Rotaflow pump – usually due to inadequate coupling interface between the ultrasonic flow sensor and the ECMO circuit. It does not occur on the Cardiohelp system. The blood flow reading disappears or is intermittent with a “SIG” flashing signal. Pump function does not change and will continue to run. Bedside staff may re-establish the flow signal electively when it is safe to do so

i. Re-establishing the flow signal during patient support:

a. The patient is changed to 100% Oxygen via the lungs (5min)

b. Circuit is clamped (post oxygenator)

c. Speed setting is immediately turned to 0 RPM

d. Ultrasound cover is opened
Extracorporeal Membrane Oxygenation (ECMO)

e. Pump head is removed
f. The contact “cream” is applied to the ultrasound windows just distal to the pump head
g. The pump head is re-inserted with the leading edge placed under the locating pin and the ultrasound cover is latched
h. The speed setting is returned to approximately 1000 RPM and the clamp is slowly removed (over 3-5 sec) while the speed setting is gradually increased until desired flows are achieved

b. Flow Sensor Management Cardiohelp/HLS platform: The flow sensor for the Cardiohelp does not require any contact “cream” (coupling medium). The sensor is clipped on to the return side (post oxygenator) of the circuit tubing with the flow sensor arrow facing in the direction of flow (away from the oxygenator). Disconnection of the flow sensor during use will result in the loss of signal. Reconnection in the opposite direction will result in a negative flow reading. If Flow Interventions are enabled this will result in an attempt to reverse flow in the circuit. For this reason the Flow Intervention function should not be enabled in the Alfred ICU
c. The Cardiohelp Flow Sensor also has an integrated bubble sensor: Bubble alarms should be reported to medical staff and the circuit checked for visible signs of air bubbles. Bubble Interventions must not be enabled during patient care in the Alfred ICU
d. Low Flow Alarms: Low flow alarms indicate that flow has fallen below the set alarm limit. It must prompt an immediate search for possible causes. Flow is determined by load and speed settings. Treatment is determined by the cause
   i. Common causes and features of low flow alarms
      a. Speed setting changed: Speed setting has been lowered and alarms have not yet been adjusted.
      b. Access insufficiency (see below): Flows should improve with a reduction in the pump speed setting
      c. Kinked or twisted circuit tubing: Visible problem corrected immediately when tubing is straightened
      d. Oxygenator occlusion: Falling blood flow with rising trans-oxygenator pressures. Does not improve with a reduction in pump speed
      e. Patient bleeding: Presents as access insufficiency (see above). Whenever access insufficiency is encountered, consider the possibility that the patient may be bleeding (even if this is not immediately evident)
      f. Air embolism: Visible air in the circuit and pump head.
      g. Significant elevation in blood pressure (VA ECMO only): Associated with an obvious change in recorded blood pressure and clinical state e.g. waking up, coughing, straining
e. Access insufficiency – Definition and Features: This is a state where the suction pressure at the access cannula is excessive for the venous return and inflow is interrupted by intermittent or partial occlusion of the inlet ports on the access cannula by the walls of the collapsible vein. Features depend on the severity, the type of access cannula (see Section 3) and the equipment platform. Commonly, features include variable or falling blood flow with or without visible and palpable access line movements.
   i. Single stage cannulae produce obvious visible and palpable “shaking” or “chattering” of the circuit tubing draining to the pump; high variation in the measured flow; and falling average flow. Blood flow will fall further and line “chattering” will worsen if pump speed is increased. Line “chattering” will stop in response to a reduction in pump speed.
   ii. Multi-stage cannulae may demonstrate partial occlusion of the cannulae access holes without any visible or palpable line movement. Blood flow may fall and will not increase if speed is
increased. In VA ECMO, pulmonary or aortic pulsatility may be lost as the right side of the heart is “sucked-down”. Definitive diagnosis requires echocardiography.

iii. The Cardiohelp/HLS system incorporates negative access pressure (pre-pump head) monitoring. Negative pressures usually increase before access insufficiency is clinically evident. Increasing negative pressures associated with stable or falling blood flow indicates early access insufficiency.

f. Access Insufficiency Causes and Treatment: Access Insufficiency is caused by inadequate venous return relative to the degree of negative access cannula pressure

i. Common causes
   a. Hypovolaemia/Bleeding
   b. Poorly sited access cannula (too low)
   c. Cardiac tamponade (common post sternotomy)
   d. Excessive RPM setting
   e. Patient coughing or straining
   f. Positional (after turning the patient)
   g. Acute vasodilatation (sedation bolus)
   h. Increased intra-abdominal pressure
   i. Severe aortic regurgitation / fatal pulmonary haemorrhage (VA ECMO)

ii. Immediate treatment is to reduce the speed setting until features disappear whilst attempting to maintain adequate patient support. If former pump speed settings cannot be re-established, then a bolus of fluid should be administered. Repeated episodes should not be treated with fluid, as massive volume overload/oedema will arise. Cardiac tamponade must be excluded or treated. Additional access cannulae may be required to access sufficient venous return after bleeding and cardiac tamponade have been excluded.

g. Circuit and oxygenator changes: These are most commonly required for aged circuits (generally 2-3 weeks of age) where clot accumulation causes coagulation system activation and inflammation. The cardinal features are rising D-Dimer with falling fibrinogen (< 2). It is very rare for oxygenators to malfunction and fail to oxygenate blood sufficiently, however, a post-oxygenator PaO2 below 200mmHg should lead to an elective circuit change-out. Rarely, circuits may need to be changed urgently for pump head or oxygenator thrombosis.

h. CRRT (Prismaflex) pressure alarms: High ECMO circuit pressures can result in CRRT high return positive pressure alarms. High ECMO circuit pressures are expected with higher blood flow rates and with the use of smaller ECMO return cannulae (e.g. VA ECMO with 15F return cannula; or dual-lumen, bi-caval (Avalon Elite) VV ECMO. Higher CRRT blood flow settings will also be expected to raise the pressure in the CRRT return circuit.

i. CRRT High pressure alarm management on ECMO:
   a. Reduce CRRT blood flow (if possible)
   b. Reduce ECMO blood flow (if possible)
   c. Replace ST 100 set with ST 150 set (Contact ECLS Co-ordinator or Equipment Nurse)
   d. PLS: Change CRRT return port to post-oxygenator connection port
   e. HLS: Swap CRRT access and return
   f. Consider non-ECMO site for CRRT return (e.g. large bore peripheral cannula)
   g. Consider inserting separate vascath

i. Pneumothorax on VV ECMO: Pneumothoraces, particularly early in the course of ECMO for respiratory failure, MUST NOT be drained unless they cause tension resulting in haemodynamic compromise. Further reductions in lung ventilation (and increased ECMO support) may control or reverse air leaks and allow inter-costal catheters to be avoided, or inserted later when lung injury is
less severe. Traditionally the commonest mode of death on VV ECMO support was bleeding and the most common site was pleural space bleeding related to inter-costal catheter insertion.

j. Cannula site bleeding: Cannula site bleeding: This is preventable by using meticulous sequential dilatational technique during percutaneous cannula insertion and carefully securing the cannulae to prevent migration. Most commonly, cannula site bleeding is due to an arterial return cannula partially “sliding out”, leaving a narrower part of the cannula at the arterial entry point. Evaluation of arterial cannula site bleeding must include vascular ultrasound to exclude vessel injury, which will require vascular surgical input.
   i. Management options include:
      a. Fully inserting the cannula to the taper
      b. Thrombotic (Kaltostat) dressings
      c. Pressure (sand bag)
      d. Cessation of heparin
      e. Vascular surgical review
      f. Repair and re-cannulation
   ii. “Purse-string” suturing should NEVER be attempted by ICU staff due to the risk of vessel or cannula damage and delayed skin necrosis which will complicate any eventual repair

17. Conversion to Hi-Flow ECMO

a. Indications: This is required when access insufficiency or hypoxaemia are limiting VV ECMO support, or when differential hypoxia is sufficiently severe in peripheral VA ECMO. It involves using two different access cannulae to access blood from both the superior and inferior vena cavae (bicalvial access) to ensure a higher proportion of venous return is captured by the ECMO circuit and facilitate the use of higher flow rates.

b. Technique:
   i. Left internal jugular vein is examined with ultrasound to exclude occlusion
   ii. 5 Clamps and 3 staff are required to complete all connections
   iii. Short (“arterial”) cannula is inserted using sterile technique into the right internal jugular vein. It is flushed and clamped before being secured at the insertion site (taking care that the additional access port is tightly closed and positioned away from the patient’s skin). The cannula should not impinge on the ear.
   iv. Ventilator FiO2 is increased to 100%
   v. Under sterile conditions the “Y” connector with long extension is primed with 0.9% Sodium Chloride and the distal (long) end (without the “Y” connector) is connected to the right jugular catheter with an “under-water” seal.
   vi. The femoral access cannula - ECMO tubing junction is draped and prepared with Betadine antiseptic
   vii. The circuit and the access cannula are clamped and the pump is stopped. An additional clamp is applied post oxygenator by the person controlling the ECMO pump – this will be the last clamp to be removed when ECMO flow is re-established.
   viii. The access tubing is removed from the existing femoral access cannula
   ix. The short end of the “Y” connector tubing is attached to the existing access cannula (underwater seal not required)
   x. The “common” end of the “Y” connector is connected to the access tubing draining to the pump head after all air is excluded (underwater seal required)
   xi. All clamps are removed and ECMO flow is re-established
18. Intra-hospital Transport

a. **Staffing:** All intra-hospital transports require the following staff: Bedside ECMO accredited ICU nurse and an ECMO accredited ICU senior registrar. Senior registrars not accredited for ECMO should be accompanied by an additional ECMO accredited staff member (ECLS Co-ordinator or ICU Consultant if possible). All ECMO lines should be held during patient movements.

b. **Emergency Drive Unit** ("Hand-crank") must be taken on all transports. Battery charge should be greater than 24 V prior to leaving. AC power should be disconnected just prior to departure. AC power should be re-established at destination.

c. **Oxygen tubing** (long length) is required

d. **Start of Shift nursing checklist** (Appendix 5 or 6, pages Error! Bookmark not defined.-Error! Bookmark not defined.) must be completed on return from transport to ensure AC power is re-established on return.

19. Weaning of ECMO support

See Appendix 8: VV Clinical Pathway, page 59
See Appendix 9: VA Clinical Pathway, page 60
See Appendix 11: Weaning VA ECMO Data Sheet, page 62

1. **VV ECMO weaning:**
   i. Circuit flow need not be reduced at any stage for weaning and therefore, no additional heparin is required
   ii. Weaning VV ECMO is achieved by progressively reducing the Fresh Gas Flow to the oxygenator. An increase in lung ventilation is required to ensure adequate CO₂ clearance.
   iii. In normal circumstances there is no requirement to wean the blender FiO₂ as part of the weaning process
   iv. It is usual to observe the patient to be stable for 4-24 hours with the Fresh Gas Flow to the ECMO circuit at 0 L/min. This is at the discretion of the treating Intensivist
   v. Echocardiography is not required

2. **VA ECMO weaning:**
   i. Formal weaning studies must be performed to assess the heart’s ability to manage the circulation without VA ECMO support. Circuit flow must be reduced to assess native heart function in the setting of an increased venous return. Flow is reduced from 2.5 L/min in a series of 0.5 L/min increments while haemodynamic and echocardiographic (TTE or TOE) data are collected according to the Weaning VA ECMO Data Sheet (Appendix 11, page 62)
   ii. Lung ventilation must be increased and oxygenator Fresh Gas Flow reduced during the weaning study
   iii. The reduced flow during the VA weaning process increases the risk of stasis and clotting within the circuit. Additional heparin is required to reduce the risk of clotting in this setting
   iv. Echocardiography is essential to assessing cardiac function during weaning from ECMO
   v. Once cardiac function has improved and ECMO decannulation is planned, ECMO flows should be maintained **above 2.5L** until decannulation takes place.

20. Cannula Removal and Circuit Disposal

**Technique:** The technique for removal of percutaneously inserted peripheral venous cannulae is given below. Femoral arterial cannulae (whether inserted percutaneously or open) and femoral venous cannulae inserted via surgical cut down approach must be removed in theatre by the vascular or
cardiothoracic surgical team. Central ECMO must be removed in theatre by the cardiothoracic surgical team.

a. **Cannula Removal:** Heparin should be ceased for at least 2 hours prior to decannulation. The patient should be adequately sedated or have received an explanation of the procedure prior to commencement. After dressings are removed, all access and return lines are clamped, the ECMO console powered off and the cannulae removed simultaneously with immediate adequate pressure applied to the vessel puncture sites with sterile gauze. There is no need for the operators to wear sterile gowns for the procedure.

b. **Returning the blood** held within the ECMO circuit to the patient prior to cannula removal carries additional risk of air and thrombus entering the patient’s circulation and volume overload. It should only be performed if there is a clinical imperative to conserve blood (e.g. Jehovah’s Witness patient)

c. **Bleeding control:** After percutaneously placed venous cannulae are removed the venous puncture site is compressed for 20 minutes by ECMO trained medical staff. The patient must remain supine and still for approximately 4 hours post cannula removal and the site monitored for re-bleeding

d. **Circuit disposal:** The circuit should be disposed of in a biohazard bag/bin with cytotoxic precautions where appropriate. Re-usable (metal) ECMO Clamps MUST not be discarded.

21. **Equipment Maintenance and management**

a. All ECMO machine components are to be serviced and maintained by Maquet service engineers as per service contract (see ICU Equipment Nurse)

b. Do not send ECMO machines to biomedical engineering (consult ECLS Coordinator if unsure)

c. All ECMO machines are cleaned in respiratory store after patient use

d. All ECMO machines must be plugged into power during storage

e. ECLS Coordinators and ICU Equipment nurse will ensure that ECMO stock is adequate

f. ECLS Coordinators will ensure a pre primed PLS circuit is ready to use at all times

g. Do not expose any part of ECMO circuit or machine to alcohol

h. Do not dispose of metal ECMO clamps

i. Do not allow fluid to come into contact with ECMO consoles or drive units (see Section 15)
Emergency responses: VA ECMO

Pump Failure

**Definition:** This is failure of either the drive console or pump head to drive the centrifugal pump and create forward circuit blood flow

**Effects:** ECMO support will stop. If the circulation is largely supported by ECMO flow, this will be associated with haemodynamic collapse with retrograde circuit flow from arteries to veins. If reasonable native cardiac function exists, varying degrees of hypotension and possibly hypoxia will occur.

**Causes:**
1. Pump head/centrifugal pump disengagement
2. Electrical motor failure – either console or pump head
3. Battery failure (no AC power connected)
4. Rotaflow Power Isolation Switch “OFF”

**Response:**
1. Clamp circuit
2. Call for help. Contact ICU Consultant and ECLS Coordinator
3. Examine for cause:
   i. Console (front): Power (On/Off Switch)
   ii. Console (front): AC Power Supply Indicator lights
   iii. Console (rear): Power Isolation Switch
   iv. External Drive: Pump head position
4. Address Cause and re-establish pump function or obtain new console
5. Engage Emergency Drive Unit (“Hand-crank”)
   i. Transfer Pump Head to Emergency Drive Unit
   ii. Rotate hand crank to 1000 rpm and remove circuit clamp
   iii. Gradually increase revs to previous speed
6. Transfer to new console
   i. Ensure power to new console
   ii. Clamp circuit
   iii. Transfer Pump Head to new console
   iv. Establish pump speed to 1000 rpm and remove circuit clamp over 3-5 seconds while increasing pump speed to obtain full flow
Emergency responses: VA ECMO

Decannulation

**Definition:** This is unintended partial or complete removal of either the ECMO access (venous) or return (arterial) cannula from the patient during ECMO support resulting in bleeding or air entrainment.

**Effects:** There will be bleeding from the cannula insertion site. ECMO support will stop. If the circulation is largely supported by ECMO flow, this will be associated with haemodynamic collapse. If reasonable native cardiac function exists, varying degrees of hypotension and possibly hypoxia will occur. In addition:

- **Access cannula decannulation:** air will rapidly enter and extensively de-prime the ECMO circuit and may reach the patient (see air embolism)
- **Return cannula decannulation:** Patient’s blood volume will rapidly be lost from the circuit until the circuit is clamped.

**Causes:**
1. Tension on ECMO lines
2. Inadequate dressing of ECMO lines
3. Failure to monitor line position in day checks

**Response:**
1. Clamp circuit and turn off pump
2. Call for help. Contact ICU Consultant and ECLS Coordinator
3. If Decannulation is partial only: Reinsert cannula (if possible) and wait for medical review
4. If Decannulation is complete: Control vessel bleeding with adequate pressure (Sternotomy for central ECMO decannulation)
5. Support patient circulation (ACLS measures)
6. Ensure appropriate ventilation (mechanical ventilation settings may need to be increased)
7. Patient management for air embolism (if required)
8. Consider re-cannulation for ECMO (new circuit will be required)
Emergency responses: VA ECMO

**Circuit Rupture**

**Definition:** This is a breach in any part of the circuit that results in blood loss from the circuit or air entrainment into the circuit.

**Effects:** The effects depend on whether the breach involves the circuit before or after the pump head.

**Pre pump-head circuit rupture:** During pump operation, this region has negative pressure and any breach will result in rapid air entrainment that will stop (de-prime) the pump causing loss of ECMO support.

**Post pump-head circuit rupture:** During pump operation, this region has positive pressure and any breach will result in forceful, rapid blood loss until the breach is rectified or the pump is stopped.

**Causes:**
1. Improperly secured circuit tubing (cable ties not applied at all junctions)
2. Broken or uncapped tap
3. Accidental puncturing or cutting of ECMO circuit tubing (e.g. suture needle or blade)

**Response Pre pump-head circuit rupture:**
1. Clamp circuit and turn off pump. Apply a proximal clamp on the access cannula(e) and a distal clamp on the return cannula
2. Call for help. Contact ICU Consultant and ECLS Coordinator
3. Support patient circulation (ACLS measures)
4. Patient management for air embolism (if required)
5. Exchange circuit (new circuit) OR De-air circuit via oxygenator and circuit ports

**Response Post pump-head circuit rupture:**
1. Secure any open tap or cover breach (if possible)
2. If bleeding controlled, call for help and await medical review
3. If bleeding not controlled: Clamp circuit and turn off pump. Apply a proximal clamp on the access cannula(e) and a distal clamp on the return cannula
4. Call for help. Contact ICU Consultant and ECLS Coordinator
5. Support patient circulation (ACLS measures)
6. Repair breach if possible. Recannulation (over a guide-wire) will be required if the return cannula or distal perfusion cannula have been breached
7. Restart ECMO once breach is repaired or overcome and all clamps are removed
Emergency responses: VA ECMO

Air Embolism

**Definition:** Air enters the circuit and then enters the patient

**Effects:** Air rapidly enters and the circuit and empties (de-primes) the pump-head of blood that will stop or greatly reduce circuit flow. Remaining air and blood in the pump-head will visibly froth. A large quantity of air bubbles will pass through the oxygenator and enter the patient’s arterial circulation. Within the patient’s circulation bubbles can collect and stop flow (pulseless electrical activity and stroke). ECMO circulatory support will stop. If the circulation is largely supported by ECMO flow, this will be associated with haemodynamic collapse. If reasonable native cardiac function exists, varying degrees of hypotension and possibly hypoxia will occur.

**Causes:**
1. Circuit rupture/breach pre pump-head  
   *(e.g. cap on the side-port of a jugular cannula during Hi-flow ECMO)*
2. Central line insertion during ECMO  
   *(e.g. during insertion of jugular line for conversion to Hi-flow ECMO)*
3. Decannulation of access (venous) line during ECMO

**Response:**
1. Clamp circuit and turn off pump. Apply a distal clamp to the return cannula
2. Call for help. Contact ICU Consultant and ECLS Coordinator
3. Cover or correct breach
4. Patient management:
   i. Position head down
   ii. ACLS management. Inotropes and vasopressors for hypotension
   iii. Adequate lung ventilation with 100% oxygen
   iv. Consider aspirating right atrium/ right ventricle
   v. Consider lignocaine, thiopentone, hypothermia, steroids, mannitol
5. ECMO circuit exchange (fresh circuit) OR De-air existing circuit
   i. Remove all clamps except distal clamp on return cannula (PUMP OFF)
   ii. Remove pump head from pump
   iii. Remove Yellow Cap from the inlet side of the oxygenator. Aspirate air from OTHER available oxygenator and circuit ports. Blood from the patient should re-prime circuit
   iv. Once all visible air is removed from pump head and tubing, air can be removed from the oxygenator by removing the YELLOW cap and running the pump (3000 rpm) with the clamp ON the return line for 2-3 minutes
**Emergency responses: VA ECMO**

**Cardiac Arrest**

**Definition:** This is sudden loss of native cardiac output during ECMO support due to arrhythmia.

**Effects:** There will be loss of arterial pulsatility. Mean blood pressure may fall depending on the degree of ECMO support. Although chest compressions are not required, arrhythmias should be treated and reversed as soon as possible.

**Causes:**
1. Ventricular Fibrillation or Tachycardia
2. Ventricular standstill
3. Asystole

**Response:**
1. Do NOT perform chest compressions
2. Call for help. Contact ICU Consultant and ECLS Coordinator (in Hours)
3. Assess blood pressure and circuit flow
4. Establish sufficient circuit flow (usually greater than 4L/min) to support systemic perfusion
5. Decrease lung ventilation (pulmonary blood flow will be minimal). Required respiratory rate may typically be 2-4 breaths per minute during cardiac arrest on ECMO
6. Examine for cause:
   i. Exclude hyper/hypo-kalaemia
   ii. Consider urgent ECHO to exclude cardiac compression
7. Address Cause and treat specific arrhythmia
   i. Defibrillation/Lignocaine/Amiodarone for VF/VT
   ii. Adrenaline for Asystole or ventricular standstill
8. After reversion, ventilator, ECMO blood flow settings, and inotrope and vasopressor support will need to be adjusted.
Emergency responses: VA ECMO

Cardiac Tamponade

**Definition:** Intrathoracic bleeding resulting in cardiac compression with severely reduced ECMO circuit blood flow and access insufficiency.

**Effects:** There will be loss of arterial pulsatility. Mean blood pressure will fall and CVP will rise. Access insufficiency.

**Causes:**
1. Postoperative bleeding following cardiac surgery (generally within first 24 hours)

**Response:**
1. Reduce ECMO speed setting (revs)
2. Call for help. Contact Cardiothoracic surgeon and registrar, ICU Consultant and ECLS Coordinator (in Hours). Bring sternotomy trolley to bedside.
3. If blood pressure and circuit flow critically low commence re-sternotomy
Emergency responses: VV ECMO

Pump Failure

**Definition:** This is failure of either the drive console or pump head to drive the centrifugal pump and create forward circuit blood flow

**Effects:** ECMO support will stop. All oxygenation and carbon dioxide removal will occur at the lungs only. Arterial oxygenation will decrease and arterial CO\textsubscript{2} will increase. Native cardiac output will remain. There may be secondary haemodynamic effects from acute hypoxia and hypercapnia.

**Causes:**
1. Pump head/centrifugal pump disengagement
2. Electrical motor failure – either console or pump head
3. Battery failure (no AC power connected)
4. Rotaflow Power Isolation Switch “OFF”

**Response:**
7. Clamp circuit
8. Call for help. Contact ICU Consultant and ECLS Coordinator
9. Examine for cause:
   i. Console (front): Power (On/Off Switch)
   ii. Console (front): AC Power Supply Indicator lights
   iii. Console (rear): Power Isolation Switch
   iv. External Drive: Pump head position
10. Address Cause and re-establish pump function or obtain new console
11. Engage Emergency Drive Unit (“Hand-crank”)
   i. Transfer Pump Head to Emergency Drive Unit
   ii. Rotate hand crank to 1000 rpm and remove circuit clamp
   iii. Gradually increase revs to previous speed
12. Transfer to new console
   i. Ensure power to new console
   ii. Clamp circuit
   iii. Transfer Pump Head to new console
   iv. Establish pump speed to 1000 rpm and remove circuit clamp over 3-5 seconds while increasing pump speed to obtain full flow
Emergency responses: VV ECMO

Decannulation

**Definition:** This is unintended partial or complete removal of either the ECMO access (venous) or return (venous) cannula from the patient during ECMO support resulting in bleeding or air entrainment.

**Effects:** There will be venous bleeding from the cannula insertion site. ECMO support will stop. If the respiration is largely supported by ECMO flow (minimal native lung function), this will be associated with severe acute hypoxia, hypercapnia and secondary haemodynamic effects. In addition, for:
- **Access** cannula decannulation: air will rapidly enter and extensively de-prime the ECMO circuit and may reach the patient (see air embolism)
- **Return** cannula decannulation: Patient’s blood volume will rapidly be lost from the circuit until the circuit is clamped.

**Causes:**
1. Tension on ECMO lines
2. Inadequate dressing of ECMO lines
3. Failure to monitor line position in day checks

**Response:**
1. Clamp circuit and turn off pump
2. Call for help. Contact ICU Consultant and ECLS Coordinator
3. If Decannulation is partial only: Reinsert cannula (if possible) and wait for medical review
4. If Decannulation is complete: Control vessel bleeding with adequate pressure
5. Ensure maximal safe lung ventilation (mechanical ventilation settings will need to be increased)
6. Support patient circulation (ACLS measures)
7. Patient management for air embolism (if required)
8. Consider re-cannulation for ECMO (new circuit will be required)
Emergency responses: VV ECMO

Circuit Rupture

Definition: This is a breach in any part of the circuit that results in blood loss from the circuit or air entrainment into the circuit.

Effects: The effects depend on whether the breach involves the circuit before or after the pump head.

Pre pump-head circuit rupture: During pump operation, this region has negative pressure and any breach will result in rapid air entrainment that will stop (de-prime) the pump causing loss of ECMO support

Post pump-head circuit rupture: During pump operation, this region has positive pressure and any breach will result in forceful, rapid blood loss until the breach is rectified or the pump is stopped

Causes:
1. Improperly secured circuit tubing (cable ties not applied at all junctions)
2. Broken or uncapped tap
3. Accidental puncturing or cutting of ECMO circuit tubing (e.g. suture needle or blade)

Response Pre pump-head circuit rupture:
1. Clamp circuit and turn off pump. Apply a proximal clamp on the access cannula(e) and a distal clamp on the return cannula
2. Call for help. Contact ICU Consultant and ECLS Coordinator
3. Ensure maximal safe lung ventilation (mechanical ventilation settings will need to be increased)
4. Support patient circulation (ACLS measures) if required
5. Patient management for air embolism (if required)
6. Exchange circuit (new circuit) OR De-air current circuit via oxygenator and circuit ports

Response Post pump-head circuit rupture:
1. Secure any open tap or manually cover breach (if possible).
2. If bleeding controlled, call for help and await medical review
3. If bleeding not controlled: Clamp circuit and turn off pump. Apply a proximal clamp on the access cannula(e) and a distal clamp on the return cannula
4. Call for help. Contact ICU Consultant and ECLS Coordinator
5. Ensure maximal safe lung ventilation (mechanical ventilation settings will need to be increased)
6. Support patient circulation (ACLS measures)
7. Repair breach if possible. Recannulation (over a guide-wire) will be required if the return cannula or distal perfusion cannula have been breached
8. Restart ECMO once breach is repaired or overcome and all clamps are removed
Emergency responses: VV ECMO

Air Embolism

Definition: Air enters the circuit and then enters the patient

Effects: Air rapidly enters and the circuit and empties (de-primes) the pump-head of blood that will stop or greatly reduce circuit flow. Remaining air and blood in the pump-head will visibly froth. A large quantity of air bubbles will pass through the oxygenator and enter the patient’s circulation. Within the patient’s circulation bubbles can collect and stop flow (pulseless electrical activity and stroke). ECMO support will stop. If the respiration is largely supported by ECMO flow (minimal native lung function), this will be associated with severe acute hypoxia, hypercapnia and often secondary haemodynamic collapse.

Causes:
1. Circuit rupture/breach pre pump-head  
   (e.g. cap on the side-port of a jugular cannula during Hi-flow ECMO)
2. Central line insertion during ECMO  
   (e.g. during insertion of jugular line for conversion to Hi-flow ECMO)
3. Decannulation of access (venous) line during ECMO

Response:
1. Clamp circuit and turn off pump. Apply a distal clamp to the return cannula
2. Call for help. Contact ICU Consultant and ECLS Coordinator
3. Cover or correct breach
4. Patient management:
   i. Position head down (Reverse Trendelenburg)
   ii. ACLS management. Inotropes and vasopressors for hypertension (bubble compression)
   iii. Adequate lung ventilation with 100% oxygen
   iv. Consider aspirating right atrium/ right ventricle
   v. Consider lignocaine, thiopentone, hypothermia, steroids, mannitol
5. ECMO circuit exchange (fresh circuit) OR De-air existing circuit
   i. Remove all clamps except distal clamp on return cannula (PUMP OFF)
   ii. Remove pump head from pump
   iii. Remove Yellow Cap from the inlet side of the oxygenator. Aspirate air from OTHER available oxygenator and circuit ports. Blood from the patient should re-prime circuit
   iv. Once all visible air is removed from pump head and tubing, air can be removed from the oxygenator by removing the YELLOW cap and running the pump (3000 rpm) with the clamp ON the return line for 2-3 minutes
Emergency responses: VV ECMO

Cardiac Arrest

**Definition:** This is sudden loss of native cardiac output during ECMO support due to arrhythmia

**Effects:** There will be loss of cardiac output and oxygen delivery. Blood pressure will fall dramatically. Chest compression ARE required. Arrhythmias should be treated and reversed as soon as possible. ECMO circuit flow can continue. Access insufficiency may occur as a result of cardiac arrest and chest compressions.

**Causes:**
1. Ventricular Fibrillation or Tachycardia
2. Ventricular standstill
3. Asystole

**Response:**
1. Call for help. Contact ICU Consultant and ECLS Coordinator (in Hours)
2. COMMENCE chest compressions
3. Assess blood circuit flow. Reduce pump speed if access insufficiency occurs
4. Address Cause and treat specific arrhythmia (ACLS pathway)
   i. Defibrillation/Lignocaine/Amiodarone for VF/VT
   ii. Adrenaline for Asystole or ventricular standstill
5. Examine for cause:
   i. Exclude hyper/hypo-kalaemia
   ii. Exclude pneumothorax
   iii. Consider urgent ECHO to exclude cardiac compression
6. After reversion, ventilator, ECMO blood flow settings, and inotrope and vasopressor support will need to be adjusted
KEY RELATED DOCUMENTS
- ECMO percutaneous cannulation guideline

REFERENCES

AUTHOR / CONTRIBUTORS
* denotes key contact

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<thead>
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<th>Name</th>
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Disclaimer: This guideline has been developed within the context of Alfred Health service delivery. Alfred Health shall not be responsible for the use of any information contained in this document by another organisation outside of Alfred Health.
Inclusion:
ECMO is indicated for potentially reversible, life-threatening forms of respiratory and/or cardiac failure which are unresponsive to conventional therapy

Or
Irreversible forms of cardiac or respiratory failure with option of VAD or Transplantation. (Age under 50)

Exclusion (All forms ECMO):
Presence of additional severe chronic organ failure (liver, lung or renal)
Presence of severe acute brain injury
Malignancy
Age > 75

Exclusions for VA (Cardiac) ECMO Support:
Cardiac arrest: initial cardiac rhythm asystole or > 60 minutes to ROSC (or ECMO commencement)
Severe chronic pulmonary artery hypertension (even first presentation) with right ventricular failure and \( P_{\text{AP}}^{\text{sys}} > \text{SBP} \)
Un-repaired aortic dissection
Un-repaired moderate-severe aortic or mitral valve regurgitation with poor left ventricular function
Late Cardiogenic Shock - Process too advanced (≥ 3)
  Lactate > 15
  Advanced microcirculatory failure with severe mottling or established purpura
  AST or ALT > 2000, or INR > 4.5
  Anuria > 4 hours

Exclusions for VV (Respiratory) ECMO Support:
Irreversible process (ILD/pulmonary fibrosis, Bronchiolitis Obliterans, Cystic Fibrosis, Lung transplant > 30 days)
Immunosuppressed
  (Other) Transplant recipients (heart, renal, bone marrow)
  HIV-advanced
Advanced Septic shock - Process too advanced (≥ 3)
  Lactate > 10
  Noradren > 1.5\(\mu\)g/Kg/min
  Severe myocardial depression
  Advanced microcirculatory failure with severe mottling or established purpura
Appendix 2: ECMO referral pathway

**REFERRING HOSPITAL**
Patient with respiratory and / or cardiac failure unresponsive to conventional therapy? 
- For ECMO

**ALFRED HOSPITAL**
Patient referred to Alfred Hospital for ECMO

**TERNARY HOSPITAL**
Patient under consideration for ECMO transfer

**CONTACT ARV**
1300 368 961

Teleconference ARV Coordinator, Alfred Hospital ICU Consultant and Referring Hospital from commencement of case

**ARV Clinical Coordination & Case Assessment**

- Optimize filling, inotropic support, and management of sepsis related or other CVS modulators.
- Has cardiovascular support been optimized?

**Is the patient stable for transfer?**

- Yes
  - Transfer to appropriate destination (consider Alfred Hospital if deterioration and subsequent ECMO likely)

- No
  - Consider ECMO retrieval

**Consider further clinical advice**

- Does the patient have contraindications for ECMO?
  - No
    - Absolute Contraindications
  - Yes
    - Ongoing Care Management

**All Types**
- Absolute: Major pre-existing comorbidity eg irreversible neurological disease, omphalocele, cardiovascular disease, malignancy with expected limited survival. 
- Relative: High pressure, high FiO2, PPV for ≥ 1 week

**Veno-venous (for resp failure)**
- Absolute: Previous hypertension, mPAP ≥ 20 mmHg, severe cardiac failure, IEF ≤ 25%, cardiac arrest
- Relative: High pressure, high FiO2, PPV for ≥ 1 week

**Veno-arterial (for cardiac failure)**
- Absolute: Severe aortic valve regurgitation, aortic dissection
- Relative: Severe peripheral vascular disease
Appendix 3: Equipment List for retrieval

Extra Corporeal Membrane Oxygenation (ECMO): Retrieval Equipment
Maquet Rotaflow/PLS Platform

Case 1 and 2 and 3

- Rotaflow drive unit
- Rotaflow emergency unit
- Rotaflow pump console
- Oxygenator Holder
- Connector securing ties
- Sterile tubing scissors
- Rotaflow flow probe grease
- Tie Gun
- 3/8 × 3/8 with luer
- 3 way tap plus extension
- 1/2 × 3/8 connector
- Oxygen tubing (5 meters)
- Skin-Cannulae Securing Tabs
- Tubing clamps ×2 (non sterile)
Extra Corporeal Membrane Oxygenation (ECMO): **Retrieval Equipment**

**Bag 1 (Cannulae)**

- Back Perfusion cannula plus adaptor (sterile)
- Spare Percutaneous Dilator Sets (Medtronic and Avalon)
- Defries Cannulation pack
- Cook dilators 15/19/21/23/25
- 4-6 ECMO Cannulae (Selected for patient need and size)

**Bag 2 (Circuit)**

- Power cord (10m)
- Spare Lovell's Circuit (sterile)
- Dual cannulation adaptor (sterile)
- ECMO circuit (pre-primed)
- Tubing clamps x 4 (sterile packet)
Appendix 4: ICU ECMO trolley equipment check list

The Alfred

Extra Corporeal Membrane Oxygenation (ECMO)

Alfred ICU ECMO Trolley Equipment List.

Major Components
- Maquet Rotaflow Console
- Remote Pump Drive (with cable)
- Emergency Hand Crank
- Heater
- Blender and Rotimeter
- Surge protector / power adaptor
- Isolation transformer  (underneath lowest shelf)
- Oxygenator Holder
- Transducer Holder
- Gas Flow tubing (with silicone end)

Drawer Contents
- Cable ties
- Cable gun
- Contact gel/crème
- Green Oxygen (gas) tubing (5 M)
- Securing dressing (Grip-locks) with velcro locks
- Metal Heater tubing connecting bridge

On Hooks
- Tubing clamps (non-disposable)  4
- Pressure Bag
Daily check required and post patient use prior to storage.

**Top of Trolley:**
- **Maquet Drive Console**
  - Ensure power cord plugged in and power point on.
  - Ensure A/C indicator light lit up on front of console.
  - Ensure pump head drive line attached to rear of drive console

**Trolley Draw:** ensure all present
- Tube of Ultrasonic grease x 1
- Metal Heater tubing connecting bridge
- Red cable tie gun
- Spare black cable tie’s x 10
- Spare Lovels cannulae securing device x 2
- 5 metres of green spare oxygen tubing

**Front of trolley:** ensure present and attached.
- Fresh gas flow meter
- Gas to oxygenator delivery tubing
- Gas blender
- Maquet water heater & Tubing

**Rear of Trolley:** ensure present and attached
- Emergency handcrank
- Oxygenator holder and arm
- Maquet Pump head and arm with attached driveline from Drive console
- Ensure flow sensor latch present and closed
- Ensure IV pole present

**Sides of trolley**
- Four circuit clamps
- Pressure bag
# Appendix 5: PLS Nursing start of shift ECMO check List

## MAQUET JOUSTRA-ROTAFLOW PUMP CHECKLIST

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

### Power Status
- Ensure Connected to AC power (Blue UPS point)
- Ensure green AC (+) LED light ON

### Battery Status
- Battery charge led on/off
- Battery charge voltage
  - Once daily check – am shift
  - Switch off at power point momentarily to display

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

### Alarm Settings
- FLIM (Lower flow limit)
  - Set 500 mL below flow
- LLIM (Lower limit)
  - Set 500 below current RPM
- HLIM (Upper limit)
  - Set 500 above current RPM

### Emergency Equipment
- Hand Clark Attached
- Spare Console Available & plugged in to power at all times
- Flow Sensor Grease Available
- Spare green O₂ Tubing available – check it reaches from oxygenator to alternative O₂ supply
- Specific ECMO clamps x4 present (brown / black handle)

### Circuit Assessment
- Access Line Status
- Still / Kicking / Moving
- Water Heater level 7/8 full
  - Top up – Tap water
- Ensure yellow cap on oxygenator de-air port (oxygenator spring various side)

### Cannula Position Check
- O₂R (intracostal space)
- Cannula length: (cm’s)
  - Wire reinforcing to skin insertion point (accessorium)
- High Flow IV Cannula length: (cm’s)
  - Wire reinforcing to skin insertion point
- Intervention necessary
- All Cannula secure (wire securing device intact)

### Blender Setting
- O₂/Air Source
  - (i.e. wall or bottle)
- Fresh Gas Flow
- PFI₂ to Oxygenator

### Nurse Initials

---

Scanned to: [Inpatients / Observations]

COMPLETE EACH SHIFT AND FOLLOWING TRANSPORT

MR
K36
# Appendix 6: Cardiohelp (HLS) Checklist checklist

## ICU Cardiohelp (HLS)

### Pump Checklist

*(Complete each shift & following transport)*

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
</table>

### Power Check

- Is A/C power connected: 
  - Yes
  - No
- LED battery light ON: 
  - ON
  - OFF
- Time for battery life: 
  - Hours
  - Minutes

### Mode

- Therapy Mode is set to BPM: 
  - BPM
  - RPM
  - Other
- User mode (VCU, OR, TM): 
  - VCU
  - OR
  - TM

### Alarms

- Low / High flow limit: 
  - Set: 0.5 Lpm below flow
  - Set: 15mmHg below P<subENARIO</sub>
  - Set: 20mmHg above P<sub>IN</sub>
  - Set: 20mmHg above P<sub>ATR</sub>
- Check Alarm Status is OFF: 
  - On
  - Off

### Emergency

- Hand Crank Available: 
  - Available
  - Not Available
- Soare Console Available: 
  - Available
  - Not Available
- Clamps available: 
  - Available
  - Not Available

### ECMO Gas

- Fresh gas source:
  - Wall O<sub>2</sub> flow meter
  - Blender FIO<sub>2</sub>
- Connected to oxygenator: 
  - Yes
  - No
- Blender Settings: 
  - FIO<sub>2</sub> / FGF
- Spare O<sub>2</sub> tubing for oxygenator available: 
  - Yes
  - No

### Patient

- Pump access line:
  - Still
  - Kicking / Moving
- Skin length (cm) of cannulae (access/return): 
  - Access
  - Return
- O2R cannula position (intercostal space): 
  - Yes
  - No
- Intervention necessary: 
  - Yes
  - No
- Dressing secure (elastoplast with suture): 
  - Secure
  - Not secure

### Confirm lab values

### Nurses Initials
Appendix 7: ECMO Daily orders and Hourly observation stickers

ECMO Daily Medical Orders

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Target</th>
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<tbody>
<tr>
<td>MAP</td>
<td>&gt;......&lt;......</td>
</tr>
<tr>
<td>CVP</td>
<td>&gt;......&lt;......</td>
</tr>
<tr>
<td>SaO2</td>
<td>&gt;......&lt;......</td>
</tr>
<tr>
<td>CO2</td>
<td>&gt;......&lt;......</td>
</tr>
<tr>
<td>ETCO2 (VA)</td>
<td>&gt;......&lt;......</td>
</tr>
<tr>
<td>Temp</td>
<td>&gt;......&lt;......</td>
</tr>
<tr>
<td>Blood Flow (L/min)</td>
<td>&gt;......</td>
</tr>
<tr>
<td>Platelets</td>
<td>&gt;......</td>
</tr>
<tr>
<td>Haemoglobin</td>
<td>&gt;......</td>
</tr>
<tr>
<td>Urine Output</td>
<td>&gt;......m/hr</td>
</tr>
<tr>
<td>Fluid Balance Aim</td>
<td>&gt;......m/hr</td>
</tr>
<tr>
<td>APTT Target (sec)</td>
<td>&gt;......</td>
</tr>
</tbody>
</table>

Consultant: Mobile:

ECMO Day: Circuit Day:

Investigations:
- CT
- BRONCH
- ECHO
- Weaning Study
- CVVHD
- Plasmapheresis
- Oxygenator Gases (see table below)
- Order/Review peripheral Vascular study(for VA ECMO)

<table>
<thead>
<tr>
<th>Results</th>
<th>0400</th>
<th>1000</th>
<th>1600</th>
<th>2200</th>
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<tbody>
<tr>
<td>APTT</td>
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<tr>
<td>Plasma Free Hb</td>
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<tr>
<td>LDH</td>
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<tr>
<td>D Dimers (once daily)</td>
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</table>

Pre oxygenator  PaCO2  PaCO2

Post Oxygenator

---/24 ECMO Observations

**ECMO Cardiohelp (HLS) Hourly Observations**

- Pump / Circuit
- Pump Flow (L/min)
- Pump Speed (RPM)
- Fresh Gas Flow
- FiO2 (Oxygenator)
- Pre/Post oxygenator mean pressure
- Oxygenator Pressure Gradient (AP)
- Venous Pressure / Oxygenator: No dots
- Access Line: Still / Moving / Kicking
- Pupils (L/R)
- Warm / Cool / Cold
- Pink / Pale / Mottled
- Pulse Palpable / Doppler / Absent

Back flow cannula Flow check with torch – Patent / Non patent

---/24 ECMO Observations

**ECMO Jostra Hourly Observations**

- Pump / Circuit
- Pump Flow (L/min)
- Pump Speed (RPM)
- Fresh Gas Flow
- FiO2 (Oxygenator)
- Pre/Post oxygenator mean pressure
- Oxygenator Pressure Gradient
- Oxygenator: No dots
- Access Line: Still / Moving / Kicking
- Neuro/Vascular Observations
- Pupils (L/R)
- Warm / Cool / Cold
- Pink / Pale / Mottled
- Pulse Palpable / Doppler / Absent

Back flow cannula Flow check with torch – Patent / Non patent
Appendix 8: VV Flowchart
Veno-Venous ECMO Clinical Pathway

Is lung ventilation safe?
TV < 6ml/kg; PIP < 30; FiO2 < 0.6

Establish Safe Lung Ventilation

Is SaO2 Safe? (88-94)

Check:
1. FGF
2. Blender
3. Flow Calibrations

Patient Arterial PCO2 Sample

PCO2 high

→ ↑ FGF

PCO2 normal

→ No Δ FGF

PCO2 low

→ ↓ FGF

Weaning FGF

FGF Off 2-24 hours

Decannulate

If low SaO2 Persisted:
Is there access insufficiency?

Improve Access

If low SaO2 Persists:
Increase circuit blood flow
(6-7L)

Pre Oxygenator SaO2 low (< 60)
(High O2 Consumption)
Consider:
1. Tolerating
2. HFO/NO/PGI2
3. Hb > 10
4. Paralysis
5. ↓Temperature

Pre Oxygenator SaO2 high (>80)
(Recirculation)
Consider:
Changing cannulae positions to
decrease recirculation

If low SaO2 Persisted:
CIRCUIT Pre-Oxygenator O2 Sample

Yes

No
Appendix 9: VA Flowchart
Veno-Arterial ECMO Clinical Pathway

Is the circulation pulsatility maintained or improving?
- No → Urgent ECHO
- Yes → Extrinsic compression

Extrinsic compression
- Yes → Early surgical treatment (prevent intra-cardiac thrombosis)
- No → No extrinsic compression

No extrinsic compression
- Yes → Medical management to maintain some intra cardiac flow (prevent intra-cardiac thrombosis)
  - Consider
  1. ↑ Inotropes (ECHO guidance)
  2. ↑ Anticoagulation
  3. ↓ ECMO flows
- No → ↑ ECMO Flow or Troubleshoot low ECMO circuit flows

Is ECMO blood flow (in addition to native cardiac output) adequate for systemic perfusion?
- No → Treat cause: (e.g. PCI or anti-arrhythmic)
  - ↓ LV load: ↑ PEEP and ↓ MAP
  - ↑ ECMO circuit blood flow
  - Consider LVAD
- Yes → ↑ ECMO circuit blood flow

Is there severe LV failure?
- Yes → Treat cause of lung shunt: (e.g. bronchoscopy and antibiotics)
  - ↑ Lung Support (PEEP and FiO2)
  - ↑ ECMO circuit blood flow
  - Consider change of ECMO mode to VV ECMO
- No → Continue ECMO Support
  (Inotropes should be minimised for cardiac recovery)

Is there (R) arm hypoxaemia (secondary to lung shunt (peripheral ECMO only))?
- Yes → Continue ECMO Support
- No → Is inotropic support minimal or ceased?

Is inotropic support minimal or ceased?
- No → Consider weaning trial
- Yes → Consider weaning trial
Appendix 10: Prevention of complications summary

Prevention of complications is fundamental to successful ECMO care. Many interventions during ECMO carry additional risks. The follow is a summary of important precautions to prevent common severe complications.

a. **Securing Cannulae:** All ECMO lines must be secured at 2 points with properly adherent skin dressings (Grip locks with skin preparation). Initial securing is the responsibility of the cannulator and cannot be delegated. All ECMO line dressings are maintained by bedside nursing staff.

b. **Cannulae Positions:** Checked each shift (as part of nursing checklist). Medical staff must also check cannulae positions radiologically when reviewing images. Any change in the position of a cannula must be referred to the ICU Consultant immediately for management.

c. **ECMO Cannulae dressings:** Sterility must be maintained and insertion sites kept unsoiled. Special attention must be given to jugular vein cannulae in particular to prevent contamination. All cannula dressings are maintained by bedside nursing staff (See Section 13f, page 26)

d. **Patient moves and turns:** A designated staff member must secure ECMO circuit lines to prevent tension or torsion during patient moves. ECMO accredited staff must be present and available to manage changes in ECMO circuit blood flow during patient turns and moves
   ii. Patients on central ECMO support with surgically placed by-pass cannulae via an open sternum should not be turned for pressure care (see Section 13g, page 27)

e. **Electrical Safety:** Do not allow water to enter the ECMO drive unit
   iii. Rotaflow external drive should always face "up" to prevent water entering in the event of a spill.
   iv. Pressurised fluid bags should be sited below the console and drive units

f. **Intra-hospital transports:** Whenever possible these should be arranged in-hours. Two ECMO accredited staff must go on all transports. A designated staff member must secure all ECMO lines during transport and patient moves

g. **Alcohol Containing Cleaning solutions** (including triclosan) should not come in to contact with the ECMO circuit as they may cause cracking of some circuit components (See Emergency Response: Circuit Rupture, pages 40 and 46). Betadine should be the only antiseptic solution stored in the ECMO patient cubicle. ICU Consultant should be notified immediately if alcohol solutions come into contact with the circuit. Alcohol and chlorhexidine body wash wipes should not be used on ECMO patients.

h. **Procedures:** No procedures are to be performed on ECMO patients without the prior consent of the managing Intensivist who has considered the risks of bleeding and alternatives for management. This includes
   vi. Suturing
   vii. Venepuncture
   viii. Exploration of wounds
   ix. Insertion of naso-gastric tubes
   x. Percutaneous tracheostomy (see Section 14f, page 31)

i. **Frictional Post pyloric feeding tubes** should not be used in ECMO

j. **Intercostal catheters** should not be inserted in patients supported with veno-venous ECMO unless there is mediastinal tension manifest as haemodynamic instability. Small or asymptomatic pneumothoraces may be managed by a reduction in lung ventilation. Pleural effusions should not be drained during ECMO. Thoracotomy may be safer. (See Section 16i, page 34)

k. **Echocardiography:** Trans-oesophageal echocardiography should only be performed if transthoracic echo windows are inadequate.
# Appendix 11: ICU VA ECMO Weaning Form

## ICU ECMO Weaning Form

<table>
<thead>
<tr>
<th>ECMO day No.</th>
<th>Weaning Study No.</th>
<th>Date:</th>
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**Doctor** ________________________________  **Nurse** ________________________________

**ECMO Type:** (circle) VA or VV  **Central/ Peripheral /Other:** ________________________________

**Echo Assessment:** (circle) No  TTE  TOE  **LVOTdiameter** __________ cm

**Heparin Bolus given:** (circle) Yes / No  **Dose:** __________________

## Time:

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<thead>
<tr>
<th>Time:</th>
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## ECMO Flow:

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<thead>
<tr>
<th>LPM</th>
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## Hemodynamics:

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<thead>
<tr>
<th>Rhythm:</th>
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<table>
<thead>
<tr>
<th>Rate:</th>
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<table>
<thead>
<tr>
<th>MAP:</th>
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<table>
<thead>
<tr>
<th>SYS/DIA:</th>
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<tr>
<th>CVP:</th>
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<tr>
<th>Oxygen Sat:</th>
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<thead>
<tr>
<th>ET CO2:</th>
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## Circulatory supports:

<table>
<thead>
<tr>
<th>Noradrenaline <em>μg/min</em></th>
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<table>
<thead>
<tr>
<th>Adrenaline <em>μg/min</em></th>
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<table>
<thead>
<tr>
<th>Milrenone <em>μg/min</em></th>
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<thead>
<tr>
<th>Dobutamine <em>μg/min</em></th>
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<thead>
<tr>
<th>Nitric Oxide (ppm)</th>
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<table>
<thead>
<tr>
<th>IABP: (ratio)</th>
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## ECHO Findings:

<table>
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<tr>
<th>LVOT VTI:</th>
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<thead>
<tr>
<th>Stroke Volume: (mls)</th>
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<thead>
<tr>
<th>Cardiac Output: (Lpm)</th>
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<table>
<thead>
<tr>
<th>Left Ventrical:</th>
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<table>
<thead>
<tr>
<th>Right Ventrical:</th>
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## Ventilation:

<table>
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<tr>
<th>Mode:</th>
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<table>
<thead>
<tr>
<th>Rate/Tidal Vol:</th>
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<table>
<thead>
<tr>
<th>Peep:</th>
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<table>
<thead>
<tr>
<th>FiO2:</th>
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<tbody>
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</table>

## Conclusions:

<table>
<thead>
<tr>
<th>Conclusions:</th>
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</table>
Appendix 12: ECMO retrieval cannulation requirements of referring centres

Extra Corporeal Membrane Oxygenation (ECMO)

Alfred ECMO retrieval team: Cannulation standard stock item requirements of referring centres.

Equipment Checklist
- Echocardiography with cardiac and vascular probe (if available)
- Large trolley (end of bed for cannulation)
- Electric clippers (to remove skin hair)
- Large Elastoplast (pick up clipped hair)
- Medium trolley (for ECMO pump)
- Central line Trolley
- Sterile gloves and gowns x 2
- Face shield with visor x 2
- Sterile gauze/ raytec (large pack)
- Sterile 50ml Toomey (wide bore outlet) syringe x 2
- Chlorhexidine in alcohol
- 20% Albumin bottle and airfilter
- 5000 units heparin ampoules x 4

Next of Kin available
Appendix 13: ICU ECMO Cannulation Trolley Equipment Check List

ECMO Cannulation Trolley Daily Checklist

PAN to check weekly or ACN to check post ECMO insertion

Trolley should always contain the following:

- 1 x Primed ECMO circuit – Circuit to be disposed of if outside 28 days of priming date (Consultant or ECLS Co-Ordinator to be notified to prime new circuit)
- 1 x Defries Cannulation Pack
- 1 x Backflow cannula and connection tubing
- 1 x 15 French Arterial cannula
- 1 x 17 French Venous cannula
- 1 x 21 French multistage cannula
- 5 x ECMO clamps
- 1 x Tube cutting scissors
- Griplock fixation device
- Cable ties and Cable tie gun
- 3 x ICU procedure drape
- 3 x Betadine
- Adhesive wipes
- Coloplast
- Disposable scalpel