ECMO Committee

(Policy No 5)

Veno-ArterialExtracorporeal Membrane Oxygenation

(V-A ECMO)General Management POLICY 2019

Policy owner: ECMO Committee. MOH	**Applies to:** All Staff in MOH and Private Hospitals in Kuwait
Section Location: Departments of Anaesthesia, Adult Intensive Care and Pain Management in all MOH and Private Hospitals in Kuwait.	**Effective date:** 01-03-2019 **Revision date**: 01-03-2022
Approved by: Head of ECMO Committee, ECMO Committee Members	
Final Approval by: MOH Undersecretary	

Purpose:

- To provide guidance for the indications and the overall management of patients on V-A ECMO (veno-arterial extracorporeal membrane oxygenation) in any Intensive Care Unit in Kuwait that deals with ECMO patients.
- To determine the roles and responsibilities of each member of the ECMO team during the patient management in the Intensive Care unit.

Policy Statement:

1. This guideline does not include advice on the referral process, transport process, or ECMO centers conditions as these are outlined in separate policies (see MOH ECMO policies 1,2 and 3).
2. These guidelines are subject to update whenever there are new international recommendations prior to the policy revision date.

Definitions:

1- **ECPR (Extracorporeal Cardiopulmonary Resuscitation)**
is the application of ECMO during cardiac arrest.Specific guidelines for ECPR are found in a separate policy (ECMO policy No 6).

2- Harlequin Syndrome/ North South Phenomena
This is when competitive flow within the aorta occurs between a recovering heart and the ECMO return flow leading to differential oxygenation of the upper and lower half of the body due to poor respiratory function (the upper part of the body is deoxygenated and the lower part of the body is oxygenated).

3- Reverse Harlequin /Reverse North South Phenomena.
This is when cardiac recovery occurs during peripheral VA ECMO which results in competitive flow within the distal aorta where the upper part of the body is well oxygenated due to adequate lung recovery, whilst the lower part of the bodyperfused by the ECMO return cannula is poorly oxygenated (mesentery and renal). This is usually due to ECMO oxygenation failure.

4- Pseudo North South Phenomena
This is when cardiac recovery occurs during central VA ECMO in the presence of good respiratory function which results in competitive flow within the proximal aorta where the upper part of the body is poorly oxygenated due to poorly oxygenated blood coming from the return central canula, whilst the lower part of the body is well oxygenated through the recovering heart and lungs.

Introduction

Veno-arterial extracorporeal membrane oxygenation (VA-ECMO) is a form of temporary mechanical circulatory support and simultaneous extracorporeal gas exchange for acute cardiorespiratory failure.All VA-ECMO circuits consist of a venous (inflow, drainage/ access) cannula, a pump, an oxygenator, and an arterial (out-flow, return) cannula. VA-ECMO can be established via peripheral or central access (Figure 1).

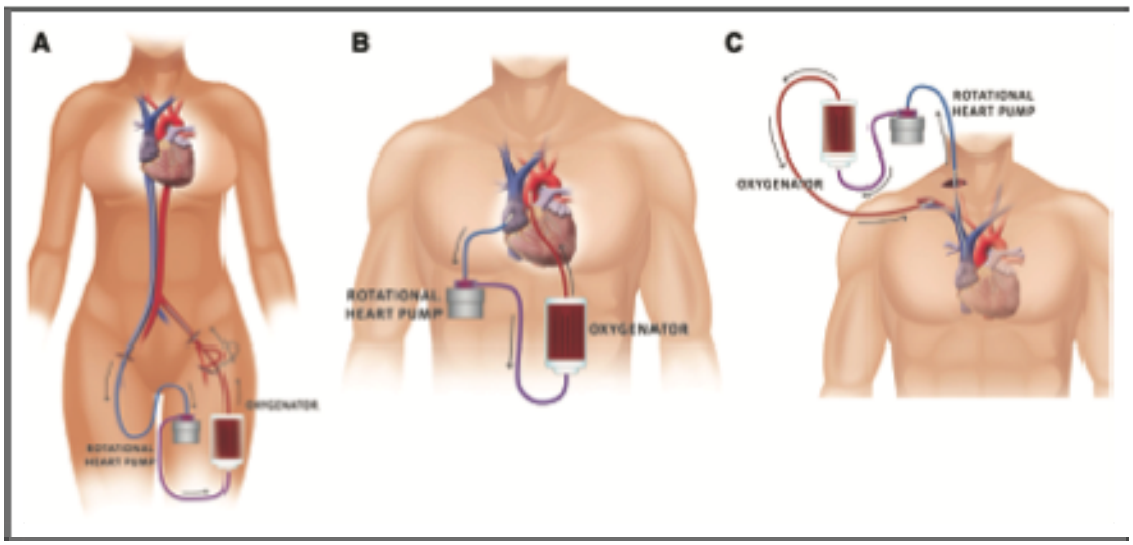

Figure 1. Central and peripheral veno-arterial extracorporeal membrane oxygenation (VA-ECMO) cannulation strategies. A, Peripheral VA-ECMO (femoro-femoral configuration). **B**, Central VA-ECMO.**C**, Peripheral VA-ECMO

Central VA-ECMO is primarily implemented in the operating room and provides short-term support, often in postcardiotomy patients unable to wean from cardiopulmonary bypass.Peripheral VA-ECMO can be initiated percutaneously or by surgical cut-down outside of the operating room for patients with refractory cardiogenic shock and cardiac arrest via femoral or internal jugular vein access canula and femoral artery returncanula. Another configuration uses the standard venous access (either via the femoral or internal jugular vein) with arterial return to a graft placed on the subclavian artery.This latter strategy has been introduced to ensure perfusion of the cerebral circulation with oxygenated blood and to allow for the possibility for patients to ambulate while on ECMO. The return canula via the femoral artery root that was placed percutaneously can also be replaced by a return canula placed in a graft connected to the femoral artery achieved by surgical cutdown in case of concerns regarding the peripheral arterial perfusion. If the return canula is placed percutaneously, a reperfusion canula should be placed to allow perfusion of the distal limb (see section 1.1 modes of vascular access for further details).

VA ECMO Referrals

The VA-ECMO service has been established in Adan Hospital adult ICU as it has fulfilled all conditions for ECMO centre establishment as determined by the MOH (see separate policy). As patients may need the ECMO service in any hospital in Kuwait (both private and governmental), an ECMO team has been established in order to evaluate these patients and make the appropriate decision regarding starting the service if needed (see ECMO indications below and appendix 1 for VA-ECMO referral form).The ECMO team will travel to retrieve patients that are not stable for transfer to Adan ICU where they will cannulate the patient and establish the pump

at their hospital and then escort them back to Adan ICU where further management of the patient will be taking place (see separate MOH ECMO Transport Policy). For stable patients, they should be transferred to Adan Hospital after being accepted by the ECMO Consultant and the ECMO service will be started in Adan ICU.

Indications and contraindications for Veno-Arterial ECMO

Indications for VA ECMO can be divided into clinical and physiological parameters which are as follows:

Clinical indications:

- Potentially reversible and severe cardiogenic shock secondary to :
  - MI
  - Fulminant myocarditis
  - Non ischemic cardiomyopathy including sepsis induced cardiomyopathy
- Pulmonary hypertension and right heart failure
- Pulmonary embolus with hemodynamic compromise
- Bridge to decision for transplant or VAD (LVAD/BiVAD)
- Support post cardiac surgery
- Medication overdose (e.gBeta , Ca # blockers , and TCA)
- Hypothermia (Drowning)
- Cardiac arrest (ECPR) which needs to fulfill the following conditions:
  - Witnessed Arrest
  - Shockable Rhythm (preferably)
  - Good quality CPR
  - Pre ECPR ACLS < 30 min
  - EtCO2 > 20 mmHgor 10
  - Peri Arrest Lactate level < 9 mmol/L
  - SOFA score <12

Physiological parameters:

(Allow 1-12 hours of inotropic support to be commenced before starting VA ECMO)

- Persisting (>30 minutes) lactate >3mmol/L or ScvO2 <50% due to cardiogenic shock
- Persisting cardiac index <2.2L/min/m2
- Evidence of end organ dysfunction due to cardiogenic shock
- Trans-thoracic echocardiography with left ventricular ejection fraction <30% or aortic velocity time integral (Ao VTI) <8cm.

Any patient being considered for VA ECMO must be discussed with the ECMO consultant

Absolute contraindications for VA ECMO:

1. Chronic medical co-morbidity with a life expectancy of less than 12 months
2. Progressive, non-recoverable heart disease and not suitable for transplant
3. Progressive and non-recoverable respiratory disease and not suitable for transplant.
4. Chronic severe pulmonary hypertension
5. Advanced malignancy
6. Graft versus host disease
7. Unwitnessed cardiac arrest
8. Cachexia due to an underlying progressive chronic disease
9. Bone marrow transplant recipients within 12 months of transplant
10. Any contraindication to transplantation
11. Peripheral arterial disease, recent aortic surgery or aortic dissection precluding cannulation
12. Aortic valve regurgitation
13. CPR >30 minutes at commencement of cannulation

VA-V ECMO is indicated for potentially reversible, severe, refractory cardiogenic shock in patients with severe respiratory failure who either have or are anticipated to have cardiac failure resolving prior to respiratory failure. It can also be used to treat harlequin/ north south syndrome as will be described later.

Section 1: Preparing for cannulation and establishing the VA-ECMO

1.1 Modes of vascular access

- The VA-ECMO circuit circulation can be achieved by establishing drainage of blood from the venous system through a cannula placed in the IVC through different routes **(Access cannula)**, and returning the oxygenated blood back to the patient through a cannula placed in the one of the large arteries in the body **(Return cannula)**
- Access cannula can be placed in the femoral vein , R atrium , and transeptal left atrium
- Return cannula can be placed in the femoral artery, subclavian/axiliary artery or aorta.
- Access and return cannulas can be combined together in one cannula called the double lumen cannula (e.gCoaxial right heart Protek duo) for right ventricular failure support +/- respiratory failure. This is placed through the jugular vein and has 2 lumens (an inflow lumen that takes blood from the right atrium and outflow lumen that sits in the pulmonary artery just at the bifurcation and delivers blood towards the pulmonary circulation. Cannula placement requires wire visualization guidance through either fluoroscopy and/or TEE. We currently use combined TEE and fluoroscopic guidance in Adan ICU and this procedure should be done in the cath lab.

- Access cannula can also be placed in the left atrium through the Tandem Life transeptalcannula which is accessed through the femoral veinand the tip is placed transeptaly in the left atrium. This is used in cases of LV distension and is placed by the cardiologists in the cath lab.
- Percutaneous access is possible in most adult patients and should be attempted first. If this is difficult, open approach by vascular/cardiac surgeon will be the alternative.
- Central access is performed by vascular / cardiac surgeons. This involves sternotomy and direct surgical cannulation of the right atrium and aorta. Institution of central ECMO occurs in theatre and requires a full surgical team (surgeon, anaesthetist, scrub nurse). The main advantages of this type of ECLS are good venous drainage and reliable arterial return to the proximal aorta in antegrade fashion. It allows full control over left ventricular decompression by placing a vent, usually via right superior pulmonary vein.
- Placement of the cordis sheath (6Fr) should be done routinely if available to aid the placement of the guide wire prior to the placement of the ECMO cannula.

1.2 Types of cannulas

- There are different types of cannulas available with different diameters and lengths, the choice of which will depend on the patient factors and type and site of ECMO access and return:

Cannula type	Size	Length	Lumens and holes	Vessel access
Single lumen (e.g. Maquet HLS, FreeLife, MedtronicBiomedicus, etc.)	15 – 26Fr	Various lengths	Access (Multi-stage/multi-hole) Return (Single hole/ single stage)	Femoral vein Internal jugular vein , right atrium , left atrium/ pulmonary vein femoral artery , subclavian/axillary artery and aorta
Double lumen (Protek duo)	27 - 31Fr	Various lengths	Multi-stage/Multi-hole	Internal Jugular
Transeptal (tandem life)	18 - 24Fr	170 - 270 cm	Access (Multi-stage/multi-hole) Return (Single hole/ single stage)	Transeptal

- The access cannula is placed in the IVC via the femoral vein for drainage.21-26Fr multistage cannula inserted via the femoral vein with the tip in the right atrium

- The return cannula is placed in the femoral artery / subclavian/axillary or aorta via the either a percutaneous US guided approach or in cases of central approach through an open surgical approach. 15-18Fr return cannula inserted into the femoral artery of the alternate limb.
- Cannulas are inserted via serial dilatation through the dilator set.
- 8Fr Super Arrow Flex 11cm backflow cannula inserted distally in the same limb as the return cannula (7Fr may be required if the 8Fr cannot be inserted). This should be done first before inserting the return canula as its much easier to place initially. Usually, the 2 guide wires are placed first (for the reperfusion canula and the ecmo return canula) and then the ecmo canula is placed followed by the reperfusion canula.

1.3 ECMO Circuit and Equipment

- There are 2 ECMO pumps available in Adan ICU (Xenios and CardioHelp)
- The circuit for the Xenios is the X-lung kit and for the CardioHelp is the Maquet HLS7 kit.
- All disposables for ECMO are kept in the ECMO trolley, which is available next to the nursing station in the surgical ICU. Further stocks are available in the medical ICU outside corridor next to M1.
- The circuit can be primed by either the perfusionist or the ECMO nurse with 0.9% Saline. Heparin dose to be added is determined by the ECMO consultant (usually 1000 IU/L). Some patients should not have heparin in the circuit (e.g. HIT or bleeding). Do not add heparin to the circuit without confirming with the ECMO consultant.
- There should always be one ECMO console primed and ready to be used at all times in the ICU. This can last for 29 days following which it should not be used. It can be used to run training drills for ECMO staff.

1.4 Cannulation for VA-ECMO

Follow the following steps for cannulation:

- Call the ECMO team to prepare for the cannulation and prime the circuit (2 ECMO doctors, ECMO nurse, and perfusionist.
- Determine ECMO type: central or peripheral
- Determine the insertion site (femoro- femoral for peripheral orfemoro – subclavian/ axillary artery or aorta or atrial – aorta or subclavian for central
- a percutaneous route is preferred for the arterial cannula for a swift access. Once the patient is stabilized, then fixing the arterial cannula through an open approach by the vascular surgeon can be performed in theatre if there is concern regarding the limb perfusion.
- Determine the cannula sizes you want to use (21-26Fr access/ multistage and 15-18Fr return/ single stage)

- Ensure arterial line and CVP line is inserted in addition to a cardiac output monitor (pulmonary artery catheter is preferable).
- Connect inotrope/vasopressor infusions and achieve haemodynamic stability
- Order 2 units packed cells and other blood products as required to allow INR &APTTr< 1.5, platelets >80, fibrinogen > 1.5, Hb between 8-10 g/dL
- Sedate and may need to paralyze the patient
- Use USS guidance for femoral and internal jugular access and TEE for dual lumen protekduo cannula placements.
- Obtain a baseline echocardiogram as a baseline for cardiac function
- Clip excessive hair at insertion sites
- Full aseptic precautions (cap, mask, gown, gloves).
- Sponge and wash the site of insertion with chlorhexidine soap extensively. Dry the sites with a sterile towel.
- Clean the access and return sites againusing chlorhexidine 2%with alcohol 70%.
- Drape with full body angiography drape. Ensure entire bed is covered (head to toe) to prevent contamination of guidewires.
- Cannulation should be ultrasound-guided using the Seldinger technique.
- Topicalize the insertion sites with local anaesthetics.
- The vessel should be approached at a shallow angle with the cannulation needle to ensure a straight path for the guidewire

Single lumen cannula technique

- 21-26Fr multistage cannula is preferred for access, 15-18 Fr single stage short cannula is preferred for return.
- Insert a cordis sheath 6 Fr on both the access and return sites to enable easy insertion of the guide wire. Ideally the skin should not be cut.
- Wire insertion, documentation of cannula position and patency should usually be undertaken using USS.
- Insert the guidewire for the reperfusion canula first then the guidewire for the ECMO cannula.
- Use a 140-260cm Amplatz extra stiff/superstiff wire for femoral vein accesswith the wire demonstrated to be within the hepatic inferior vena cava by USS.
- Use 80-160cm Amplatzextra stiff/superstiff wire forreturn cannula and ensure the insertion point to be at the common femoral artery anddistantly above the superficial femoral artery using USS guidance.
- Once wires are in place give up to 5000 IU of heparin systemically unless contraindicated.
- Serial dilators should be used to serially dilate the skin and soft tissues to one size above the cannula size (if the dilators are available). If the correct above size dilator is not available, use an artery forceps to dilate the insertion site that is not dilated maximally with the dilator set.
- Once the cannula is inserted and the stylet and guidewire is removed, apply the clamp (you need 2 clamps for access and return).
- The cannula should be inserted under USS guidance to ensure optimal position with the access cannula at the level of the hepatic veins and return within arterial desired vasculature.
- Attach 50mL bladder syringe containing heparin-saline (1000 units in 1L 0.9% saline unless contraindicated and after discussion with the ECMO consultant)to the end of each lumen, unclamp, and flush the whole 50 ml then re-clamp.

- Turn on the gas flow to the oxygenator using an FiO2 of 1.0 and a sweepflow of 1L/min increasing gradually as titrated by the CO2 level on the blood gas.The perfusionist should hand the clean loop to the cannulating doctor
- The cannulating doctor should cut the circuit between the two clamps, allowing enough length on both access and return lines to prevent any tension on the circuit. (Note: Pump trolley is usually kept at the right hand side of the patient if femoro-jugular or tandem heartlines or at the foot of the bed if femo-femoral lines).
- Connect the circuit to cannula using a wet joint avoiding air entrapment and ensure secure connection and then unclamp the circuit and start the ECMO flow with 1L/minute and gradually increasing until reaching the maximum flow that provides adequate MAP (between 60-80mmHg) and adequate oxygenation (>SpO2 95).
- The sweep flow rate to be decided in discussion with the ECMO consultant. It usually starts with 1 L/min and increased gradually as guided by the CO2 on the blood gas. Be very cautious with hypercapnic patients not to quickly reduce the PCO2 as this may precipitate intra-cerebral haemorrhage.
- Increase sweep flow by 0.5l/min every 10 minutes with ABG done every 10 minutes to avoid sudden drop in the CO2. If initial PaCO2>50, increase sweep slowly to bring PaCO2 down slowly (10-20 mmHg/hour).
- Establish baseline anticoagulation if no contraindication with 10units/kg/hr heparin (max1000 units/hour). See appendix 2 for anticoagulation guidelines.
- Manipulate cannula positions to obtain optimal circuit flows and minimize recirculation
- Continue placing the reperfusion canula over the guidewire.
- If difficulty in placing the arterial canula percutaneously then call the vascular surgeon for an open approach.
- **See ECMO initial parameters below**

Double lumen cannula (Protec duo)

- The dual lumen cannula is inserted via the right internal jugular vein.
- Use a 260cm Amplatz extra stiff/superstiff wire for the insertion, which should be placed using TOE and flourscopic guidance for the entire wire insertion. Use a cordis sheath with PAC supplied in the kit to place the tip of which in the right pulmonary artery
- Thread the guide wire through the PAC and pull out the PAC maintaining the wire in the Right pulmonary artery
- Serial dilators followed by dual lumen dilators, should be used to serially dilate the skin and soft tissues to one size above the cannula. If not available, use an artery forceps to dilate the skin and subcutaneous tissue.
- The cannula should be inserted under TEE and fluoroscopic guidance to ensure optimal position with the line positioned just below the bifurcation of the PA to ensure bilateral delivery of oxygenated blood.

Securing access and return lines

- This must be done by the cannulating doctor
- Lines should be secured with at least 3 points of suture to the skin using a purse-string suture at the skin site.

- Following commencement of VA-ECMO, secure the cannula firmly to the skin with 1.0 sutures placed on 3 different sites (the skin insertion level and 2 sites proximal to that)
- Mark the level of the cannula insertion site with a marker pen and document on the ECMO monitoring form.
- Measure the distance from the skin insertion level to the cannula metal end and document it.
- Insertion site dressed with a large tegaderm, keeping the lines visible.
- The lines should be covered at points of fixed curvature with split tubing to prevent kinking if available.

1.5 Initial set up

- Adjust blood flow to target an Scvo2 of >60-65%, whilst allowing some cardiac ejection (approximate 10-20mmHg pulse pressure).
- A Y-connector is preferred for the backflow cannula circuit connections using ¼" tubing
- A blood flow of 150-250mL is required down the backflow cannula, a gate clamp may be required
- Ventilation should be protective at all times (ie<6mL/kg ideal body weight with Pplat not higher than 28cm H2O). Initial ventilation goals are to prevent pulmonary tissue alkalosis as this can injure the lungs and promote ARDS (ie reduce minute ventilation) and to promote lung recruitment (optimizePEEP). Once cardiac recovery occurs then it is essential to optimize ventilation to prevent the development of Harlequin syndrome.

For VA-V ECMO

- A gate clamp will be required to modify the flow through the arterial and venous returns (aim 1L venous flow initially)

Section 2: Management during the VA-ECMO

2.1 Targets for Initial Treatment

- Flow: 60-80 mls/kg/min
- ECMO FiO_2: 100%
- Sweep Flow 1L/ min increase slowly according to PCO2
- SaO_2: 100% (from R arterial canula)
- MvO_2: 60-75%
- SpO_2: 95-100% (need to have pulse oximetry on both hands left and right).
- PCO_2: 35-45 mm Hg
- MAP: 60-80 mm Hg
- pH: 7.35-7.45
- Platelet count: greater than 80,000
- Hematocrit: greater than 28%
- PO2 from R arterial line sample between 10-20kpa. Titrate down ventilator FiO2

followed by the ECMO FiO2 to reach this target.

2.2 Investigations

2.2.1 Admissions investigations

- CT brain/chest/abdomen
- The routine ICU investigations
- Admission transthoracic echocardiogram(repeat after initial ECMO insertion)
- Bronchoscopy with samples for microbiology and cytology if respiratory failure.

2.2.2 Ongoing investigations:

- Daily ICU blood tests as per unit policy
- Daily CK and troponin.
- Coagulation measurement as per ECMO anticoagulation protocol
- Daily D-Dimer and fibrinogen
- Daily LDH
- Second daily triglycerides if on parenteral nutrition or on infusion of over 200mg/hour propofol
- CXR daily for respiratory failureunless requested otherwise
- Trans-thoracic echocardiography daily for patients on VA ECMO and as required. Measurements should include aortic valve and left ventricular outflow tract Velocity Time Integrals and measurement of LV distension.

2.3 Monitoring during VA ECMO

- Cerebral oximetry
- PA catheter
- Bilateral lower limb oximetry
- Right radial/brachial arterial lineas a surrogate measure for brain blood gases
- Right hand/R ear SpO2monitoras well as left hand to compare the SpO2 and early detection of Harlequin Syndrome.
- Flowmeters to assess the femoral and the reperfusion cannula blood flow rates

2.4 Circuit related Management

2.4.1 Anticoagulation:

1. Do not commence baseline anticoagulation until a CT brain has been performed demonstrating no intracranial haemorrhage and after confirming with the ECMO consultant. If the decision is to start heparin, titrate to the APTTr target set by the ECMO consultant (usuallyAPTTr maintained between 1.5-2 (APTT 40-50 seconds)
2. If concern for bleeding, reduce the APPTr to 1.2-1.5.

3. See anticoagulation protocol (appendix 2)

2.4.2 Circuit pressures limit

1. P1 (access cannula/pre-pump pressure)
2. P2 (post pump/pre-oxygenator pressure)
3. P3 (return cannula/post-oxygenator)
4. Delta P (P2-P3)= <50mmHg or 15mmHg above the trend value or which ever is lowest)

- P1 should not exceed –50mmHg, however some patient might require more negative pressure which will be acceptable as long as no line chattering or excessive haemolysis is taken place. These pressures are dynamic with cannula size and circuit diameters. Always make a note of your base line Delta P and monitor trends.
- P3 pressures are dynamic with cannula size and circuit diameters. Always make a note of your base line Delta P and monitor trends.

2.5 Patient Related Management

2.5.1 Hemodynamics:

- On VA support there is direct hemodynamic support provided by the extracorporeal circuit. The patient should be managed with inotropes, vasodilators, blood volume replacement etc. as if the patient were not on extracorporeal support. Titrating meds should be aimed at minimizing inotropes and avoiding LV distension, north south phenomena, reverse of north south phenomena and pseudo north south phenomena.
- Echocardiography is an excellent tool to assess hemodynamic function and help guide management during VA ECLS. Documentation of aortic valve dynamics and LV diameter and functionality should be done daily.

2.5.2 Ventilator management (if respiratory failure):

- Patients are on high FiO2 and ventilator settings during cannulation. The goal of ventilator management on ECLS is to use FiO2 <0.4, and non damaging "rest settings (PPlat<25)"
- In many patients the lung may proceed to total consolidation before recovery occurs, but this might be avoided by maintaining some inflation pressure as high pressures are decreased.
- Each patient is different, but a general algorithm for ventilator management is as follows:

First 24 hours:

- Moderate to heavy sedation.
- Pressure controlled ventilation (inspiratory pressure Pi = 10, PEEP = 10, I:E 1:1, rate 10 (the three 10 role)
- FiO2 0.5.

- If initial PaCO2>50, increase sweep slowly to bring PaCO2 down slowly (at a rate of 10-20 mmHg/hour)

After 24-48 hours:

1- Aim for stable hemodynamics and reduce and stop pressors if possible.
2- Moderate to minimal sedation.
3- Pressure controlled ventilation (inspiratory pressure Pi = 10, PEEP = 10, I:E 1:1, rate 10 (the three 10 role) and encourage spontaneous breathing.
4- FiO2 0.4 and continue it at that level whilst on ECMO.

After 48 hours:

1- Minimal to no sedation.
2- PCV as above or PSV with insp pressure 14-18 and PEEP 10-16 to obtain minimal TV with optimum lung mechanics.
3- Trach or extubate within 3-5 days

- Endotracheal Cuff pressure has to be monitored daily ensuring pressures between 20-25 cmH2O.
- Progress of pulmonary recovery should be assessed by a daily 100% test unless otherwise specified by the Consultant (100% via ventilator for 15-30 minutes with pre and post ABG/ see below), in combination with pulmonary dynamic compliance and improvement in the end-tidal CO2 to arterial PCO2 relationship
- Tidal volume has to be monitored daily without changing the ventilatory setting in order to monitor the improvement in the lung function by in increasing trend of the TV.

2.5.3 Bronchoscopy

- Bronchoscopy and airway lavage are facilitated by extracorporeal support and should be used as indicated.
- Lighter sedation, prone positioning, and chest PT may allow mobilization of distal secretions and may reduce the need for bronchoscopy.

2.5.4 Recruiting trials:

- None until significant aeration on CXR and > 100mls tidal volume.
- After aeration, Cilley test. (Increase FiO2 to 1.0 with no other changes. Positive test is rapid increase to SaO2 100%). If positive Cilley test, start recruitment:
  - Controlled pressure ventilation : PEEP 25 cmH2O , TV to keep P plataue< 28 cmH2O, Rate of 5, I:E ratio 3 :1 for 5 minutes.
  - Or CPAP with spontaneous breathing at 25cm H2O for 5 minutes.
  - Then return to rest settings
- Re-adjust ECMO flow if recruitment is successful. No airway PPlat>25cmH2O.

2.5.5 Positioning and Activity Management:

- After 24-48 hours, start sitting several hours/ days.
- Prone positioning if there is posterior consolidation with some open lung anteriorly.

- Be careful not to dislodge cannulas. Exercise in bed. Progress to sitting bedside, standing, walking as tolerated. Increase flows and sweeps during activity to maintain goal SaO2 and PaCO2.
- Ensure ECMO registrar, ECMO nurse and perfusionists are present for the mobilization.

2.5.6 Haemostasis and bloodvolume

Standard transfusion targets for the non-bleeding patient are:

- Hb around 9-10g/dl.
- Platelets >50
- INR <1.5
- Fibrinogen >1.5

If active bleeding, ensure the following:

- Cease heparin
- Keep Platelets >100
- Keep INR and APTTr<1.5
- Keep Fibrinogen >2. Cryoprecipitate is preferred if available to replace fibrinogen on ECMO for the bleeding patient as this also provides a rich source of von Willebrand's Factor.
- Commence tranexamic acid infusion
- Source control via interventional radiology or surgery

2.5.7 Sedation

- Use precedex and remifentanil for sedation
- Fentanyl and 2% Propofol can also be used and titrated to a Richmond Agitation and Sedation Score as set by the consultant.
- Until stability is achieved patients should remain on an infusion of neuromuscular blocking agents although this should be ceased as soon as appropriate.

2.5.8 Feeding

- Nasogastric tubes should be inserted as per standard ICU policy.
- For patients with gastric stasis, nasojejunal tubes should be inserted, guided by Cortrak if available. If NJ feeding is required, the NG should be left on free drainage to start with unless feeding is commenced.
- TPN: See separate ECMO nutrition policy.

2.5.9 Aperients

- Prokinetic agents should be started if bowel motion is significantly delayed (lactulose, erythromycin, and/or neostigmine sc)

2.5.10 Temperature

- Maintain Temperature at 36 C.
- Consider Targeted Temperature Management if ECPR

2.5.11 Stress ulcers prophylaxis

- All patients should be on a proton pump inhibitor as per ICU stress ulcer prophylaxis guidelines.

2.5.12 Infection and Antibiotics

- Give antibiotics at cannulation (initial broad spectrum) only if patient not on antibiotics.

2.5.13 Positioning and Activity Management:

- After 24-48 hours, start sitting several hours/ days.
- Prone positioning if there is posterior consolidation with some open lung anteriorly.
- Be careful not to dislodge cannulas. Exercise in bed. Progress to sitting bedside, standing, walking as tolerated. Increase flows and sweeps during activity to maintain goal SaO2 and PaCO2.

2.5.14 Nursing checklist

- This has to be done once per shift by the ECMO nurse (see appendix 3)

2.5.15 Doctors checklist

- This has to be done once per day by the ECMO Senior registrar (see appendix 4)

Section 3: Weaning from VA-ECMO

Patient should exhibit signs of cardiac function recovery including daily improvement of cardiac Dynamics. Assess the patient daily for cardiac recovery.As the heart improves, competitive flow between the heart and the ECMO pump will develop. During this period particular attention must be paid to the possibility of Harlequin syndrome (see below). Consideration will need to be given to potential outcomes including recovery, ventricular assist device, cardiac transplant and palliation.Apart from during the readiness to wean assessment, blood flow should be weaned to no lower than 2.0L/min.

Daily assessment for weaning should includeimprovement in the following parameters:

1- Echo parameters(MPI, TPSE , pulmonary hypertension, recovery of WMA, improvement in EF , increased aortic and LVOT maximum velocity) and LV diameter.

2- PA catheter parameters (PAP↓, wedge pressure≤18 , CI ≥2.2, O2 extraction ≤ 35%)

3- Arterial line pulsatility.

Once the above parameters are improving, Start weaning as follows:

1- Wean the ECMO flow in steps (50 – 100 ml / hr) till flow of 1L/min

2- With each reduction obtain Swan parameters ensuring either improvement or static hemodynamics

3- Look for improved pulsatility of the arterial waveform and maintenance of normal sinus rhythm

4- Perform either TEE or TTE to confirm improvement or static hemodynamics:

- MPI (myocardial performance index): should be increased to ≤0.4
- TAPSE (tricuspid annular plane systolic excursion)≥ 12mm
- Improvement in EF (> 25%)
- Increased aortic velocity index (VTI>12cm)
- Increased LVOT maximum velocity :> 1m/sec
- Look for pulmonary hypertension. If present may indicate LV distension.
- Recovery of WMA (wall motion abnormality)
- Increase inotropic support if needed
- Keep Impella or IABP. they should be the last to wean
- Assessing the above parameters may require reduction in ECMO flow to upload the heart and decrease afterload.

5- Once the ECMO flow is down to 1L/min with improved parameters. The patient will be ready for decannulation.

Decannulation:

- ECMO consultant, ECMO nurse, perfusionist and vascular surgeon should be present.
- Cease heparin 2 hours prior to decannulation
- Prepare 2 units of RCC.
- Lie patient flat to reduce risk of air embolism, consider neuromuscular blockade for patients with jugular cannula
- For access canula, using an aseptic technique and local anaesthetic, place a deep vertical mattress or purse-string suture at the insertion site prior to removing it.

- For return canula, this should be removed by the vascular surgeon as often there is a clot/ thrombosis and the vessel will need to be repaired by the vascular surgeon.
- Clamp circuit at the access and return cannula
- Stop circuit and remove the cannulas. The blood in the circuit and patient are the same and blood does not routinely need to be transfused back into the patient. However if a restrictive approach to transfusion is required then cell salvage might be indicated, discuss with perfusion/ECMO consultant.
- Venous duplex of the decannulated, vessel(s) should be performed 24-48 hours following the removal of cannula to assess for the presence of deep vein thrombosis and arterial aneurysm and pseudoaneurysm.
- If USS is positive for thrombus, then start therapeutic anticoagulation.

Section 4: Troubleshooting and VA ECMO complications

Specific complications of VA ECMO include:

1- North South Phenomena (Harlequin Syndrome)

This phenomenon is usually evident in patients with reasonably good LV and impaired RS function. This can lead to cerebral and coronary hypoxia.This is monitored using a combination of blood gases from the right radial arterial line and saturations from the right hand/ear and cerebral oximetry. Initial management should include maintaining adequate ECMO blood flow, optimizing lung ventilation. Failure of endogenous RS improvement would necessitate the addition of a venous return limb in the right atrium connected to the ECMO circuit through a Y connector turning the VA ECMO into VAV ECMO.

2- LV distension:

This can occur in due to:

- No cardiac ejection
- Incompetent aortic valve
- LV afterload exceeds the LVEDP whichusually results in massive pulmonary oedema and pulmonary haemorrhage.

If LV distension left untreated, permanent ventricular damage can occur. The following steps should therefore be taken:

- Insertion IABP
- Insertion of Impella
- Reduction of ECMO flow if tolerable
- Vasodilators if BP allows
- Conversion to central cannulation

3- RV failure

In patients with RV failure with RS impairment that is not due to an obstructive phenomena or severe pulmonary hypertension. Dual lumen Protek due cannula would be the cannula of choice.

4- Reverse Harlequin syndrome

This occurs when the cardiac recovery results in competitive flow within the distal aorta and the upper part of the body is well oxygenated due to adequate lung recovery, whilst the lower part of the body, mesentery and renals are poorly oxygenated. Poor lower body oxygenation can occur to either a failing circuit or due to an inappropriately low in circuit FiO2. To assess lower body oxygenation, measure the blood gas at the backflow cannula. The backflow cannula blood gas should be titrated to a PaO2 15-30kPa and a PaCO2 5-6kPa. If the PaO2 is not in this range and it was previously then sigh the oxygenator, if this does not improve the PaO2, then increase FiO2. If there are concerns about membrane function, then the gases should be retaken on circuit FiO2 1.0.

5- Distal Limb Ischaemia

This can be avoided by placing a backflow cannula or doing an open approach for the return canula placement by the vascular surgeon in the opposite limb after stabilization of the patient.

6- Post Decannulation Reperfusion

This can occur following decannulation leading to compartment syndrome.The incidence is 13-25%. The limb should therefore have hourly neurovascular monitoring for the first 24 hours following decannulation.

Other common complications of ECMO in general will include the following:

7- Hypoxaemia

Hypoxaemia on VA ECMO should be managed by:

- Maximizing circuit blood flow
- Maximize ventilation parameters
- Add a venous atrial limb
- Reduce CO if haemodynamics allow
- Reducing oxygen consumption
    - Controlling temperature to 36-36.5 degrees C
    - Sedation

- Neuromuscular blockade

- Increasing oxygen delivery
  - Blood transfusion
- Optimize mechanical ventilation

8- Access insufficiency

Access insufficiency should be managed by:

- Avoidance of raised intra-abdominal pressure
- Avoidance of raised intra-thoracic pressure
- Control of coughing/movement if required
- Optimizing cannula position
- Optimizing patient position
- Optimizing circulating blood volume (usually aim to avoid giving volume)

9- Hypotension

Defined as MAP < 60 mmHg

- Increase ECMO flow to max
- Volume resuscitation with objective monitoring (PAFC, TTE,TEE)
- Hydrocortisone 300 mg / day infusion if vasoplegia is suspected
- Vasopressors to max doses (Vasopressin / Norepinephrine / phenylephrine/and last id adrenaline but not more that 0.1 mcg/ kg/min)
- May need to use inotrope such as dobutamine

10- Bleeding

The incidence of bleeding and coagulopathy, including hemolysis is between 5-79%. For bleeding you need to do the following:

- Decrease heparin to APTT ratio of 1.2-1.5.
- D/C heparin if still bleeding
- Platelet transfusion
- FFP for factors, VWF replacement.

- Check D-Dimers, Ifanti-fibrinolytics is present, Change the circuit.
- Local control, reop as needed with a low threshold.
- Do ROTEM

11- Infection

The incidence of infection is between 17-49%. If this occurs then circuit needs to be changed.

12- Membrane failure

i. Signs of membrane failure:

- Rising trans-membrane pressure (double from baseline over the course of a shift or over 50mmHg).
- Falling blood flow for the same RPM or a need to increase RPM for the same blood flow.
- Falling post-membrane PaO2. If a reduction in post-membrane PaO2 is the only sign of a failing membrane, assessment of oxygen transfer is required using the formula: (post membrane oxygen content – pre membrane oxygen content) x 10 x blood flow. Should there be no other sign of a failing membrane other than a reduction in post-membrane PaO2, a faulty blender should be excluded by connecting to an oxygen cylinder. Another sign of significant membrane thrombus may be the development of disseminated intravascular coagulopathy (fall in platelets and fibrinogen).

ii. Causes of membrane failure

- The development of thrombus (common).
- Membrane infection (rare).
- Hypertriglyceridemia (>10), or if the patient is on total parenteral nutrition, then lipid may disrupt gas exchange.

iii. Management of membrane failure:

- Change the circuit

13- Haemolysis

i. Signs of haemolysis

- Increased bilirubin and LDH.
- Blood film demonstrating fragments.
- Red (or dark brown in extreme cases) urine;
- Increasing plasma free Hb (> 0.5)
- High potassium.
- Renal failure.
- Jaundice, (late sign).

ii. Causes of haemolysis

- Thrombus formation within the pump head.
- Sustained periods of access insufficiency with very negative access pressures.

- Sepsis, drug reactions or patient factors such as fragile red blood cells.

iii. Management of haemolysis

- Change the circuit

14- Thrombosis

The incidence of thrombosis is 1-22%. If this occurs, then discuss with ECMO consultant re anticoagulation.

15- Air in the circuit (air embolism)

i. Signs of air embolism

- Air within the circuit

ii. Causes of air embolism

- Allowing any access for air into the patient or extracorporeal circulation, for example having vascular access on the negative pressure side of the circuit or leaving caps off other intravascular devices/
- Inadequately de-airing infusions.

iii. Management of air embolism

- De-air the circuit
- Circuit change may be required

16- Circuit/Console failure (hand crank for CardioHelp and pump change for Xenios)

iv. Signs of console failure

- Sudden loss of console functions.

v. **Causes of console failure**

- Loss of power or due to a fundamental problem with the ECMO pump.

vi. Management of console failure

- Hand crank initially
- Ensure console connected to UPS
- Change the console if required

17- Gas failure

- All ECMO carts are equipped with a small C/D sized oxygen cylinder. It should be full, open and have a 1/4" tubing adapter attached to the outlet.

- In the event that a gas failure is identified (or suspected), this cylinder should be turned on at the same rate that the air/02 blender was set at, gas seen to be flowing from it and the green tubing removed from the blender and attached to the cylinder outlet.
- The reason for the gas failure should then be identified, rectified and the gas supply returned to the blender. If the blender is thought to be at fault, replacements can be found on vacant ECMO carts.
- The on call perfusionist should be informed of the failure at the earliest opportunity. It should be noted that in the event of a central gas supply failure, all ECMO patients would require cylinders. Plans should be made to ensure that sufficient oxygen is available until wall gas supplies are restored.

18- Membrane fiber rupture

- Membrane fiber rupture is identified by evidence of blood in the gas exhaust port at the bottom of the oxygenator. It is rare that membranes spontaneously rupture. It is usually a result of a manufacturing defect or damage in transit. It is also extremely rare that a rupture will noticeably compromise gas exchange.
- Membrane fiber ruptures generally clot of their own accord and circuit change is seldom indicated. Any blood dripping from the exhaust port of the oxygenator should be reported to the ECMO consultant and monitored. Should it not stop then a circuit change will be undertaken.

19- Unplanned Decannulation

i. Signs of decannulation

- Removal of the cannula from the vessel – either partial removal or complete removal.
- If partial removal the only sign may be the cannula insertion site measurement has changed.
- If the decannulation occurs on the access cannula, massive air embolism may occur.
- Total decannulation leads to massive blood loss (return cannula) or massive air embolism (access cannula).

ii. **Causes of decannulation**

- Decannulation is secondary to inadequate fixation of the cannulae and/or inappropriate tension being placed on cannulae (e.g. during transfer).

iii. Management of decannulation

- If partial, simultaneously reinsert cannula until side holes are covered, de-air circuit, replace patient's circulating volume and inform ECMO consultant/perfusionist
- If cannula completely removed then simultaneously clamp the return line and turn pump off, apply pressure to the cannula site, establish emergency ventilation settings, replace patient's circulating volume and inform ECMO consultant/perfusionist

20- Cardiac arrest

- The ECMO consultant should be informed of any episode of cardiac arrest in an ECMO patient.
- If cardiac arrest occurs during VA ECMO, the usual ACLS algorithm should occur, including CPR. The circuit should be assessed for function and providing it is adequately functioning and not the cause of the cardiac arrest, should continue to run. If the circuit is the cause of cardiac arrest, then the problem leading to circuit failure should be addressed.

Section 5: Circuit change (infection/ blocked circuit)

Patients dependent upon ECMO for life support, either veno-arterial or veno-venous may at times have significant circuit related problems, including air embolus, thrombosis or leakage requiring change. The urgency of this change is dependent upon the individual circumstances of the patient, including their ability to be supported by conventional means.

5.1 Preparation

- Conventionally ventilate the patient using the emergency ventilator settings (Pressure AC PEEP 10, Pinsp 20, rate 20, Tinsp 1sec, FiO2 1.0 – NB may need to increase Pinsp to higher level (eg 30-40) to have a life sustaining tidal volume).
- Circulation should be supported according to hemodynamic parameters including vasopressors (vasopressin, Norepinephrine) and/or inotropes (Dobutamine, Levosimendan, Milrinone, Epinephrine). Dosage and choice would be of consultant decision.

Perfusionist

- Prime a circuit
- 4x3/8" straight connectors

Nursing

- Set up a trolley with a procedure pack
- Make up a solution of 10000 units heparin in 1L of 0.9% sodium chloride solution in a sterile jug
- 2 x 50mL catheter tipped syringe
- 6 sterile ECMO clamps
- 2 x Circuit scissors
- Betadine (aqueous) and bowl
- 6 sterile green drapes (loose, without central hole)
- Ensure gloves/gowns/masks available (x3)
- Ensure cardiac arrest trolley at bedside
- Ensure atropine (3mg) and adrenaline (1mg 1:10000) are available at bedside

- Transfusion may be required, assess Hb following circuit change.

5.2 Method (min 2 people required, one of which must be consultant)

- Using non-alcoholic betadine clean the circuit currently attached to the patient
- Lay one drape under the current circuit and one over the circuit distal to where you intend to clamp the access and return, so that the working area is sterile (distal is towards the pump)
- Clamp and cut the replacement circuit and add in a straight 3/8 inch connector onto both the access and return aseptically.
- Lay the new circuit on top of the drape ensuring access and return are on the correct sides
- Clamp both the access and return limbs of the current circuit distal to the cannula join
- Cut the circuit between the clamps
- Connect the replacement circuit using a wet join with heparinised saline
- Remove all clamps and go back onto ECMO
- Ensure that circuit joins are gun-tied

Section 6: ECMO Team

The ECMO team consists of the following:

1- ICU ECMO Consultant

2- ICU ECMO SR/ Registrar

3- Perfusionist

4- ECMO nurse

5- Cardiac/vascular surgeon (if open approach is required)

The roles and responsibilities of each member of the team is as follows:

a- ECMO Consultant

Adan Hospital ICU ECMO consultant will be responsible for receiving the referrals, assessment, approval of all patients referred for VA-ECMO from Adan Hospital or any other hospital (private or governmental) in Kuwait. The ICU ECMO consultant is also responsible for the overall management of the ECMO patient once accepted for VA-ECMO. Assessment and management involve the following:

- Accepting the patient for starting the ECMO after confirming the suitability and the indication

- Cannulation or supervision of cannulation by the ICU SR

- Initial ECMO parameters setup and further parameter changes
- Retrieval of the patient if unstable for transfer
- Daily review of all ECMO patients
- Medical reference for all other ECMO staff
- Involvement in all key decision making (e.g. weaning, withdrawal of therapy, bleeding and other complications management)
- Supervision of junior staff in Adan ICU.

b- ECMO Registrar/Senior Registrar

- Retrieval of the patient if unstable for transfer
    - Insertion and removal of the percutaneous cannula under supervision of the ECMO consultant.
    - General management of the ECMO patient and ECMO circuit under the supervision of the ECMO consultant.
    - Be familiar with all the complications that may develop and its management.

c- Perfusionist

The perfusionist will provides 24 hr cover for:

- Initiation of ECMO
- Priming of circuits
- Circuit maintenance and nursing support
- Retrieval of the patient if unstable for transfer
- Three times daily review of patients on ECMO
- Attendance for all inter and intra-hospital transport of patients
- Attendance at all procedural interventions.

d- ECMO Nurse

All patients on ECMO require overview by a second ECMO nurse, in addition to a dedicated bedside nurse. 24 hour nursing cover is required to:

- Maintain a safe environment for the management of a critically ill, ventilated patient with a wide range of complex care needs.
- Ensure safe monitoring of the ECMO patient including monitoring all the ecmo parameters as illustrated in the ECMO monitoring form (appendix 4).
- Immediate call to the medical staff and perfusionist whenever any of the parameters are outside the determined range indicated by the ECMO consultant as documented in the ECMO monitoring form.
- Be familiar with the different kits needed for the ECMO cannulation as per the ECMO equipment list (appendix 5), which should be all available in the ECMO Cart and ensuring its availability and replacement whenever it's been used.

e- Cardiac surgeon/vascular surgeon

- Responsible for surgical cannulation if percutaneous approach fails or causes compromise to the limp perfusion and hence open approach is required.
- Responsible for surgical decannulation unless recommended otherwise and repair of any damaged vessels secondary to cannulation.

References

1. Clinical Guideline. Extracorporeal Membrane Oxygenation (ECMO) for acute cardiac and respiratory failure in adults. Guy's and St Thomas NHS Foundation Trust. May 2017. Dr Nicholas Barrett.
2. ELSO (extracorporeal life support organization) patients care practice guidelines. https://www.elso.org/Resources/Guidelines.aspx
3. ECMO: Extracorporeal Cardiopulmonary Support in Intensive Care (The Red Book)" published by ELSO.
4. Advances in mechanical circulatory support. VA ECMO for cardiogenic shock and cardiac arrest. Cardinal considerations for initiations and management. Rao et al. Circ Heart Fail. 2018; 11:e004905. Sept 2018

APPENDIX 1
ECMO Referral Form (page 1)

MINISTRY OF HEALTH
KUWAIT

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Adan Adult ICU ECMO Referral Form (VA ECMO)

Please complete this consultation form for all ECMO referrals to Adan Hospital.

Referring Hospital _____ Patient name _____
Referring Specialty _____ Civil ID number _____
Referring consultant _____ Gender: M / F Age _____
Referral date _____ Unit _____ Ward_____ Bed_____
Admission diagnosis _____ File no _____

History (including comorbidities) _____
_____

Patient parameters (*has to be completed, otherwise the consultation will be rejected):

* Pre-morbid functional status □ bed bound □ chair bound □ mobile
* Pre-morbid conscious status □ Alert and oriented □ Demented □ Coma/ vegetative status
*Current GCS E ____ V ____ M ____ Total score ____ /15

Ventilation

*Duration of conventional mechanical ventilation _____ Days
*SpO2 _____% PO2 _____ mmHg *FiO2 _____ ***PaO2/FiO2 ratio*** _____ mmHg
*PIP (peak insp pressure/ PAW) _____cmH2O ***PEEP*** _____ *TV_____ *RR _____
Lung Compliance (mls/cmH2O) _____(calculated as TV/(PIP – PEEP)
CXR quadrants (number of quadrants with infiltrations seen on CXR: alveolar consolidation) 1 point per quadrant, minimum 0, maximum 4) _____

Cardiovascular parameters:

*HR _____ *BP _____ *CVP _____ *Temp _____ *SCVO2 _____ (<50%)
*CO _____ *Cardiac index _____L/min/m2 *left ventricular ejection fraction_____ % (< 30%)
*Aortic velocity time integral (AOVTI) _____ (<8cm)

(Inotropes/vasopressors) Agent: _____ Dose _____mcg/kg/min
Agent: _____ Dose _____mcg/kg/min
Sedation : Agent: _____ Dose _____
Agent: _____ Dose _____
Muscle relaxants: Agent: _____ Dose(bolus/infusion)_____

Investigation results:

*wbc _____ *Hb _____ *Plt ____ *INR_____ *PT_____ *APTT_____ *Bil _____ *AST_____*ALT_____
*urea_____ *Cr _____ *Lactate_____ (>3 mmol/L) *UO _____mls/hr *Dialysis Yes / No
*Blood Gas : pH _____ PO2 _____ ***PCO2*** _____ HCO3 _____ BE_____

Signature and stamp of referring Doctor _____ Date: _____
Designation (minimum Specialist) _____ Telephone number _____

Consultations have to be discussed verbally with the ECMO Consultant in Adan Hospital. For adult ICU ECMO referral please contact the ICU on-call doctor by phone (96623263) as well as filling this form and faxing it to (23946102) to ensure a prompt response to the referral.

APPENDIX 1
ECMO Referral Form (page 2)

MINISTRY OF HEALTH
KUWAIT

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Indications and contraindications for Veno-Arterial (VA ECMO)

Clinical indications:

- Potentially reversible and severe cardiogenic shock secondary to :
  - MI
  - Fulminant myocarditis
  - Non ischemic cardiomyopathy including sepsis induced cardiomyopathy
- Pulmonary hypertension and right heart failure
- Pulmonary embolus with hemodynamic compromise
- Bridge to decision for transplant or VAD (LVAD/BiVAD)
- Support post cardiac surgery
- Medication overdose (e.g Beta , Ca # blockers , and TCA)
- Hypothermia (Drowning)
- Cardiac arrest (ECPR) which needs to fulfill the following conditions:
  - Witnessed Arrest
  - Shockable Rhythm (preferably)
  - Good quality CPR
  - Pre ECPR ACLS < 30 min
  - EtCO2 > 20 mmHg or 10
  - Peri Arrest Lactate level < 9 mmol/L
  - SOFA score <12

Physiological parameters:

(Allow 1-12 hours of inotropic support to be commenced before starting VA ECMO)

- Persisting (>30 minutes) lactate >3mmol/L or ScvO2 <50% due to cardiogenic shock
- Persisting cardiac index <2.2L/min/m2
- Evidence of end organ dysfunction due to cardiogenic shock
- Trans-thoracic echocardiography with left ventricular ejection fraction <30% or aortic velocity time integral (Ao VTI) <8cm.

Absolute contraindications for VA ECMO:

1. Chronic medical co-morbidity with a life expectancy of less than 12 months
2. Progressive, non-recoverable heart disease and not suitable for transplant
3. Progressive and non-recoverable respiratory disease and not suitable for transplant.
4. Chronic severe pulmonary hypertension
5. Advanced malignancy
6. Graft versus host disease
7. Unwitnessed cardiac arrest
8. Cachexia due to an underlying progressive chronic disease
9. Bone marrow transplant recipients within 12 months of transplant
10. Any contraindication to transplantation
11. Peripheral arterial disease, recent aortic surgery or aortic dissection precluding cannulation
12. Aortic valve regurgitation
13. CPR >30 minutes at commencement of cannulation

****Murray Score**

Each parameter scores between 0 and 4 and an average of the 4 parameters scoring is calculated to get the final Murray score. A score of ≥ 3 is an indication of VV-ECMO.

Murray Score	0	1	2	3	4
PaO2/FiO2 on 100% O2	≥40kPa (300mHg)	30-40kPa (225-299 mmHg)	23-30kPa (175-224 mmHg)	13-23kPa (100-174 mmHg)	<13KPa (100mmHg)
CXR quadrants	Normal	1	2	3	4
PEEP (cmH2O)	≤5	6-8	9-11	12-14	≥15
Compliance (ml/cmH2O)	≥80	60-79	40-59	20-39	≤19

Murray score can be calculated through the CESAR trial website (conventional ventilation or ECMO for severe adult respiratory failure) on:
http://cesar.lshtm.ac.uk/murrayscorecalculator.htm

APPENDIX 2
Heparin Protocol for VV ECMO

a) Upon initiation of ECMO, give intravenous loading dose of 5000 unit of unfractionated heparin

b) Start infusion rate of 15-18 unit/kg/min

c) Monitor aPTT Q6hr (target aPTT 40-60 sec; aPTT ratio 1.5-2.0)

d) Adjust heparin infusion rate as following:

e) For high risk patients for intracerebral hemorrhage, reduce Heparin infusion to achieve a target of APTT values of 1.2 – 1.5. Consult the doctor (go down or up by one box in the below table).

aPTT	Bolus	Stop infusion	Rate change
<30	2000 unit	No	Increase by 300 unit/hr
31-40	1000 unit	No	Increase by 100 unit/hr
41-60	0	No	No change
61-70	0	No	decease by 100 unit/hr
71-80	0	30 minutes	decrease by 200 unit/hr
81-100	0	60 minutes	decrease by 300 unit/hr And call MD

APPENDIX 3 –A

Safety Checklist - Cardiohelp

Appendix 3 - A

Patient Name: _____ **CID No.** _____ **Bed No.** ____ **Day:** ____ **Date:** _____

Bedside ECMO Safety Inspection Checklist (Cardiohelp)	7-2	2-10	10-7
Cannula and Circuit Check (with a light source)			
• Tip to tip check with manual feel of all tubing and connections			
• Access and return cannula position, no bleeding, no infection (ensure transparent dressing, if covered with gauze remove to inspect)			
• Color comparison – Strong / Mild / No			
• No Chattering			
• No Air			
• No Clots (If yes, document on the diagram)			
• No Kinking			
• Flow sensor check → Correct direction and tube (return/arterial line)			
Oxygenator / Pump Check			
• No Clot			
• Pre – Post membrane pressure			
• No Water / Blood leaks			
• No Air → Should listen			
• Pressure transducer connections			
• Position (lower than the patient's heart level)			
Oxygen / Gas Blender Check			
• Sweep flow set value: _____ Sweep flow reading: _____			
• ECMO FiO2 set at _____.			
• Sight test to eliminate condensation			
• O2 source connected to main O2 pipelines			
• Spare O2 Cylinder (Full and connected to flow meter)			
Heater / Cooler Check			
• Tight connections switched on and plugged to power source.			
• Temperature set value: _____ Temperature reading: _____			
Hand Crank Check			
• Visible and accessible (Should be at the level of the oxygenator)			
• Tested (with flow to green lighting)			
Console Check			
• Check reading against the set value (If different inform the doctor)			
• RPM			
• Blood Flow			
• P int, P vent, ΔP			
• Appropriate intervention alarms * ΔP should be 15 mmHg above baseline trend or 50 mmHg or whichever is lower			
Extras Check			
• Clamps x4			
• 50 ml lower lock syringes x 3			
• Light source			
• ECMO plugged to maintain power source			
• ECMO support cart available and properly stocked.			
• Pedal pulses and peripheral pulses checked			
• Correct cannula placement is checked by Dr. _____			

7-2		2-10		10-7	
IN	OUT	IN	OUT	IN	OUT

APPENDIX 3 –B

Safety Checklist - Xenios

Appendix 3 - B

Patient Name: _____ **CID No.** _____ **Bed No.** ____ **ECMO Day:** ___ **Date:** _____

Bedside ECMO Safety Inspection Checklist (Xenios)	7-2	2-10	10-7
Cannula and Circuit Check (with a light source)			
• Tip to tip check with manual feel of all tubing and connections			
• Access and return cannula position (no migration and correct skin marking), sutures, no bleeding, and no infection. (Ensure transparent dressing, if covered with gauze remove to inspect)			
• Color comparison – Strong/Mild/ No			
• No Chattering			
• No Air			
• No Clots (If yes, document on the diagram)			
• No Kinking			
• Flow sensor check → Correct direction and tube (return/arterial line)			
Oxygenator / Pump Check			
• No Clot			
• Pre and Post membrane pressure, ΔP			
• No Water / Blood leaks			
• No Air → Should listen			
• Pressure transducer connections			
• Position (lower than the patient's heart level)			
Oxygen / Gas Blender Check			
• Sweep flow set value: _____ Sweep flow reading: _____			
• ECMO FiO2 set at _____.			
• Sight test to eliminate condensation			
• O2 source connected to main O2 pipelines			
• Spare O2 Cylinder (Full and connected to flow meter)			
Heater / Cooler Check			
• Tight connections, switched on and plugged to power source. • Temperature set value: _____ Temperature reading: _____			
Backup Pump Drive and Battery Check			
• The backup pump is tested, back-up battery is fully charged			
Console Check			
• Check reading against the set value (If different inform the doctor)			
• RPM			
• Blood Flow			
• P1, P3, ΔP			
• Appropriate intervention alarms			
Extras			
• Clamps x4			
• 50 ml lower lock syringes x 3			
• Light source			
• ECMO plugged to maintain power source			
• Pedal pulses and peripheral pulses checked			
• ECMO support cart available and properly stocked.			
• Correct cannula placement is checked by Dr. _____			

7-2		2-10		10-7	
IN	OUT	IN	OUT	IN	OUT

APPENDIX 3 – C
ECMO Data Sheet

Appendix _____

ECMO DATA SHEET

ECMO TYPE	☐ V-A ☐ V-V ☐ Other _____
☐ Single Lumen ☐ Dual Lumen	

Date	
Location	
ECMO Cannula Inserted by:	
Nurse	
Perfusionist	

PATIENT DATA

Name		**Age / Sex**	
Nationality		**Weight / Height**	
Civil ID		**Blood Group**	
Hospital No		**EF %**	
Diagnosis		**Murray Score**	
ECMO Indication		**Resp Score**	

ECMO ACCESS LINE		**ECMO RETURN LINE**	
Site		**Site**	
Cannula Brand		**Cannula Brand**	
Cannula Size		**Cannula Size**	
Inserted Length		**Inserted Length**	
Skin Marking Length		**Skin Marking Length**	

DUAL LUMEN CANNULA

Site	
Cannula Brand	
Cannula Size	
Inserted Length	
Skin Marking Length	

**Skin marking is from the insertion site up to the end of the metal rim of the cannula

PERFUSION DATA

ECMO Console		**Priming Solution**				
Oxygenator		VITAL SIGNS DURING CANNULATION				
Gas Blender		**HR**	**BP**	**MAP**	**SPO2**	**CVP**
Heater/Cooler						
IABP		**PUMP TIMING**				
CRRT		**DATE & TIME ON**		**DATE & TIME OFF**		
		TOTAL TIME ON ECMO: _____				

COMMENTS: _____

_____

Reason for Termination of ECMO: _____

_____

Adan ICU. Updated March 23, 2018.

APPENDIX 4
ECMO Monitoring Form

Patient Name: _____ **CID No.** _____ **Bed No.** ____ **ECMO Day:** ____ **Date:**_____

ECMO Monitoring Form (VA ECMO)

(Hourly observation unless stated otherwise)

DATE												
TIME												
SPO2												
Ventilator FiO2												
TV												
PIP/PI												
PEEP												
Plateau												
Compliance												
ECMO FiO2												
Sweep Flow												
FLOW												
RPM												
P- Ven (P1)												
P-Art (P3)												
Del-P (P2-P3)												
pH (6 hourly)												
PCO2 (6 hourly)/ Sentec CO2												
PO2 (6 hourly)												
HCO3 (6 hourly)												
B.E. (6 hourly)												
ABG SaO2 (6 hourly)												
ABG Lac (6 hourly)												
APTT (6 hourly)												
APTT Ratio (6 hourly)												
Heparin Infusion												
D-Dimer (daily)												
Fibrinogen (daily)												
Hb (6 hourly)												
Platelet (6 hourly)												
Lac (daily)												
LDH (daily)												
Triglyceride (daily)												
Heart Rate												
MAP												
CVP												

Targets to be filled daily by the ECMO consultant (please specify targets if different from the set value)

DAILY ECHO FINDINGS:		Platelets _____ (>50)	HR _____ (50-70bpm)
EF _____ (>25%)	ECMO Flow _____	Fibrinogen _____ (>2)	MAP _____ (65-80mmHg)
MPI _____ (≤0.4)	LV Diameter _____	Heparin _____ ml/min	CVP _____ (10-14mmHg)
TAPSE _____ (≥12mm)	PAP _____	APTT Ratio _____(1.5-2.0)	CO _____ (4-5L/min)
VTI _____ (>12cm)		APTT _____ (40-60s)	CI _____ (2.2-2.5L/min)
LVOT _____ (>1m/sec)		Plateau _____(< 25cm H2O)	PWP _____ 14-16mmHg)
Pulsatility of arterial waveform present? : Yes / No		PaO2 _____ (8-12 kPa)	PEEP _____ (10-15)
Aortic valve opening? : Yes / No		PaCO2 _____ (4-6 kPa)	

Other instruction: _____ Length from incision site to the end of metal rim _____

Adan ICU. Updated January 2019

APPENDIX 5
ECMO CANNULATION ITEMS

Hibiscrub	1 bottle
Surgical Scrub Brush	2
Sterile Gown	4
Sterile Gloves (All sizes)	2 each
CHLORHEXIDINE(70%ALCOHOL+2% CHLORHEXIDINE)	1 bottle
ANGIO STERILE DRAPE L	2
ULTRASOUND PROBE COVER	2
ULTRSONIC GEL (sterile)	1
INSERTION KIT WITH DILATORS	2
CORDIS 6FR VASCULAR SHEATH	2
AMPLATZ EXTRA STIFF GUIDE WIRE	2
BMW (Hi-Torque guide wire)	2
Surgical Blade with handle	2
Desired CANNULA (as per the Doctor's request)	1
50 CC CATHETER TIP SYRINGE (filled with heparinized saline, if not contraindicated)	8
Heparinized Saline 0.9 % (5000 IU in 500 mL)	
DRESSING SET	2
CUTDOWN SET	1
Clamps (Sterile)	8
Sterile Gauze (4x4)	1 pack
20 CC SYRINGE	2
10 cc Syringe	2
MERSILK SUTURE '0' and '1'	3 each
BIOPATCH	2
Chlorhexidine Dressing	2
Sterile marker	1
Tegaderm	2

ECMO Committee

(Policy No 5)

Veno-arterialExtracorpeal Membrane Oxygenation

(VV-ECMO) General Management POLICY 2019

Policy owner: ECMO Committee. MOH	**Applies to:** All Staff in MOH and private Hospitals in Kuwait
Section Location: Departments of Anaesthesia, Adult Intensive Care and Pain Management in all MOH and private Hospitals in Kuwait.	**Effective date:** 01-03-2019 **Revision date**: 01-03-2022
Approved by: Head of ECMO committee, ECMO committee members	
Final Approval by: MOH Undersecretary	

_____ _____

MOH Undersecretary Date: