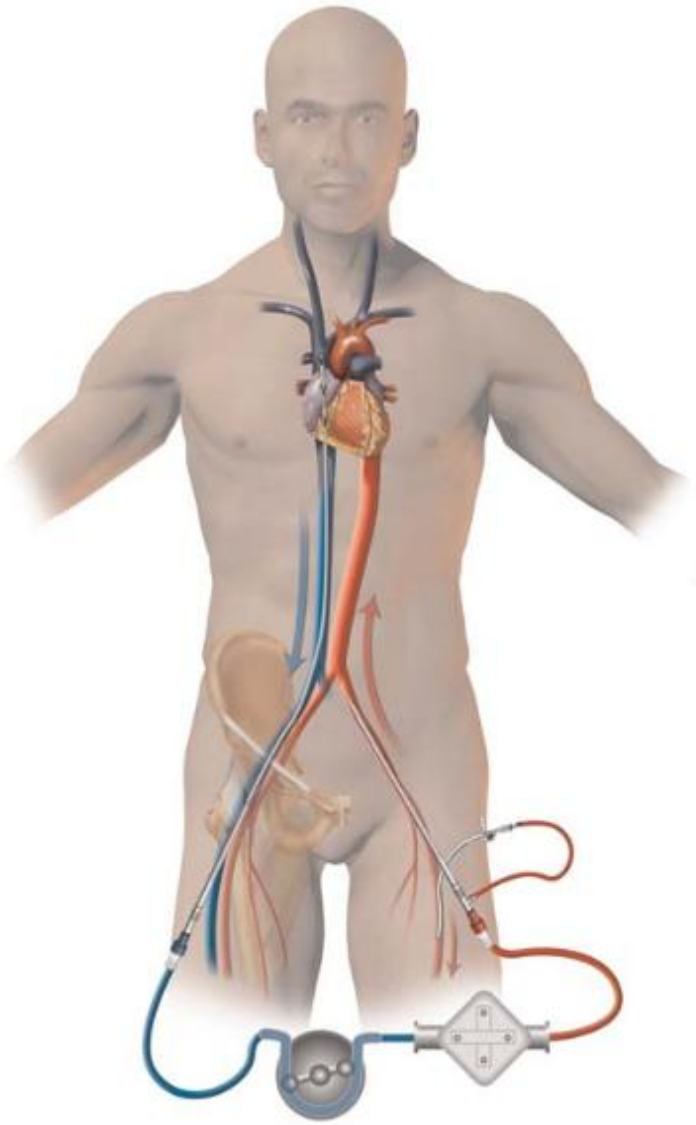
Peripheral Extracorporeal Life Support

Clinical Guidelines 2021



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EMERGENCY PROCEDURE SECTION

Introduction

Extracorporeal life support (ECLS) is a treatment for patients who have failed to respond to other less invasive critical care therapies for the treatment of severe respiratory or cardiovascular failure where there is a **realistic chance of reversibility** in the initiating disease process and an associated high risk of death (typically >80%). As ECLS is a type of advanced supportive therapy with significant life threatening complications its use is currently restricted to patients who are most likely to benefit. In practical terms this means patients with few or ideally no co-morbidities.

A decision on whether a patient is suitable for ECLS therapy is made by agreement between the treating Intensivist and at least one of the ECLS trained Intensivists. The outcome of both treated and referred but declined patients will be subject to regular review at the ECLS governance meeting. Reasons for acceptance or refusal will be explicit and documented for discussion.

This clinical practice guideline is for use on wards 118 and 111 for the management of patients undergoing **peripheral** Extracorporeal Life Support (ECLS) therapy. **Central** ECLS has many features in common with peripheral ECLS but almost exclusively occurs in the specific context of cardiac surgery and so will not be discussed further in these guidelines. For specific information on central ECLS consult the ward 111 guidelines.

Types of ECLS

There are two main types of ECLS termed Veno-venous or Veno-arterial. They have many features in common but also some specific differences which will be discussed in the relevant sections.

In simple terms, Veno-venous ECLS (VV ECLS) is used to support the failing lung with deoxygenated blood drained from a large central vein (or veins) by a centrifugal pump, oxygenated and returned via another large central vein close to the right atrium, to minimise the problem of extracorporeal circuit recirculation.

Veno-arterial ECLS (VA ECLS) is used to support the failing heart with or without associated respiratory failure. It too drains deoxygenated blood from a large central vein (or veins) but instead of returning the oxygenated blood to a patient's venous system it is returned to their arterial system in a *retrograde fashion*.

As these terms can become confusing in an extracorporeal circuit, our preference is to use the terms **drainage** to refer to the cannula that removes ***de****oxygenated* blood and **return** for the cannula that returns ***re****oxygenated* blood to the patient.

At the time of writing these guidelines there is little high level evidence for management of the ECLS patient and these guidelines have been developed based on expert opinion from other centres and will evolve over time. I gratefully acknowledge the help of Dr Alain Vulysteke (Papworth, Cambridge), Dr Nick Barrett (GSTT, London), Dr Michael O'Leary (RPAH, Sydney), Dr Lisen Hockings (The Alfred, Melbourne) and Dr Daniel Brodie (New York Presbyterian Hospital) for allowing me access to their institutional guidelines to help formulate our own.

Indications for VV ECLS

VV ECLS

This is a rescue therapy for patients with refractory hypoxaemia (or hypercarbia) who have failed to respond to conventional or alternative (e.g APRV, HFOV, iNO, proning) strategies to achieve lung protective ventilation and/or an oxygenation goal.

Standard Indications for VV ECLS:

1. Hypoxaemia: P/F ratio < 10kPa on FiO_2 1.0 or Murray score ≥ 3
2. Hypercapnoea: $PaCO_2$ > 11kPa or pH < 7.20 (H^+> 63nmols/L)
3. Compliance: < 20 mls/cmH_2O or P_{plat} > 30 cm H_2O
4. Less than 7 days high pressure mechanical ventilation

Although the definition of ARDS is well accepted, 'severe' ARDS may be recognised by the some of the following features:

Murray score > 3.0 or >2.5 with rapidly progressive deterioration
Severe hypoxaemia (P/F < 10kPa for > 1 hr on FiO_2 1.0)
Respiratory acidosis (pH < 7.20 (H^+> 63nmols/L for > 1 hr)
P_{plat} > 30 cm H_2O in absence of high pleural pressure (e.g. abdominal distension)

Murray Lung Injury Score:

Score	0	1	2	3	4
P/F ratio (kPa)	>40	30-40	20-30	10-20	<10
Compliance mls/cmH_20	>80	60-80	40-60	20-40	<20
PEEP (cmH_20)	<5	6-8	9-11	12-14	>15
CXR infiltrates quadrants	none	1	2	3	4

Compliance (mls/cmH_2O) = tidal volume/P_{plat} - PEEP

Total score/4 = ***Murray Lung Injury Score***

Pathologic conditions that may require VV ECLS include but are not limited to:

Severe ARDS from any cause
Uncontrolled Air Leak Syndromes
Pulmonary contusion
Inhalation Injuries (gastric contents, near drowning, smoke)
Refractory Status Asthmaticus

Indications for VA ECLS

VA ECLS

Veno-arterial ECLS is used for short-term support in patients with severe heart (or heart and lung) failure where volume therapy, vasoactive medication and intra-aortic balloon counter-pulsation have failed to provide adequate systemic perfusion. The decision to deploy VA ECLS is often made urgently in patients with acute circulatory shock not responding to conventional support therapies or not weaning from intra-operative cardiopulmonary bypass. There is an emerging role as a resuscitative tool in refractory cardiac arrest in highly selected cases.

Indices of tissue hypoperfusion include systemic hypotension, mental status changes, oliguria, core - peripheral temperature gradient, skin mottling, myocardial ischaemia and serum lactate concentration. In patients with satisfactory arterial oxygenation and haemoglobin concentration, inadequate systemic perfusion can be inferred by mixed venous oxygen saturation less than 70%.

Deoxygenated blood is drained from the inferior or superior vena cava and oxygenated blood is returned to the femoral artery (peripheral VA ECLS) or ascending aorta (central VA ECLS).

Peripheral VA ECLS can be deployed rapidly (femoral artery and vein cannulation) and is appropriate when native lung function is satisfactory and sternotomy or cardiac surgery is not applicable. Central VA ECLS is most often employed in patients who fail to wean from conventional intra-operative cardiopulmonary bypass after cardiac surgery. In patients with heart failure and poor native lung function, central VA ECLS is preferred to peripheral VA ECLS to avoid poorly saturated blood from the dysfunctional native lungs being ejected into the proximal aorta, however consideration of *peripheral* Veno-arterial-venous VAV ECLS is also possible.

Pathologic conditions that may require VA ECLS in ward 118
Refractory cardiac arrest
Ischaemic cardiogenic shock
Bridge to decision regarding suitability for therapy (eg, revascularisation) or for longer term support (e.g. VAD, transplantation)
Acute decompensation of Dilated Cardiomyopathy
Massive pulmonary embolism
Acute fulminant myocarditis
Sepsis with profound cardiac depression
Overdose of cardiac depressant medication

A scoring system the SAVE score may be useful to quantify the chances of survival in potential VA ECLS candidates.

Contraindications to ECLS therapy

As ECLS can cause life-threatening events, patient selection is an important factor in minimising these. Bleeding complications remain the commonest cause of morbidity in ECLS patients.

Absolute contraindications to all forms of ECLS

1. Inadequate vascular access
2. Progressive and non-recoverable heart disease (and not suitable for transplant)
3. Progressive and non-recoverable respiratory disease (irrespective of transplant status) unless accepted for transfer to a lung transplant centre **prior** to starting ECLS in Edinburgh
4. Advanced malignancy (irrespective of potential curative status)
5. Graft versus host disease
6. Frailty due to an underlying progressive chronic disease
7. History of variceal disease, liver cirrhosis or other bleeding diathesis
8. Previously documented poor functional status eg not independent of ADLs
9. Refusal of blood products

Specific absolute contraindications to veno-venous ECLS

1. Severe (medically unsupportable) heart failure
2. Severe chronic pulmonary hypertension and right ventricular failure (mPAP≥50mmHg)
3. Cardiac arrest (ongoing)
4. Severe immunosuppression (transplant recipients >30 days, advanced HIV, recent diagnosis of haematological malignancy, bone marrow transplant recipients). The outcomes for these patients have been uniformly poor
5. Pulmonary Fibrosis exacerbation.

Specific absolute contraindications to Veno-Arterial ECLS

1. Severe aortic regurgitation (e.g Pressure Half time <250ms)
2. Aortic dissection.

Relative contraindications to all forms of ECLS

1. Age>70
2. Inability to receive anticoagulation
3. Duration of conventional mechanical ventilation >7 days, with high inspiratory pressures (Pplat>30cmH20), high FiO2 (FiO2 >0.8) or evidence of significant ventilator induced lung injury
4. Trauma with multiple bleeding sites
5. CPR duration >60 min
6. Severe multiple organ failure
7. CNS injury
8. BMI <18 or >40

Patient preparation for ECLS

Please ensure that the mandatory investigations and procedures outlined below have been carried out and enacted prior to ECLS cannulation. It is important to remember that ECLS cannulas are large and bleeding can be brisk and significant. Please ensure patient's next of kin is available for assent to this procedure.

Investigations:

- FBC & Coagulation studies (≤2 hours ago)
- U&E's, Ca, PO4, Mg, LFTS (≤ 12 hours ago)
- Accurate patient weight in kilograms and height in centimetres

Blood products:

- INR & aPTTr are ≤1.5; and if not, have had appropriate treatment to achieve this- discuss options with haematology especially if the patient is likely to be intolerant of large volume treatment with FFP
- Fibrinogen ≥ 1.5g/l; and if not, have had appropriate treatment to achieve this- discuss options with haematology especially if the patient is likely to be intolerant of large volume treatment with FFP
- Platelets are at least 100 x 10^9/L; and if not, have had appropriate treatment to achieve this- discuss options with haematology.
- Hb at least 100g/L; and if not, have had appropriate treatment to achieve this- discuss options with haematology.
- Even if the above targets are already achieved please have
    - 2 units of RCC crossmatched, with patient for cannulation then during ECLS run ensure repeat crossmatch every 72 hours.
    - 4 units of FFP on site (available but not thawed)
    - 2 pools of platelets.
- **Pre-existing vascular access:** We prefer to use the Right Internal Jugular and either Femoral veins/arteries for ECLS cannulation. If these sites already have lines in situ, we will insert new lines and have any drugs transferred over to this new line prior to cannulation. Please do not remove any lines that you already have in these sites
- CVP lines. We will usually insert a new 5 lumen CVC +/- Vascath.
- Arterial lines. We prefer to have a right radial arterial line for monitoring. If you have any femoral arterial lines please leave them in situ.
- Peripheral cannula. If these are not required please remove them.

Other tubes:

- Urinary catheter in situ and working
- Nasogatric tube in situ and checked that is working and sited correctly
- Consider a faecal management system and start laxatives

Sedation, Analgesia, Antibiotic & Paralysis Management of the ECLS Patient

Unlike most ICU patients we will aim for the ECLS patients to be heavily sedated at least initially. This is because cannula dislodgement can be life threatening and patient movement can lead to circuit flow interruption.

During Cannulation and Transfers
The patient should be anaesthetised and paralysed as dictated by their physiological status. The bolus paralytic agent of choice is rocuronium.

In the ICU
Sedation is required to be deep for the initial stages of ECLS therapy and due to the pharmacokinetics of sedative and muscle relaxants in the extracorporeal circuit, high doses of these agents may be required. Lipophilic agents may sequestrate in the circuit and may need to a change in drug choices. Our first line sedative agents remain propofol (should not exceed 150mg/hr) and alfentanil. Midazolam may be added as a third agent. Measurement of triglycerides may require to be checked especially if the patient is also on TPN. Other agents such as clonidine, dexmedetomidine or ketamine may also be used at the Consultants discretion. A weaning plan for ECLS patients with high doses of opiates and benzodiazepines needs to be in place during the recovery phase. Sedation should be titrated to a RASS of -3 to -4 when assessable, but will be bespoke to individual patients during a run.

Antibiotics
Unlike for other indwelling cannula it will be usual practice to give at the time of cannula insertion prophylactic antibiotics as a one off dose. Piperacillin/Tazobactam 4.5g for the non penicillin allergic plus teicoplanin 400mg if known MRSA.
Alternative is teicoplanin 400mg + ciprofloxacin 400mg + metronidazole 500mg.

Muscle relaxants
Rocuronium is the bolus muscle relaxant of choice for ECLS patients undergoing procedures and transfers. Suxamethonium should not be used due to risks of hyperkalaemia. For continuous paralysis we will use atracurium, titrated to a train of four count of 2:4. Daily review by the ECLS Consultant should include the ongoing requirement for muscle relaxation. Normally continuous paralysis will be continued for a maximum of 48 hours.

<u>Suggested starting doses are: but individual titration is required</u>
Midazolam (1mg/ml) 0 to 10mls/hr
Alfentanil (0.5mg/ml) 0 to 10mls/hr
Propofol 1% (10mg/ml) 0 to 15mls/hr
Ketamine (10mg/ml) 0 to 5mls/hr
Rocuronium 10mg/ml as bolus 1mg/kg
Atracurium intial bolus 0.5mg/kg
Atracurium continuous infusion 0.3-0.6 mg/kg/hr

Equipment and Perfusion Services support

All equipment used for ECLS procedures will be stored, checked and ordered by the perfusion service and 118 critical care nurses. This will include the Levitronix pump and heparin bonded circuit and oxygenator, the Maquet cannulaes, Amplatz guidewires and dilators. The disposables will be kept in the ECLS cart which will be kept checked at least weekly by the ECLS nursing and perfusion staff.

Circuit and oxygenator- heparin bonded tubing and Medos Hilite 7000LT (or equivalent- stock dependant)

- The circuit and oxygenator will be primed using a full aseptic technique by the perfusion service using Plasmalyte 148 as the crystalloid of choice.

- All **positive pressure access ports** in the circuit will have pigtails connected to 3 way taps with smart sites attached to all ports except for those directly attached to the pressure transducers.

- Once the access priming port on the inlet line to the pump has been used it will remain permanently capped off to prevent air entrainment.

- During an ECLS run a second "standby" circuit and oxygenator will also be primed and available. One standby circuit is acceptable for more than one ECLS patient, but it should be replaced as soon as possible if used.

- The standby circuit when prepared aseptically can be used in emergency situations up to 30 days. If used microbiological samples should be taken as soon as feasible from the pre and post oxygenator sites.

- Elective circuit changes should have a new circuit rather than using the standby circuit. The standby circuit if not used should be kept for future water drills.

Perfusion service attendance

- Initiation of ECLS and during the ECLS run until patient stable
- Priming of circuits and circuit emergencies.
- Circuit maintenance and nursing support and advice
- Twice daily post oxygenator blood gas sampling **using the 100% for 20 minutes test if oxygenator FIO2 <100%** & PRN pre oxygenator sampling
- ECLS transports. Intra-hospital all non-emergency transports to be planned during the day
- Decannulation until patient stable
- Twice daily reviews to occur preferentially at the medical ward round times 0930 and 2030 and as requested by medical or nursing staff.

- A current perfusion staff rota and contact details should be permanently available and relayed to the bedside nurse, ECLS specialist nurse and nurse in charge of the ITU each shift.

Percutaneous Cannula Insertion

Peripheral ECLS cannulation can be performed on the ICU but may also be done in theatre, (often T17). The cardiac catheter lab or cardiothoracic theatres also have appropriate facilities. Fluoroscopy should ideally be used for all cannulations, and therefore a theatre table that is radiolucent is required. ECLS cannulae are inserted using full sterile precautions as per ward 118 standard guidelines and with a real time ultrasound guided seldinger technique. The ICU ultrasound machine can be used for this purpose.

Cannulation team:

This will minimally consist of an

- ECLS trained Critical Care Consultant
- An assistant usually the ECLS nurse
- Perfusionist
- Consultant Anaesthetist/Intensivist
- Radiographer with Image Intensifier.

Routine Preparation for VV and VA ECLS Cannulation- *bring ECLS trolley to theatre/bedside*

- All staff members assembled for pre-procedure briefing
- Patient and equipment checklist carried out
- Patient on radiolucent table in correct orientation.
- Check have correct size of cannulas, and fluoroscopy
- Decide on cannulation sites and explicitly state mode of ECLS VV or VA
- Remove excessive hair first if necessary with clippers, head, neck and knees to umbilicus
- Use the "ECLS Box" as this contains everything needed
- Ultrasound machine with linear probe selected, plugged in and in ergonomic spot for the operator
- 20mls of Xylocaine 1% with adrenaline 1:200,000
- Registered nurse prepares heparin solution with ECLS nurse (once scrubbed), (for heparin locking cannulae post insertion): 5,000(u) in 500ml of saline in a sterile receptacle. ***Omit heparin in ECPR cases.***
- TOE probe in position if needed
- Bolus heparin (50u/kg; usual dose requested is 3000 to 5000u) ready to give once guidewires in place. In theatre Anaesthetist is asked to do this.
- Standard heparin infusion drawn up (1000u/ml) in 40ml syringe.
- Prophylactic antibiotics chosen and drawn up for administration.
- ECLS machine and circuit primed and ready to use
- ACT machine warmed up and ready to use.

Percutaneous cannula insertion technique for VV ECLS

The cannulae used for ECLS are large and are placed using a seldinger technique with serial dilatation. Limited skin incisions should be made to ensure as tight a seal around the cannula as possible to prevent troublesome bleeding. Survey the vascular access points with ultrasound prior to starting to scrub up. For VV ECLS (if using a FEM –Jug configuration) it is best to place the internal jugular cannula first as the stiff guidewire will pass through the SVC, RA and into the IVC. Placement of the femoral cannula first risks entanglement of this guidewire. Attach a smart site to the luer port on the return cannula BEFORE placement.

1. Patient MUST be on a radiolucent table.
2. Clip excessive hair from neck, chest and knees to umbilicus as required
3. Wash cannulation site with Chlorhex 2%/70% alcohol and wait until dry
4. Head to toe sterile drape with space over relevant neck and groin areas
5. Infiltrate xylocaine 1% with adrenaline 1:200K to the vascular access points.
6. Use a real time US technique cannulate the vein. Enter the vein at a shallow 30 degree angle.
7. Insert under fluoroscopic guidance, the amplatz 0.035 superstiff wire and screen into position to a position below the diaphragm for jugular cannula and ensure that it passes through the heart in a straight line without kinks. For the femoral venous drainage cannula the guidewire needs to be placed just below the diaphragm ensuring it doesn't enter the hepatic vein. If using fem-fem VV ecmo configuration, the return guidewire is placed into the RA.
8. Give 50u/kg of heparin systemically at this stage & prophylactic antibiotics
9. Once the wires are in position serial dilate the subcutaneous tissues with the appropriate dilator kit, eg to 24F for the 25F cannula. Make sure that there isn't a skin bridge between the guidewire and the dilator before starting to dilate. It can be useful on occasion in patients with firm skin to use an artery clamp to gently open up the subcutaneous tissues if the distance to the vessel is more than 4-5cm.
10. During exchange of dilators ensure that the guidewire is held firmly by an assistant and that on removal of the dilator the operator presses over the insertion site with a swab to prevent excessive blood loss. The assistant's role is to hold the guidewire steady and load on the next dilator and then final cannula.
11. During cannula insertion continuous fluoroscopy should be used. The larger cannulas often require to be advanced in to the vessel with a firm forward pressure and a twisting motion. Screen the cannula into the ideal position.
12. Remove the wire 1st completely THEN cannula obturator, clamp, deair and then flush and hepsal lock with the 50ml catheter tipped syringe.
13. De-air and connect the cannulae. Slowly start ECLS. Optimise position and then secure cannulae in the approved manner. Cable tie cannula to circuit.
14. On table AXR and CXR for confirmation of final cannula positions. Ensure with TTE subcostal IVC view that drainage cannula below the hepatic vein.

Cannula Configuration for VV ECLS examples

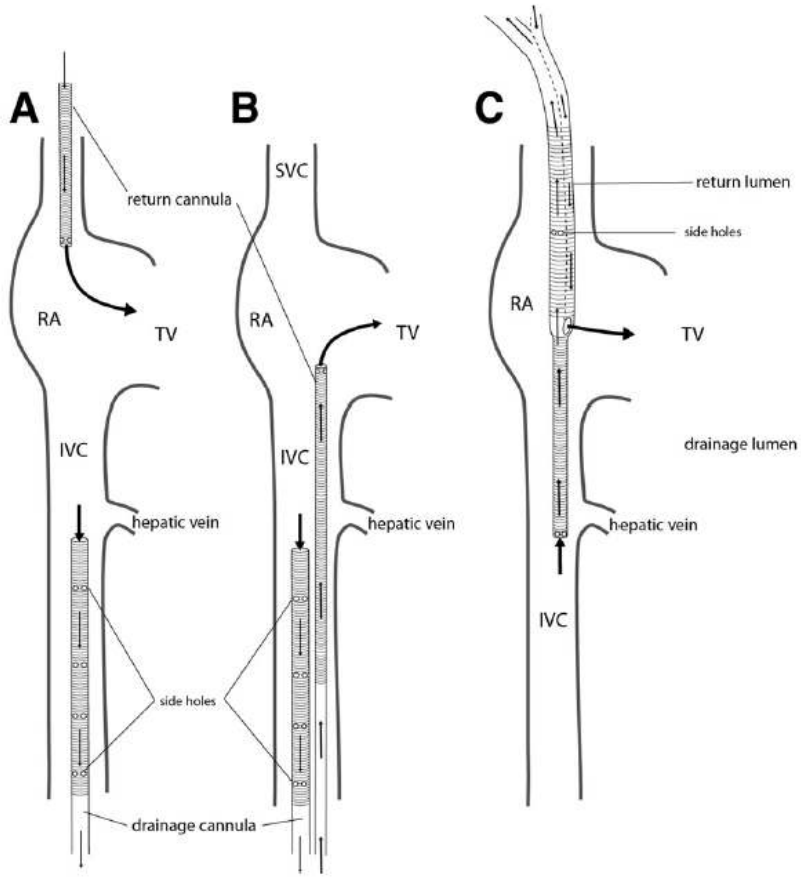


Fig 7. Cannula configurations for VV ECMO. (A) Femoroatrial cannulation: drainage is via a large multiport cannula introduced into a femoral vein and advanced to the mid-IVC; return is via a short cannula introduced into the right internal jugular vein and advanced to the SVC-RA junction. (B) Femorofemoral cannulation: drainage is via a large multiport cannula introduced into a femoral vein and advanced to the mid-IVC; return is via a long cannula introduced into the contralateral femoral vein and advanced to the RA. (C) Double-lumen cannulation: drainage and return are via a double-lumen cannula introduced into the right internal jugular vein. The cannula is advanced until the tip lies in the mid-IVC, just distal to the hepatic vein. Drainage is from the IVC and the SVC, and return is to the RA. See text for details. TV, tricuspid valve.

Positioning of the Cannulas

Our two options for VV ECLS configuration are either Femoro-atrial **(figure A)** or femoral -femoral configuration **(figure B)**.
For all cannula insertions real time ultrasound should be used in conjunction with fluoroscopy and transthoracic or transoesophageal echocardiography where required.

For **configuration A**, the femoral cannula should be placed just below the hepatic vein usually 5 to 10cm below the diaphragm. It can be assessed more accurately with TTE using the subcostal IVC view. The atrial cannula should be placed at the SVC/RA junction which can be readily seen on fluoroscopy and confirmed with the RV Inflow view on TTE or more readily with TOE.

For configuration B, the drainage cannula should be inserted into the LEFT femoral vein and placed just below the hepatic vein and is multi staged. The return cannula should be placed into the RIGHT common femoral vein and is a single stage cannula placed into the RA. The right is chosen as it is shorter than the left. The last 5cm of the return cannula is radiolucent so on fluoroscopy, so final positioning should be aware of this. Recirculation is problematic if the drainage and return are too close together.

Veno-Venous ECLS cannula choices

Two or Three cannula configuration

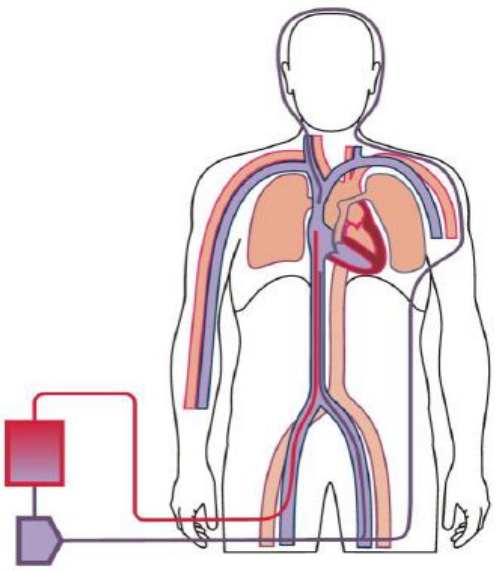
Our commonest current option for venous drainage and return cannulas is *usually* a **two** cannula circuit design (fem-femoral or fem-jugular). The **three** cannula configuration may be considered in patients over 100kg to allow for adequate capture of cardiac output. It is important that the largest drainage cannula possible should be used. This can be estimated from the ultrasound diameter of the vessel e.g 23F will fit into an 7.6mm diameter vessel and 25F a 8.3mm diameter vessel. (French gauge/3 equals diameter in mm of cannula). This should be measured with the US machine.
The 2 cannula set up with a 25F **drainage** and a 17Fr **return** should allow for adequate flow rate in most adults.

2 Cannula Set up

- Maquet HLS Venous cannula usually 25Fr (55cm long) (BE PVL 2555) as **drainage cannula** in (usually LEFT)femoral vein advanced to diaphragm with fluoroscopy and ultrasound below hepatic vein.
- Medtronic Biomedicus RIGHT femoral tip draining 19F or 21F (50cm long) (CB-96670-019, CB-96670-021) as **return cannula** OR
- Maquet HLS Arterial cannula usually 17Fr (15cm long) (BE PAS 1917) as **return cannula** in Right Internal jugular vein advance to SVC-RA junction.

3 Cannula Set up

- As above but with **additional femoral drainage cannula** 19Fr (BE PAL 1923) advanced to Common iliac vein/lower 1/3rd IVC.
- For FEM –FEM set up it may be easier to use both indwelling femoral cannulae as drainage with appropriate repositioning and RIJ return in the case of a FEM-JUG configuration with a 17F
- A Y connector will need to be added into the ECLS drainage if this system is used



Veno-Arterial ECLS cannula choices

Peripheral VA cannula configuration

The configuration is almost always femoro-femoral. Venous **drainage** and arterial **return** cannulas are selected based on vessel size. It is important that the largest drainage cannula possible should be used. This can be estimated from the ultrasound diameter of the vessel e.g 23F will fit into an 7.6mm diameter vessel and 25F a 8.3mm diameter vessel. The 2 cannula set up with a 23Fr or 25F **drainage** and a 17Fr **return** should allow for adequate flow rate in most adults. Due to the potential for leg ischaemia a further leg reperfusion cannula must be sited when performing peripheral VA ECLS and we will place drainage and return cannulae in opposite legs.

2 Cannula Set up

- Maquet HLS Venous cannula usually 25Fr long (BE PVL 2555) as **drainage cannula** in Right femoral vein advanced to IVC/RA junction below hepatic veins with fluoroscopy and ultrasound
- Maquet HLS Arterial cannula usually 17Fr short (BE-PAS 1715) as **return cannula** in left femoral artery advanced into the common iliac artery.

Leg reperfusion cannula options

1. Ipsilateral Posterior Tibial OR Dorsalis pedis retrograde set up- see details at end of guidelines or
2. A 8.5 FR., Edwards introflex swan introducer sheath (ward 118) (REF: I300BF85)-Note if using the I300F85 the haemostasis valve can disconnect! Placed *antegradely* into the superficial femoral artery.

Percutaneous cannula insertion technique for VA ECLS

The cannulae used for ECLS are large and are placed as preference using a seldinger technique with serial dilatation. Limited skin incisions should be made to ensure as tight a seal around the cannula as possible to prevent troublesome bleeding. Survey the vascular access points with ultrasound prior to starting to scrub up. The overall technique for peripheral VA ECLS cannulation is identical to that of VV ECLS with the exception of the requirement **for a distal reperfusion cannula** to placed to prevent lower limb ischaemia. This is best achieved by placing the reperfusion cannula BEFORE starting to insert the main return cannula. **For details of the preferred Posterior tibial OR Dorsalis pedis artery reperfusion and the superficial femoral reperfusion options see the details at the end of the guidelines.** De-air and secure the cannulae in the standard fashion. Ensure that the pedal pulses have been marked out for the nursing staff with an indeible marker-preferably PRIOR to starting to cannulate vessels if required. Nursing staff observations should occur hourly and any change in colour, temperature or loss of pedal pulses be relayed to the ECLS team immediately.

ECMO Cardiopulmonary Resuscitation

We are able to run a limited ECPR service in the RIE. The requirement for rapid insertion of cannula during a cardiac or peri-arrest scenario requires the following modification to our routine technique of cannulation.

The main differences are as follows:

- No use of fluoroscopy unless immediately available eg Cath lab
- Default cannula size is Maquet 19F 38cm for drainage
- Default cannula size is Maquet 17F 15cm for return
- No reperfusion cannula until return to ICU but placed < 6 hours from cannula placement. May need discussion with Vascular Registrar ASAP for timing of this if needs open exposure
- Routine therapeutic hypothermia to 33 degrees for 24 hours

The best outcomes in cardiac arrest patients are in those who achieve ROSC within 10 minutes of cardiac arrest. ECPR is indicated in those patients who remain in cardiac arrest with the following criteria:

For more details see the RIE 118 ECPR Guideline

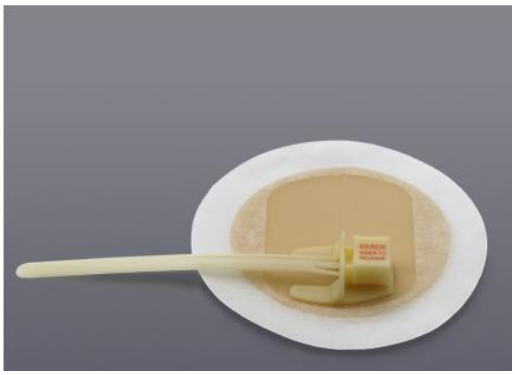
Securing the cannula

The idea is to limit the chances of bleeding from the cannulation sites, prevent dislodgement and kinking of the cannulae and circuit. A 2.0 silk suture tied alongside the cannula so that any force pulling the cannula out of the patient is opposed should be inserted. The needle should never be inserted underneath the cannula to avoid damaging it. Our routine will be to use a minimum of 3 points of security for each cannula with a suture and 2 Hollister devices as below. For the jugular cannulas (including bicaval) the circuit should be directed towards the patients head and secured with a "headband" device and the tubing then directed distally after following a lazy loop. The lower part of the hairline may be shaved to allow the securing device to adhere. Adhesive permafoam is placed on the head, chest, abdomen & leg to act as islands for the circuit to lie upon. The tubing will then be secured to the permafoam islands with clear tegaderm so as to allow for visual inspection of the circuit, and avoid damage to the patients skin. Keep the tubing in a straight long axis configuration. For Femoro- atrial cannula configuration it is easier if the femoral cannula is sited on the same side as the jugular cannula e.g RIJ then Right femoral vein. For femoro-femoral configuration line security is as per above. Cable ties should be used to reinforce all areas of potential disconnection.

Dressing changes and Cannula surveillance

These should be undertaken every 5 days or when soiled using an aseptic technique. Any dressing changes should aim to occur during 0900 to 1800 hours and require a minimum of 2 people. One person should be tasked with only controlling the cannula position and dressings should be removed in a direction toward the insertion point of the cannula rather than away from so as to not dislodge the cannula. The ECLS nurse should always be involved in these procedures.
A microbiological swab should be sent every time the dressings are taken down. Clear tegaderm dressings to allow for cannula surveillance should be used preferentially.

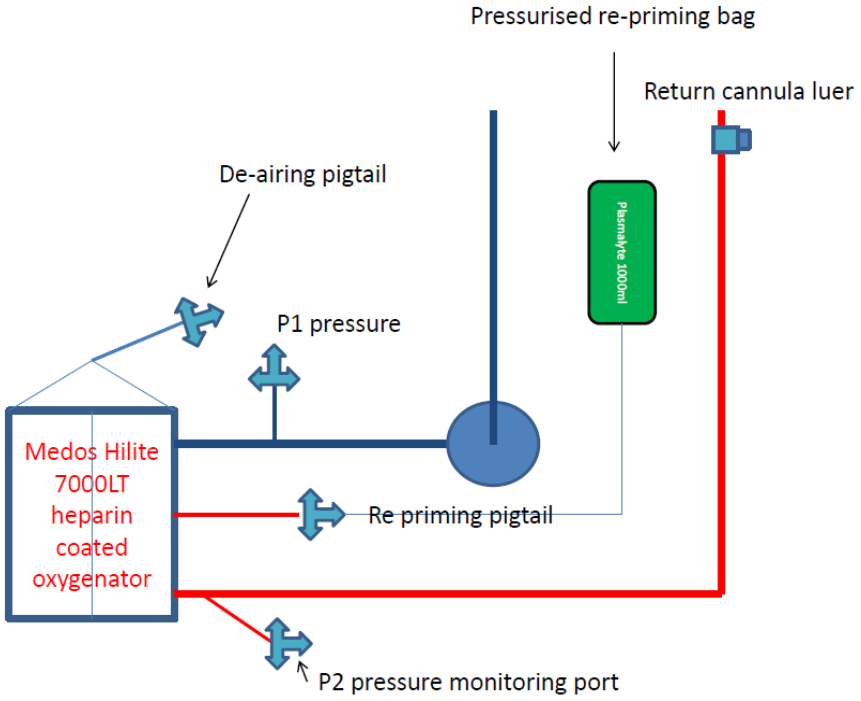
Hollister Horizontal tubing device



Circuit Configuration

A major goal of ECLS treatment is to make it as safe as possible. With this in mind we use a very simple circuit configuration, which minimises as far as possible risk of accidental air entrainment, risk of bleeding or areas of blood stasis. To reduce the risk of air entrainment **we never allow any** access to the circuit on the negative pressure side of the circuit, that is, between the drainage cannula and the centrifugal pump. There is still a risk of air entrainment during procedures that access the venous system of the patient eg central venous access and for this reason these procedures should only be carried out by Consultant staff and it may be necessary to reduce the flow rate of the pump temporarily during these procedures. The only other access points in our circuit are from the pre and post oxygenator pressure transducers, which are always at a **positive pressure** and so opening these risks blood loss.
To reduce the risk of bleeding **we use heparin bonded circuit components** where possible. It is important to note that **protamine is contraindicated** for use even in bleeding patients as it inactivates the heparin coating and may lead to rapid thrombus formation in the circuit. Thrombus formation is also kept to a minimum by keeping the flow rate above 2L/minute at all times, flow rates below this may occur during a weaning trial in VA ECLS but this is usually in the context of aiming to cease mechanical circulatory support.

The circuits will be made up and maintained by the perfusion service. They are always available for advice and troubleshooting. During an ECLS run there will be a pre-primed "emergency" ECLS circuit available at all times. When made up as a completely aseptic procedure it will last for 30 days. It is only to be used in an emergency. For semi-elective changes a new fully primed circuit should be used.



Circuit Pressure Monitoring

We routinely monitor **pre-oxygenator pressure and post oxygenator pressure.** These are labelled P1 and P2 respectively. They are levelled at a position that is at the same height as the oxygenator. We also routinely calculate the **transoxygenator pressure, ΔP (difference between P1 and P2).** Flushing of the transducers should be kept to a minimum and they should be maintained at 300mmHg of pressure in the pressure bag at all times, once pressurised the roller clamps can be kept closed and only opened if flushing is needed. We do not measure the pre-pump pressure as a safety measure to avoid potential air entrainment into the circuit. The rationale for measuring this pre pump circuit pressure is to detect excessive negative pressure and prevent suction events and haemolysis. A study by Sheldrake et al demonstrated that with modern centrifugal pumps negative pressure monitoring is not essential and that clinically significant problems are related to unstable venous drainage flow rather than the negative pressure per se. *The key observation to make is that of fluctuating circuit flow, line shaking and high RPMs to maintain circuit flow (eg>4500 rpm with the levitronix). The detection of these is readily identified at the bedside.*

Pre-oxygenator pressure (P1) It should always be greater than P2. Maximum pressure should be **<350mmHg.**

The pressure of this will depend on the type of oxygenator we use and will be influenced by

- Blood flow rate – it goes up with increasing blood flow rate
- Resistance- higher with smaller return cannula. In VA ECLS if patients arteriolar tone increases so will the resistance and hence the P1 pressure
- Expect higher P1 pressures with VA ECLS compared with VV ECLS
- Progressive clotting of the oxygenator results in **increased P1** pressure

Post-oxygenator pressure (P2) Should be **<300mmHg**

The pressure of this will depend on the type of oxygenator we use and will be influenced by

- Blood flow rate – it goes up with increasing blood flow rate
- Resistance- higher with smaller return cannula. In VA ECLS if patients arteriolar tone increases so will the resistance and hence the P2 pressure
- Expect higher P2 pressures with VA ECLS compared with VV ECLS
- P2 increased by return cannula kinking, patient bearing down, coughing, cannula misplacement
- Progressive clotting of the oxygenator results in **decreased P2** pressure

Transoxygenator pressure(difference between P1 and P2) <60mmHg acceptable but higher might suggest oxygenator problem.

- Increases when oxygenator starts clotting
- **>150mmHg** suggests need to replace oxygenator

Starting and Maintaining Anticoagulation on ECLS

Unfractionated heparin is the drug of choice with Argatroban as second choice if the patient has proven HITT. Actual bodyweight up 125kg will be used for heparin dosing. Heparin should be given intravenously via a central vein, or in specific circumstances directly into the circuit on a pre-oxygenator port. This will be decided upon by the ECLS consultant. The heparin infusion will be 1000units/ml as per standard NHS Lothian guidelines.

Heparin dosing during cannulation

Once the guidewires are in situ the loading dose of heparin will be decided upon by the cannulating consultant. This will usually be 50units/kg intravenously, max 10,000 units, usual dosing 2500 to 5000u.

On commencement of ECLS we measure after 6 hours anti Xa levels (see anti-Xa monitoring section next)**.**

- Start at 10 units/kg/hour (rounded up to nearest 100 units) intravenously via a central vein as per ICM Consultant usually no more than 90 minutes from bolus.
- The target anti Xa depends on the mode of ECLS being used. VV or VA with high risk of bleeding (0.2-0.4); or VA or VV with thrombus (0.3-0.7)

Usual first 24 hour targets for an ECLS patient are:

- Starting platelet count ≥ 100; Haemoglobin ≥ 100g/L
- Beyond 6 hrs aim for VV ECLS or VA ECLS specific, anti Xa level or an aPTTr of 1.5-2.0 if on argatroban
- Fibrinogen >1.5g/L

Precautions

- Patients who have recently received or concurrently receiving thrombolytic therapy
- Heparin Induced Thrombocytopenia and Thrombosis(HITT)
- History of HITT < 100 days
- Severe thrombocytopenia (< 30,000 platelets/mm3)
- Concurrent aspirin therapy or other antiplatelet agents

Re-commencement of ECLS after a period off anticoagulation

- The loading dose will be decided upon by the ECLS consultant.
- The starting rate will be decided upon by the ECLS consultant. This will usually be to start at the dose previously used to achieve adequate anticoagulation.
- The target anti Xa or APTTr will be specified by the ECLS consultant.

Anti-Xa Monitoring for Heparin Anticoagulation in Extracorporeal Life Support (ECLS)

Objective

- These guidelines concern the use of systemic intravenous unfractionated heparin (UFH) for anticoagulation in patients receiving **ECLS.**
- The aim is to provide a standardised approach using anti Xa monitoring ***in place*** of APTTr.

General Principals

- UFH provides rapid and titratable anticoagulation preventing clot formation hazardous to the circuit and patient whilst avoiding excessive bleeding.
- The benefits of instituting UFH have to outweigh the risks.
- ACT monitoring has no further role after initial UFH bolus dose at cannulation and should not be used to adjust UFH.
- Unless at high risk of bleeding, more intensive anticoagulation is required for VA ECLS than VV ECLS.
- Any patient with a true heparin allergy needs to be discussed with haematology prior to cannulation.

Pharmacology

- The half-life of an established UFH infusion varies but approximates between 1.5 and 6 hours toachieve a steady-state level.
- Heparin pharmacology varies between patients. Clinical evaluation of the individual patient is required to ensure appropriate anticoagulation. Regular evaluation and discussion with the ICU and Haematology Consultant may be required.

Medical patients

- During cannulation when guidewires are placed a bolus dose of UFH is usually given at 50 units/kg (eg 2500-5000 units). This will be decided by the cannulating consultant and is omitted in ECPR cases. An ACT target of 180-220 can be used at this point.
- UFH infusion is commenced *only* after discussion with the ICU consultant (consider the results of baseline FBC and coagulation screen, plus any CT brain to ensure intracerebral haemorrhage is excluded).
- Start UFH infusion at 10 units/kg/hr (use actual body weight up to max of 125kg) and monitor with anti-Xa level.
- **ACT monitoring has no further role and should not be used to adjust heparin.**

- VA ECLS cases that have a high risk for bleeding the lower anti Xa level 0.2-0.4 can be used (see below)
- Consider higher UFH starting rate (eg 18 units/kg/hr) if high risk of circuit or patient thrombosis (eg pulmonary embolism).

Surgical patients

- Post cardiotomy patients often bleed in the immediate peri-operative period thus UFH infusion initiation will likely be delayed for at least 12 hours.
- This approach is safe as long as extracorporeal blood flow is adequate (i.e. over 3L/min).
- When active surgical bleeding has ceased and there is agreement with the ICU and Surgical Consultants, commence the UFH infusion at 10units/kg/hr (omit bolus). Monitor using anti Xa level at 6 hours.
- **ACT monitoring has no role and should not be used to adjust heparin.**
- If the patient remains high risk for bleeding in VA ECLS the lower anti Xa level 0.2-0.4can be used before increasing to full protocol 0.3-0.7 (see below). This is at the discretion of the ICU Consultant.

Monitoring

- Measure anti-Xa level ("Unfractionated Heparin Assay All Sites" on Trak) after 6 hours from commencing UFH. Further monitoring is as described in the relevant chart
- Once three levels are in range without adjusting the rate, monitoring can be changed to twice daily
- More intensive anticoagulation is required for VA ECLS than VV ECLS hence there are two separate infusion charts (see appendix) with distinct therapeutic ranges. The high risk for bleeding protocol uses the same target ranges as per VV ECLS.

Anti-Xa level for VV ECLS (or VA ECLS with high risk for bleeding): 0.2-0.4 U/ml

Anti Xa level for VA ECMO (or VV ECLS with thrombus): 0.3-0.7 U/ml

Ongoing management of heparin

- *Minimum dose* is 5u/kg/hr when patient is not bleeding. If anti Xa is supratherapeutic at this low level discuss with ECLS Consultant. *Maximum dose* no more than 20u/kg/hr without discussing it with the ECLS Consultant.

    - When measuring anti Xa, the blood sample used must always be collected before any samples taken for blood gas analysis to prevent contamination from pre-heparinised syringes.
    - Repeat anti Xa **six** hourly if within range or as per mode specific chart
    - Check platelets every 24 hours
    - Check fibrinogen every 24 hours (target >1.5)

- *If heparin is >2500 units/hr to achieve target. consider* measuring antithrombin (AT) activity. If AT activity is <60%, it is likely that AT concentrate will need to be administered. Discuss with haematology about appropriate dosing (approximately 50 units/kg usually). FFP can be used as an alternative.

- Protamine is contraindicated for all patients on ECLS as it can cause serious circuit related thrombosis.

Management of bleeding (see also anticoagulation management with major bleeding section)

- Notify perfusionist and ECLS consultant
- Usual management would be to
    - Reduce or cease heparin
    - Replace any haemostatic deficiencies (ie platelets >100, fibrinogen >2, Hb 8-10, INR <1.5)
    - Consider tranexamic acid infusion per protocol
    - Source control
- Do NOT give protamine

Heparin-induced thrombocytopenia (HITT)

- It is normal for platelets to fall on ECLS, commonly by at least 50%. If platelets persistently < 50 x 10^9/L and evidence of thrombosis consider heparin induced thrombocytopenia (use BSH guidelines 2006 to score risk)
- Obtain expert advice from Haematology prior to ELISA and/or aggregometry screening.
- Argatroban is the suggested anticoagulant for HITT on ECLS, see relevant guideline
- There is no data to guide whether heparin bonded circuit components should be changed if HITT develops.

Heparin Adjustment table for VA ECLS or VV ECLS with thrombus

TARGET UFH: **Anti-Xa LEVEL 0.3-0.7 units/ml**

Anti-Xa level	**INFUSION ADJUSTMENT:**	**REPEAT UFH Anti-Xa level:**
>1.2	Stop for 1 hour and decrease rate by 500 units (0.5ml)/hr	2 hours
0.9-1.2	Decrease infusion rate by 300 units (0.3ml)/hr	6 hours
0.71-0.9	Decrease infusion rate by 200 units (0.2ml)/hr	6 hours
0.3-0.7	No change in infusion rate	6 hours or after 3 consecutive levels 0.3-0.7, 12 hourly
0.15-0.29	Increase infusion rate by 100 units (0.1ml)/hr	6 hours
0.06-0.14	Increase infusion rate by 200 units (0.2ml)/hr	6 hours
<0.06	Increase infusion rate by 400 units (0.4ml)/hr and administer bolus of 80 units /kg (maximum 10,000 units)	6 hours

OTHER INSTRUCTIONS

UFH stands for unfractionated heparin (iv heparin)

- UFH-anti-Xa levels are taken in a green citrated tube; fill tube to the level, send to haematology
- To order on TRAK: go to “search for order”, click on “order item” then enter “heparin”, then click on “Unfractionated Heparin assay All sites”: call RIE laboratory to inform sample is coming; WGH and SJH sites must courier samples to RIE lab.(ext 26093, OOH page 6550)
- Check UFH Anti-Xa level 6 hours after initiation, then adjust rate to achieve therapeutic range of **0.3-0.7 units/ml** using the **dose adjustment table** above. Measure the UFH-anti-Xa level 6 hours after each dose change
- Monitor FBC daily and be vigilant for heparin-induced thrombocytopenia
- If therapeutic range for UFH-anti-Xa level is not reached within 24 hours, seek advice from haematology
- Do <u>not</u> stop the heparin infusion to check the UFH-anti-Xa sample
- Do <u>not</u> take the UFH-anti-Xa sample from the limb with the infusion (or the same line in the case of central lines)

Heparin Adjustment table for VV ECLS or VA ECLS with high bleed risk

TARGET UFH: **Anti-Xa LEVEL 0.2-0.4 units/ml**

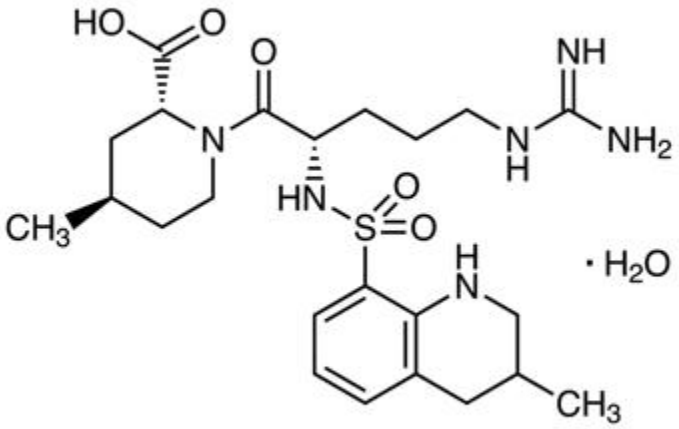
Anti-Xa level	**INFUSION ADJUSTMENT:**	**REPEAT UFH Anti-Xa level:**
>1.2	Stop for 1 hour and decrease rate by 500 units (0.5ml)/hr	2 hours
0.81-1.2	Decrease infusion rate by 300 units (0.3ml)/hr	2 hours
0.61-0.8	Decrease infusion rate by 200 units (0.2ml)/hr	6 hours
0.41-0.6	Increase infusion rate by 100 units (0.1ml)/hr	6 hours
0.2-0.4	No change in infusion rate	6 hours or after 3 consecutive levels 0.2-0.4, 12 hourly
0.1-0.19	Increase infusion rate by 100 units (0.1ml)/hr	6 hours
0.06-0.09	Increase infusion rate by 200 units (0.2ml)/hr	6 hours
<0.06	Increase infusion rate by 300 units (0.3ml)/hr	6 hours

OTHER INSTRUCTIONS

UFH stands for unfractionated heparin (iv heparin)

- UFH-anti-Xa levels are taken in a green citrated tube; fill tube to the level, send to haematology
- To order on TRAK: go to “search for order”, click on “order item” then enter “heparin”, then click on “Unfractionated Heparin assay All sites”: call RIE laboratory to inform sample is coming; WGH and SJH sites must courier samples to RIE lab.(ext 26093, OOH page 6550)
- Check UFH Anti-Xa level 6 hours after initiation, then adjust rate to achieve therapeutic range of **0.2-0.4 units/ml** using the **dose adjustment table** above. Measure the UFH-anti-Xa level 6 hours after each dose change
- Monitor FBC daily and be vigilant for heparin-induced thrombocytopenia
- If therapeutic range for UFH-anti-Xa level is not reached within 24 hours, seek advice from haematology
- Do not stop the heparin infusion to check the UFH-anti-Xa sample
- Do not take the UFH-anti-Xa sample from the limb with the infusion (or the same line in the case of central lines)

ARGATROBAN is used when heparin is contra-indicated e.g with HITT.



APTTr is the method used to titrate this rather than anti-Xa.

We do not use separate targets for VV ECLS or VA ECLS when using ARGATROBAN except at the direction of the ICM Consultant.

Activated Partial Thomboplastin Time ratio **target 1.5 to 2.0**

aPTT ratio	Infusion rate change
>3.1	Stop infusion for TWO hours, then re-check aPTTr. Reduce rate by at least 50%
2.1 – 3.1	Stop infusion for 60 minutes, then re-check aPTTr. Reduce hourly rate by 0.05 micrograms per kg per minute
1.5 – 2.0	No change
1.4 or below	Increase hourly rate by 0.05 micrograms per kg per minute

Argatroban (Exembol) Guidelines for the Adult ECLS patient

Patient group

Argatroban is indicated for anticoagulation in adult patients with heparin-induced thrombocytopenia (HIT) Type II. The use of argatroban for critical care patients on ECLS is an unlicensed indication with limited evidence largely drawn from case studies or personal communications.
Argatroban is contra-indicated in patients with severe hepatic dysfunction (Child-Pugh C).

Pharmacology/Pharmacokinetics

Argatroban is a direct thrombin inhibitor that acts independently of antithrombin III. The effect is monitored using the aPTTr although ACT, INR and thrombin time (TT) will also be extended.

Argatroban has a fast onset of action and reaches steady state within about 4 hours in patients receiving ECLS. It is hepatically metabolised with a terminal half-life of about 1 hour in patients with normal hepatic function although the half-life may be longer on ECLS. The primary metabolite is only weakly active with 40 fold less antithrombin activity. Argatroban mainly distributes into extracellular fluid. Protein binding is relatively low at 54% with a large volume of distribution.

Hepatic impairment significantly reduces clearance. Patients with a Child Pugh score of 7 to 11 clear argatroban slowly, at 26% the rate of healthy volunteers. An elevated bilirubin has also been shown to correlate with reduced clearance whereas this is not the case for indocyanine green plasma disappearance rates in ECLS patients. Severe renal failure in the absence of hepatic impairment does not significantly affect clearance.

It is known that critically ill patients with multi-organ failure require lower doses than other patient groups, even in the absence of overt hepatic impairment. For patients receiving ECLS the doses required may be even lower, therefore low starting doses with frequent monitoring are recommended.

Argatroban infusion

First prepare a 250mg in 250ml infusion
The solution for infusion may be 5% glucose (preferred) 0.9% Sodium chloride or compound sodium lactate
The bag should be mixed by repeated inversion of the diluent bag for one minute.
When thoroughly mixed remove 25mL (25mg) from this bag into a 50mL syringe and further dilute to 50mL with 5% glucose (or other diluent as above) and mix thoroughly to make a concentration of 500mcg/mL
Administer using a dedicated infusion line

Commencement of ECLS

A loading dose is not recommended
A suggested starting dose for patients who are low risk for thrombosis is 0.2 microgram/kg/min intravenously via a central vein
Doses of 0.5 microgram/kg/min or more may be used for patients with known or suspected thrombosis.
Argatroban should be given intravenously via a central vein using a dedicated line, or in specific circumstances directly into the circuit on the pre-oxygenator port. This will be decided upon by the ECLS consultant and perfusionist. Only perfusion may make connections to the circuit.
The target aPTT ratio is 1.5-2.0 unless otherwise specified by the ECLS consultant eg. 2-2.5 if HIT with thrombosis
Steady-state plasma argatroban concentrations increase proportionally with dose and correlate well with anticoagulant effects.
Check aPTT ratio every two to four hours until two consecutive aPTT ratios are within the target range. Frequency may then be reduced to six hourly or as specified by the ECLS consultant.
The table below gives suggested dose adjustments but larger or smaller dose changes may be appropriate

Re-commencement of ECLS after a period off anticoagulation

The starting rate will be decided upon by the ECLS consultant. This will usually be to start at the dose previously used to achieve adequate anticoagulation.
Check aPTT ratio every two to four hours after re-starting infusion until two consecutive aPTT ratios are within the target range. Frequency may then be reduced to six hourly or as specified by the ECLS consultant.

Monitoring Argatroban

- When measuring aPTTr, the blood sample used must always be collected before any samples taken for blood gas analysis to prevent contamination from pre-heparinised syringes.
- Check the aPTTr every three to four hours until in range
- Repeat aPTTr six hourly if within range or as specified by the ECLS consultant
- Check platelets every 24 hours (the usual target is over 80, in cases of HITT, senior haematology advice is required regarding transfusion)
- Check fibrinogen every 24 hours (target >1.5)
- Check TEG from theatres if requested by ECLS consultant

Management of bleeding on Argatroban

- Notify perfusionist and ECLS consultant
- Usual management would be to
- Reduce or cease argatroban
- Replace any haemostatic deficiencies (ie fibrinogen >2, Hb 8-10, INR <1.5, the usual target for platelets in the bleeding ECLS patient is >100, in cases of HIT, senior haematology advice is required prior to transfusion)
- Consider desmopressin or tranexamic acid infusion as per protocol
- Source control
- There is no specific antidote to argatroban

References:

Mitsubishi Pharma Europe Ltd. Summary of product characteristics for Exembol. May 2012
Beiderlinden M et al. Argatroban in Extracorporeal Membrane Oxygenation. Artificial Organs 2007;31(6):461-465
Cornell T et al. A case series describing the use of argatroban in patients on extracorporeal circulation. ASAIO J 2007;53:460-3.

ECLS anticoagulation management in Special Circumstances

Anticipated surgery or major procedure (not yet bleeding)

- Cease heparin/argatroban for 4 hours
- Ensure pump flow rate is always ≥ 2.0L/min
- Replace platelet and coagulation factor deficits
- Start tranexamic acid prior to surgery see tranexamic acid under major bleeding
- Manage post surgery as for the bleeding patient

During concurrent CVVH

The ECLS patient is systemically anticoagulated so additional anticoagulation via the CVVH circuit is not required. If the CVVH circuit clots consider higher increasing pre-dilution and low dose epoprostenol after discussion with the ECLS Consultant.

Development of HITT during ECLS

The patient is only exposed to heparin coating for a short period of time when the circuit is new because the circuit is rapidly coated with human proteins. Hence the circuit, oxygenator and pump housing should all continue to be used for as long as possible. If a patient develops suspected or confirmed HITT, switch to argatroban (see Critical care guideline for use of argatroban in ECLS patients). It is unclear whether heparin bonded components of the circuit contribute to HITT to a significant degree but in a proven case new cannulas, and circuits without heparin bonding may need to be used.

Post coronary artery stent procedure/ACS protocol

The patient will be on dual anti-platelet therapy (DAPT) which should be continued especially so with drug eluting stents. Fondaparinux should be ceased and heparin continued guided by bleeding status and aPTTr/anti Xa . Tirofiban infusion can be continued as long as no major bleeding complications occur. Inform the cardiologists if this is required and discuss the need for ongoing tirofiban in the context of DAPT and systemic anticoagulation and a high risk of bleeding.

ECLS anticoagulation management in with major bleeding

Bleeding patient (includes post surgical/procedure)

This is bleeding at a rate of more than 2mls/kg/hr or a Hb drop >10g/L 6 hourly. Remember to consider hidden bleeding with femoral cannulae eg retroperitoneum.

Actions

- Vascular surgical review to assess options for local control
- Obtain a TEG to allow for targeted haemostatic therapy.
- Initially reduce heparin, anti Xa lower end of relevant range
- Replace all haemostatic deficiencies (2-3 pools cryoprecipitate if fibrinogen <2g/L, platelets if count < 100, 15mL/kg FFP to keep INR <1.5)
- Consider ceasing all heparin, but only in consultation with ECLS consultant and perfusionist. Ensure circuit flow never falls below 2.0L/minute minimum.
- Commence tranexamic acid (see dosing below).

Life threatening bleeding

Contact ECLS Consultant and Perfusionist immediately.

Actions

- Activate major haemorrhage protocol
- Vascular surgical review to assess options for local control
- Obtain a TEG to allow for targeted haemostatic therapy.
- Initially stop heparin or argatroban infusion
- Replace all haemostatic deficiencies (2-3 pools cryoprecipitate if fibrinogen <2g/L, platelets if count < 100, 15mL/kg FFP to keep INR <1.5)
- Consider ceasing all heparin, but only in consultation with ECLS consultant and perfusionist. Ensure circuit flow never falls below 1.0L/minute minimum.
- Commence tranexamic acid (see dosing below).
- Consider rVIIa, 45micrograms/kg, only in consultation with ECLS and Haematology consultants and perfusionists as there is a significant risk of circuit thrombosis. NB there is a 5% risk of arterial thrombosis.
- Consider late options (local tamponade, surgery, palliation)

Tranexamic acid dosing- notify the perfusionist if tranexamic acid is commenced

Prepare 5g in 50mls solution
Give a loading dose of 1g over 30 min, if massive blood loss, repeat the loading dose
Follow this with an infusion of 125mg/hr to 250mg/hour until the syringe is empty and a total of 5g has been given.
Reduce to a maintenance infusion rate of 125mg/hour if continued beyond 5g.
Convulsions associated with toxicity.
Reduce maintenance dose if renal or hepatic dysfunction is present. The loading dose remains unchanged.

Ventilator management of the ECLS patient

The goal of ventilator management of the patient undergoing ECLS therapy is to provide adequate oxygenation and CO2 clearance whilst limiting the effect of positive pressure ventilation on the cardiac (RV mainly in VA ECLS) and respiratory system. There is limited data to support one mode of ventilation over another. We have chosen to use a volume targeted and pressure limited mode of ventilation to avoid known factors that are associated with ventilator induced lung injury and avoid debate about other modes of ventilation in this particular group of patients. Adequate sedation to inhibit spontaneous breathing is advisable in the early phases of ECLS treatment; if high doses are required paralysis should be introduced. There will be no "weaning" of these ventilator parameters by the bedside nurse during an ECLS run except under the explicit instructions of the ECLS Consultant or Intensivist in charge. Spontaneous ventilation will be useful and attempted once stability on ECLS has been achieved.
Once ECLS is established then ensuring that tidal volume is reduced to a maximum of 6ml/kg ideal body weight whilst preventing derecruitment by using an adequate level of PEEP with a Pplat (<26cmH_20) form the main goals of our lung protective ventilatory strategy. In addition avoidance of hyperoxia in the alveolus by reducing the FIO2 on the ventilator to <60% should also be achieved. There are theoretical concerns of reverse diffusion of oxygen (from the pulmonary artery to the alveolus) during VV ECLS (not with VA ECLS) if the FiO_2 is reduced too far. In practice aiming for an FiO_2 between 0.4 and 0.6 will usually avoid this, and if the patients' arterial saturations are within target the ventilator FiO_2 can and should go lower.

Example 1st line settings are start with FiO_2 of 1.0 and wean as able to ≤60% ASAP

- SIMV volume control Vt 6ml/kg, Pplat <26 cmH_20, PEEP 10 cmH_20, RR 10

It should be understood that in very non compliant lungs tidal volumes less than deadspace eg <100mls may be all that is possible. In VA ECLS ETCO2 of 3-4kPa are acceptable.

Oxygenation targets

The lower threshold of safe oxygenation isn't known but a balance between circuit flows, low alveolar oxygen levels and target PaO2 in an individual patient must be struck. As a rule of thumb targeting a PaO2 of 8kPa is thought to be acceptable and should be aimed for when possible. Capturing 60% of cardiac output is the key intervention to achieve this when lung gas exchange is practically nil. Special attention to upper body oxygenation is specifically required during VA ECLS.

Emergency ventilator settings

In the event of an unexpected interruption to the circuit flow rescue ventilator settings will be prescribed by the ECLS Consultant and confirmed with the bedside nurse during rounds. An example would be FIO2 1.0, Vt 400mls, PEEP 10, respiratory rate of 20.

Procedural hazards whilst on ECLS

All necessary interventions should be carried out where possible in a planned way and by Consultant staff from the relevant specialty during 0900 to 1800. For required interventions the liberal use of adequate sedation combined with paralysis is wise to achieve the best conditions for the procedure.

Bronchoalveolar lavage

No blind miniBALs to be taken due to risk of occult mucosal injury and haemorrhage.

Nursing turns

These need to be planned and have enough staff to manage them at least 5 people one of whom will be the ECLS specialist nurse or Consultant. Rapid movement should be avoided as should coughing which can cause interference with the ECLS circuit flow. Individuals whose sole task is to manage the cannulas and ETT rather than moving the patient should be explicitly identified at the outset.

Pneumothoraces

These may not need to be automatically drained. If possible avoidance of ICD insertion is the default strategy whilst on ECLS. Discussion with the ECLS Consultant is mandatory. If drainage is required a “minimal cut” technique will be used and cardiothoracic surgery may need to be involved. Bipolar diathermy should be used for haemostasis as routine.

Respiratory Physiotherapy & suctioning

This can be undertaken as routine but high volume and high pressure hand bagging via the C circuit should be avoided. Suctioning of the endotracheal tube should be gentle and infrequent due to the risks of haemorrhage. The ECLS Consultant should be informed if there are concerns about mucous plugging and decide upon whether direct suctioning of the airway under direct vision with a bronchoscope is indicated. If so saline washes with 1:100,000 adrenaline should be considered (1mg adrenaline in 100ml of 0.9% saline) to reduce the risk of mucosal haemorrhage.

Surgery

Required surgery should be undertaken as indicated irrespective of being on ECLS. Refer to ECLS in special circumstances for anticoagulation management.

Tracheostomy

There is no good evidence currently that early tracheostomy is overwhelmingly beneficial and the risk of major bleeding is significant in the ECLS patient, therefore this procedure will not be routinely carried out whilst the patient is undergoing ECLS, but individualised decision on per case basis.

Routine Management of the ECLS Patient

The vast majority of routine care of the ECLS patient is the same as for all critically ill patients. Listed below are particular points of difference between the two groups.

Blood tests- all taken through arterial line. No subcutaneous injections, intramuscular injections, finger stick glucose or peripheral venepuncture while on ECLS run.

- ABGS 3 hourly, less often once stable and prn
- FBC, Coagulation studies 4-6 hourly
- U&Es, LFTS, Ca, PO4, Mg, LDH, plasma free haemoglobin 12 hourly
- Blood cultures daily via arterial line
- Re cross match every 72 hours, 2 units of RCC.

Bowel management- to limit the number of patient turns, these patients should have a faecal management system in place and prescribed regular laxatives aiming to have liquid stool. Prescribe Senna 10mls nocte and docusate 100mg 8 hourly. Follow critical care guidelines for treatment of constipation if above not successful after 72 hours.

Circuit surveillance- hourly checks of the integrity of the circuit need to be undertaken starting at the drainage cannula insertion point and followed around the circuit to the return cannula. Areas on the tubing of clot formation should be noted on the chart for future comparison. All luer connections should be tested so that they are finger tight in clockwise direction. All 3 way taps directions should be checked. No alcohol should be used on the circuit at anytime.

CXR- daily and prn timed to be when ECLS nurse specialist or Consultant available aim for 0900 to 1700. Out of hours to be discussed with the ECLS Consultant first.

CT- of head (non contrast) and chest, abdomen and pelvis (with contrast) within 24 hours of admission for baseline during 0900 to 1700. Liase with ECLS Consultant and radiology Consultant about timing.

DVT prophylaxis- not required as these patients are systemically anticoagulated whilst on an ECLS run. No TEDS on cannulated limb.

Fluid balance and Renal Support- many patients will require renal supportive therapy, this will be considered early to achieve tight control of fluid balance in the context of oliguria We will use a vascath to achieve separate dedicated venous access. It should be noted that connecting and disconnecting the vascath has a major potential for air embolus and should therefore only be undertaken by the ECLS nurse specialist or perfusionist. We do have CVVHD machines that can be connected directly to the ECLS circuit but this requires circuit modification. The aim where physiology allows is to get the patient to euvolaemia rather than pursuing a negative fluid balance per se. This will often take a number of days. Maximum fluid loss per day will be no more than 2000mls/day in most circumstances. During the initial commencement on ECLS further volume may be required.

GI Management- ECLS patients are at high risk of stress ulceration and should be prescribed omeprazole 40mg iv or NG once per day once enteral absorbtion established. NG tubes that become dislodged during an ECLS run should be replaced under gentle direct vision via the mouth rather than the nose. The nasal bridle should not be used whilst the patient is on an ECLS run. Enteral feeding as per unit 118 guidelines.

Humidification-A wet circuit should be used whilst these patients are on an ECLS run.

Invasive procedures- these should be performed in daylight hours after discussion with an ECLS Consultant and be performed by a Consultant from the relevant specialty only ie no registrar new lines, operations, chest drains, endoscopies.

Mouth Care-care with mouth care in light of anticoagulation. No suctioning of oral cavity with yankauer suckers use soft endotracheal catheters. Oral care with soft toothbrush.

Oxygenator function- monitored by difference between P1 and P2. Should be less than 150mmHg. Post oxygenator blood gases performed 12 hourly in both VV and VA ECLS. With a sweep gas FIO2 of 100% should be > 20kPa.

Pressure area care- all turns require to be planned and should happen during the day when possible. The hoist rather than rolls may be used to avoid dislodging cannula for moves other than pressure area care eg sheet changes. An ECLS specialist nurse or Consultant should be immediately available during these procedures. A nimbus 3 mattress or equivalent pressure relieving mattress should be used at all times.

Sedation- see the sedation section for detail. Sedation holds are not to be undertaken whilst on ECLS unless specifically requested by the Consultant.

Temperature management- this can be manipulated with the heater/cooler device attached to the oxygenator. High fevers can adversely affect the ability to oxygenate the patient optimally and hypothermia adversely affect haemostasis. The aim is usually to maintain normothermia but where clinically indicated, mild hypothermia (to 35Cº) may be performed. While the heater cooler is running, the setting on its LED display should be set to 37C.º The heater-cooler component of the oxygenator may fail after a few days, however this is not usually an indication for changing out the oxygenator as normothermia should be attainable with conventional techniques (Bair Hugger). The heater-cooler settings should only be altered by the perfusion staff unless the nurse has been trained to do this. On discontinuing ECLS a number of patients become pyrexial this must be treated promptly with physical cooling measures aiming for normothermia.

Transfusion triggers- During cannulation Hb ≥100g/L. Otherwise routinely >80g/L if not bleeding. Keep over 90g/L if on going bleeding. Platelets keep over 50 x 10^9/L if not bleeding, >100 x 10^9/L if bleeding. Also correct fibrinogen above 1.5g/L at all times.

Vascular surveillance – this is specifically important in VA ECLS where limb ischaemia can happen due to thrombus formation or failure of the backflow cannula to perfuse the lower limb adequately. Hourly checks of pedal pulses with Doppler is required.

VAP prophylaxis- same as non ECLS patients.

Specific management of VV ECLS

The aim is to capture around 60% of the patients cardiac output and traumatize the blood passing through the extracorporeal circuit as little as possible. The key components to achieve this are ensuring adequately sized cannulas are inserted, with the drainage cannula being the most important component.
Fluid balance is also important but the aim is to achieve euvolaemia and the patients usual dry weight rather than chasing a negative fluid balance as a goal in itself. This may take a few days to achieve especially in patients with ongoing septic shock. The amount of fluid a patient can tolerate to be taken off will vary with the specific pathology and where they are haemodynamically in their illness. As a general rule a maximum of no more than 2000mls negative per 24 hours should be targeted.

Initial starting parameters and goals for VV ECLS patient

- Circuit flow of 50-80ml/kg/minute (usually 3-6L/minute adequate)
- Sweep gas flow 50-80ml/kg/minute- titrate to normocapnia slowly over a few hours if the patient was significantly hypercapnic before ECLS, aim approx 1kPa /hour. Cerebral oxygenation adversely affected by acute alkalosis
- Sweep gas FIO2 of 1.0
- No kicking or line chatter at target circuit flow, may need to fluid load if this occurs start with 5mls/kg and repeat
- MAP 65-70mmHg
- PaO2 ~8kPa, Spo2 88-92%
- Oxygen saturation drainage cannula 65%-75% (higher S_DO_2 indicates recirculation)
- Oxygen saturation return cannula 100%
- H^+ 35 to 45nmol/L
- aPTTr 1.5 to 2.0
- Hb on starting ECLS ~100g/L, platelet count ~ $100x10^9$/L, fibrinogen ≥1.5g/L
- ECLS should be started and up titrated slowly over 5 to 10 minutes to avoid haemodynamic instability to the patient.
- Arterial line- this should have a normal trace and pulse pressure- doesn't have to be in the right radial in VV ECLS
- Saturation probe- can be anywhere on the patient.
- If SpO2 and PaO2 not improving despite adequate flows on the ECLS circuit (3-6L/minute) consider recirculation as a problem. If patients SaO2 is lower than the preoxygenator S_DO_2 sample, recirculation is occurring.

Specific management of peripheral VA ECLS

In addition to the general points made for VV ECLS this mode should only be employed when native lung function is good enough to supply safe oxygenation of the patient in the context of cardiovascular support. If native lung function is also poor consideration of **central** VA ECLS instead should be pursued to avoid the problem of hypoxic blood being supplied to the brain (via the lungs) and oxygenated blood being supplied to the rest of the body via the femoral artery return cannula. To detect this potential problem it is very important during peripheral VA ECLS that a **right radial arterial line** and an ear pulse oximeter are used as routine part of patient monitoring. An additional problem is that far from "resting" the heart VA ECLS in fact increases the afterload markedly that the failing ventricle has to eject against. This can lead to stasis in the LV with thrombus formation and pulmonary oedema. Consideration of prophylactic inotropic support (adrenaline, dobutamine, levosimenden) or in the form of an Impellar device should be decided early before these complications occur. Drs Neil Uren, Nick Cruden and Peter Henriksen from cardiology have training in inserting this device. Atrial septostomy is an accepted alternative leading to a left to right shunt.

Initial starting parameters and goals for VA ECLS patient

- Circuit flow of 50-80ml/kg/minute (usually 3-6L/minute adequate)
- Sweep gas flow 50-80ml/kg/minute- titrate to normocapnia slowly over a few hours if the patient was significantly hypercapnic before ECLS, aim approx 1kPa /hour. Cerebral oxygenation adversely affected by acute alkalosis
- Sweep gas FIO2 of 1.0 potential to titrate downwards if very hyperoxic
- MAP 65-70mmHg
- No kicking or line chatter at target circuit flow, may need to fluid load if this occurs start with 5mls/kg and repeat
- Pulse pressure of minimum 10mmHg to ensure cardiac ejection- may require inotrope
- PaO2 ~8kPa, Spo2 88-92%; reduce MV to achieve ETCO2 of 2.5 to 4.0
- Oxygen saturation drainage cannula 65%-75% (higher S_DO_2 indicates recirculation). Lower than 65% indicates inadequate circuit flow rate.
- Oxygen saturation return cannula 100%
- H^+ 35 to 45nmol/L
- aPTTr 1.5 to 2.0
- Hb on starting ECLS ~100g/L, platelet count ~ $100x10^9$/L, fibrinogen ≥1.5g/L
- ECLS should be started and up titrated slowly over 5 to 10 minutes to avoid haemodynamic instability to the patient.
- Arterial line- **ensure placed in right arm**. This should have a pulsatile trace if the heart is ejecting which should be aimed for. Saturation probe- ear probe or right hand.
- Remember that in centrifugal pumps blood can flow from the aorta to the IVC if the pressure generated by the pump is below the patients aortic pressure.
- Regular echocardiography TTE or TOE

Common Problem troubleshooting

VENO-VENOUS ECLS

Suction Events

A suction event occurs when the negative pressure of the centrifugal pump causes the IVC (or SVC in a bicaval cannula) to collapse onto the drainage cannula, resulting in an immediate loss of ECLS flow. Early warning signs include line shaking or "chatter". These are probably the most frequent events occurring during ECLS.

Causes:
- Hypovolaemia
- High circuit flows
- Patient coughing
- Patient ventilator dysynchrony
- Patient turns.

Ensure:
- Immediate reduction of the pump speed to zero to relieve suction
- Restart ECLS slowly up to a level of RPM below which the suction event occurred

Consider:
- Fluid challenge
- Increased sedation or paralysis
- Always check cannula position

Low Circuit Flow

Low circuit flow for a given pump speed or high RPM for a normal circuit flow implies obstruction in the circuit.

Causes:
- Thrombus in the pump- noise, visible thrombus, increasing plasma free Hb
- Thrombus in the oxygenator-increasing ΔP, worse PaO_2, increased $PaCO_2$
- Obstruction of drainage cannula- kinked, suction event, hypovolaemia, malpositioned cannula, clot in drainage cannula

Consider:
- Imaging of cannula position, check for kinks, repositioning, additional cannula
- Give fluid challenge
- Circuit/Oxygenator change if clot formation
- Increase anticoagulation

VENO-VENOUS ECLS

It is always worth remembering that the sweep gas FIO_2 controls the **postoxygenator** PO2 and the **flow rate** of the sweep gas controls the PCO_2. A reliable target to aim for acceptable oxygenation is to capture 60% of native cardiac output.

Worsening hypoxia

Causes:
- Decreased circuit flows
- Increased Cardiac Output (increasing shunt bypasses the ECLS circuit)
- Recirculation of returned oxygenated blood into the drainage cannula
- Decreased FiO2 to the oxygenator or ventilator
- Oxygenator failure
- Gas tubing leak or disconnection

Ensure:
- Pump flow is adequate (> 2/3 cardiac output), may need check with TTE
- 100% oxygen is being supplied to the oxygenator
- Oxygenator is functioning correctly (Post oxygenator pO2 40-80kPa)
- Recirculation minimized (see below)

Consider:
Increasing pump flow / increasing ventilator PEEP, FiO2 / cooling patient to 35ºC. Rarely increasing Hb to >100g/L. These changes MUST NOT be performed without the approval of the ECLS Intensivist.

Increasing circuit flow rate does not improve oxygenation

Look for **recirculation**:

If the drainage and return cannulae are too close together, recirculation of blood may occur between them (oxygenated blood is drawn down the drainage cannula).This should be less of a problem with Avalon cannulae, but you may need to check that return lumen is optimally orientated and or in the RA not IVC or SVC with echocardiography. Hence increasing ECLS flow may not improve the patient's oxygenation.

To diagnose recirculation:

A high preoxygenator S_DO2 (>75%) in combination with a low patient SaO2 (<85%) suggests clinically significant recirculation is occurring. Conversely, a low preoxygenator S_DO2 (<60%) in combination with a low SaO2 (<85%) indicates that the patient's cardiac output (or oxygen consumption) is abnormally high and/or the ECLS flow is too low.

VENO-VENOUS ECLS

Worsening hypercarbia on VV ECLS

Causes
- Decreased sweep gas flow
- Oxygenator failure

Ensure:
- Pump flow is adequate (>2/3 cardiac output)
- Oxygen flow to oxygenator is at least twice the pump flow rate, maximum on Hilite 7000 LT is 14L/minute

Consider:
Increasing oxygen flow rate to the oxygenator,/ ECLS flow rate / increasing ventilation /cooling patient to 35ºC/Coughing the oxygenator

Low post oxygenator PO_2 or High PCO_2

A low postoxygenator PO_2 (<10-15 kPa) or a high post oxygenator PCO_2 may be caused by:

Causes:
- Build up of water vapour in oxygenator- (NB: usually pump and patient PCO2 increased, with patient and oxygenator PO2 unchanged. ΔP unchanged)
- Oxygenator failure- (NB:both patient & pump PO2 and PCO2 decreased. ΔP increased should be <150mmHg))
- Inadequate sweep gas flow rate or FIO_2
- Gas transfer capabilities are exceeded (rare)

Ensure:
- Correct FIO_2 (always at 100%) and Sweep gas flow rates and connections
- Try to "cough" the circuit to remove water vapour. This is done by the ECLS specialist nurse, perfusionist or Consultant increasing the sweep gas flow rate to 10l/min for 60 seconds. Clear or frothy fluid may be seen leaving the exhalation port of the oxygenator.

If this manoeuvre does not solve the problem, consideration should be given to changing the oxygenator or adding a second oxygenator in parallel with the first.

Common Problem troubleshooting

VENO-ARTERIAL ECLS

Worsening hypoxia

Differential hypoxaemia (lower PaO2/SpO2 in the upper body compared to the lower body) can occur during peripheral veno-arterial ECLS when there is severe respiratory failure combined with a high cardiac output. In this situation, the heart is supplying the upper body with de-oxygenated blood, while the ECLS circuit supplies the lower body with oxygenated blood. To detect this problem, patient blood gases should be sampled as close to the heart as possible (hence a right radial arterial line is preferable to a left radial line). Similarly, monitoring of the oxygen saturation of the upper body should be performed with a pulse oximeter on the right hand or with an ear probe SpO2 monitor.

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To treat differential hypoxaemia, the following steps may be necessary:

- Ensure the oxygenator is functioning correctly (return line pO2 > 20kPa)
- Ensure the ECLS flow is as high as possible (within constraints of return line pressure) <300mmHg
- Increasing the patient's ventilation/ PEEP / FiO2
- Consider central cannulation or return via subclavian gortex graft, VAV ECLS

Worsening hypercarbia- same issues as VV ECLS

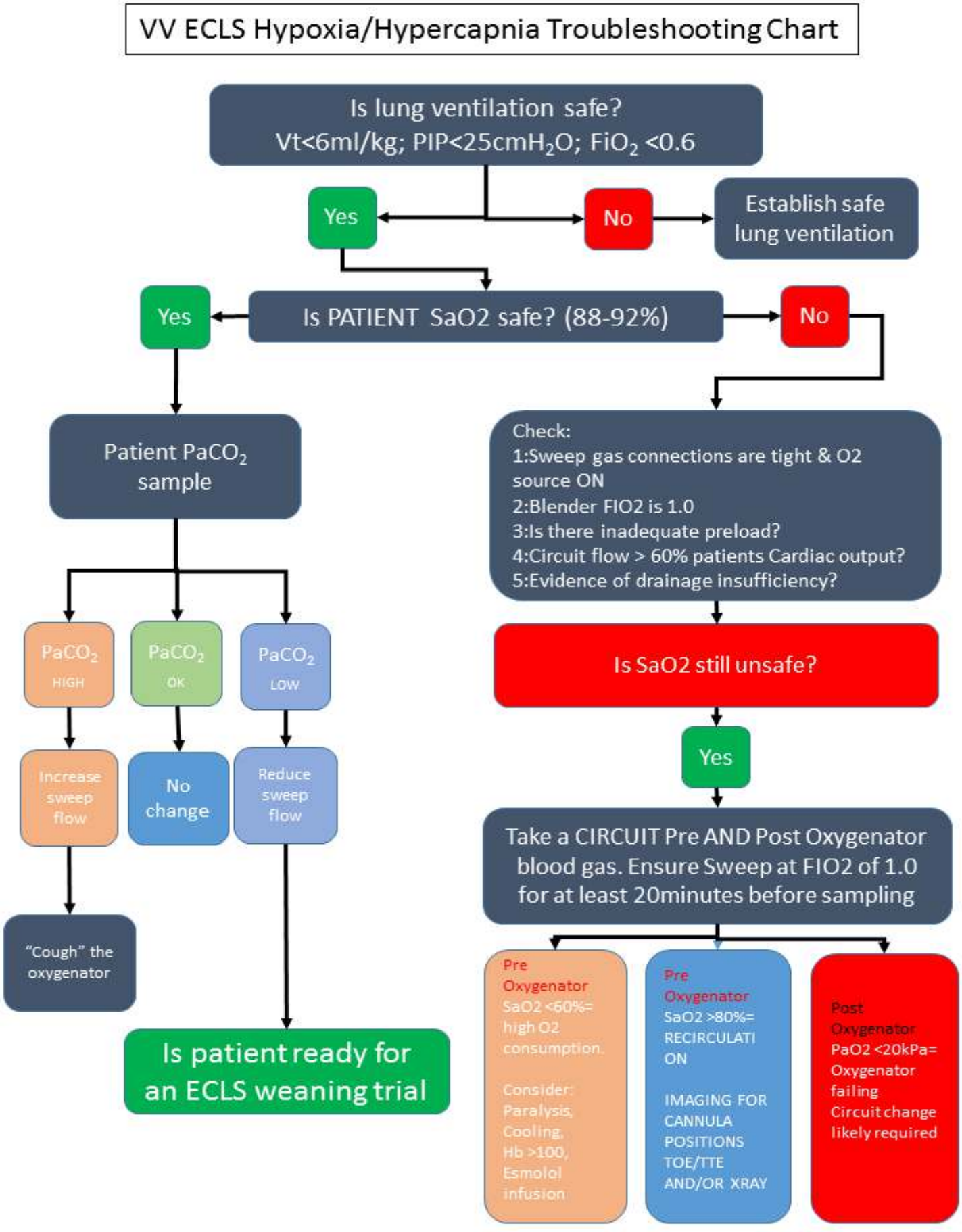
Ensure:
Pump flow is adequate (>2/3 cardiac output)
Oxygen flow to oxygenator is at least twice the pump flow rate

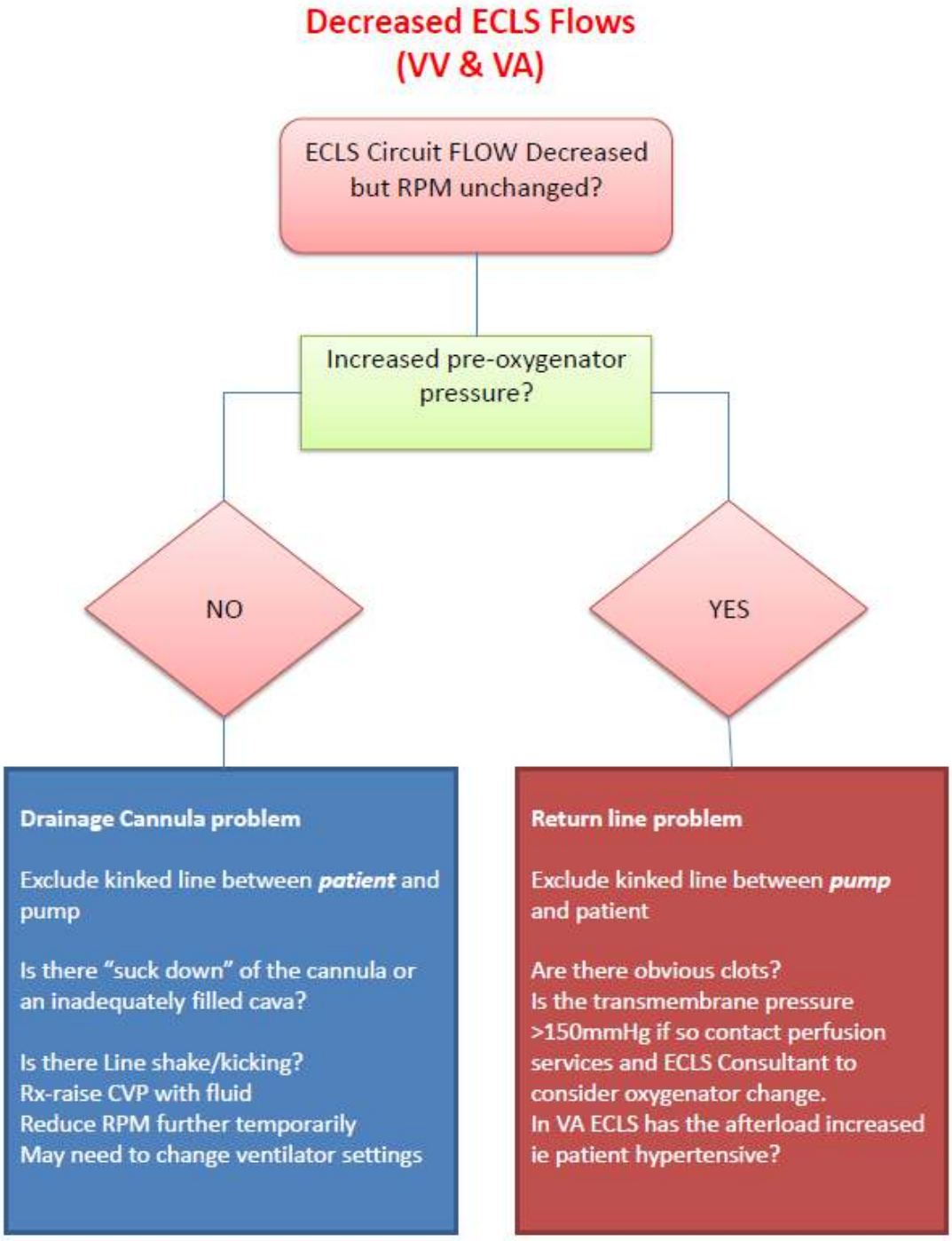
Consider:
Increasing ECLS flow rate / increasing ventilation /cooling patient to 35ºC/Coughing the oxygenator

Low Flows

Causes
- Hypovolaemia (look for a kicking access line)
- Clot in oxygenator (look for increased transoxygenator pressures)
- Kinked tubing
- Catheter against vessel wall
- Clot in access line

Action
- Give fluid, monitor CVP this will fall if circuit flows are increased in VA ECLS making circuit flows worse
- Reposition tubing
- Assess for clot formation and inform ECLS Intensivist and Perfusionist.


VV ECLS Hypoxia/Hypercapnia Troubleshooting Chart
Is lung ventilation safe?
Vt<6ml/kg; PIP<25cmH2O; FiO2 <0.6
Yes
No
Establish safe lung ventilation
Yes
Is PATIENT SaO2 safe? (88-92%)
No
Patient PaCO2 sample
Check:
1:Sweep gas connections are tight & O2 source ON
2:Blender FIO2 is 1.0
3:Is there inadequate preload?
4:Circuit flow > 60% patients Cardiac output?
5:Evidence of drainage insufficiency?
PaCO2 HIGH
PaCO2 OK
PaCO2 LOW
Is SaO2 still unsafe?
Increase sweep flow
No change
Reduce sweep flow
Yes
"Cough" the oxygenator
Take a CIRCUIT Pre AND Post Oxygenator blood gas. Ensure Sweep at FIO2 of 1.0 for at least 20minutes before sampling
Is patient ready for an ECLS weaning trial
Pre Oxygenator SaO2 <60%= high O2 consumption.
Consider: Paralysis, Cooling, Hb >100, Esmolol infusion
Pre Oxygenator SaO2 >80%= RECIRCULATION
IMAGING FOR CANNULA POSITIONS TOE/TTE AND/OR XRAY
Post Oxygenator PaO2 <20kPa= Oxygenator failing Circuit change likely required


Decreased ECLS Flows
(VV & VA)
ECLS Circuit FLOW Decreased but RPM unchanged?
Increased pre-oxygenator pressure?
NO
YES
Drainage Cannula problem
Exclude kinked line between patient and pump
Is there "suck down" of the cannula or an inadequately filled cava?
Is there Line shake/kicking?
Rx-raise CVP with fluid
Reduce RPM further temporarily
May need to change ventilator settings
Return line problem
Exclude kinked line between pump and patient
Are there obvious clots?
Is the transmembrane pressure >150mmHg if so contact perfusion services and ECLS Consultant to consider oxygenator change.
In VA ECLS has the afterload increased ie patient hypertensive?

Trouble Shooting Guide for ECLS		
Symptom	**Potential Cause**	**Intervention**
Low patient SpO_2	Oxygenator failure	Check pre- and postoxygenator blood gas and pressures "Cough " the oxygenator Replace oxygenator
	Disconnected sweep gas or FIO_2	Check connections and Gas blender FIO_2
	Increased Oxygen Consumption (VV) eg S_DO_2<60%	Increase circuit flows, Sedate and paralyze ± cool Increase ventilator FIO_2
	Inadequate circuit flow (VV)	Increase circuit flow
	Upper body hypoxia(VA)	Increase circuit flow, change to VAV ECLS or Central VA ECLS
Low oxygen saturation in drainage line (<60%)	Low circuit flows (VV) Increased Oxygen consumption (VV)	Increase circuit flow Sedate and paralyze ± cool Look for sepsis
High oxygen saturation in Drainage line (>80%)	Recirculation (VV)	Perform echocardiogram Reposition cannulae Change to VAV ECLS
Bleeding	Coagulopathy	Check and correct coagulopathy
	Surgical and cannulation site bleeding	Transfuse blood products Lower aPTT target Stop heparin Surgical exploration with cautery
	Gastrointestinal bleeding	GI endoscopy + above
	Airway bleeding	Airway endoscopy +above
Suction events	Hypovolemia	Assess volume status Give fluid Sedate and paralyze
	Tamponade (VV)	Perform echocardiogram
	Tension pneumothorax	Perform chest radiograph or thoracic USS
High plasma haemoglobin	Clots in circuit High negative inlet pressure (centrifugal pump)	Check circuit, change component or entire circuit

Weaning VV ECLS

As the underlying process improves the CXR will clear and lung compliance will improve.

Trial off VV ECLS

- Once adequate tidal volumes are achieved (4-6mL/kg), ability to wean from ECLS can be considered.
- To assess adequate oxygenation, turn the ventilator to FiO2 100%, aiming for a PaO2 >20kPa if unable to achieve this postpone weaning for further 24 hours then reassess. If achievable place patient onto an acceptable e.g $FIO_2 \leq$ 60%. Then aim to wean the blood flow to 3L/min provided adequate systemic oxygenation is maintained
- Leave the ECLS FiO2 100% throughout the wean
- Wean the sweep gas flow by 1L/hr and reassess PaCO2 every hour. Provided that PCO2 allows pH >7.30 (H^+ > 30) and the respiratory work is acceptable (RR <30, TV 4-6mL/kg, comfortable pattern), wean until sweep flow is ceased.
- Once sweep flow is off, disconnect the gas line and observe the patient 4-6 hours and manipulate the ventilator as required. If PaO2 >8 on FiO2 <0.6 and PaCO2 adequate to maintain pH >7.30 (H^+ > 30) with acceptable respiratory work, plan to cease ECLS.

Ceasing VV ECLS and decannulation: this should only occur during 0800 to 1800 hours.

- Sedate +/- paralyse patient to reduce risk of air embolism/venous hypertension
- Let vascular team know about plan and times.
- Cease heparin for 2 hours
- Clamp circuit at the drainage and return cannulae
- Stop pump. The haematocrit in the circuit and patient are the same and blood does not need to be transfused back into the patient.
- Remove drainage cannulae with direct pressure over the insertion site for 30 minutes- do not use the femstop device.
- Place a deep vertical mattress suture(s) at the insertion site 30 minutes after cannula removal and post 30 minutes of direct finger pressure over wound. This will need to be removed at 7 days, ensure on discharge note.
- After 30 minutes of cannula removal the insertion site wounds should be observed for bleeding every 15 minutes for 4 hours post removal. The area should NOT be covered over by a sheet during this time.
- Venous duplex 24-48 hours following the removal of cannulae to assess for the presence of deep vein thrombosis (it is estimated to occur in up to 20% of patients)

Weaning VA ECLS

VA ECLS is a short term solution and is expected if successful to be required for less than 7 days to allow stunned or hibernating myocardium to recover. In certain circumstances eg myocarditis or post partum cardiomyopathy the time course will be much longer and these patients should be referred to the heart failure service in Glasgow as early as possible.

Weaning regime:

- Use the VA weaning process tool (see appendix). Always use TTE/TOE to evaluate RV and LV prior to and during weaning process.
- Increase anticoagulation during this process
- Reduce pump flow by 0.5L/min every 5 minutes and assess response. Minimum 1L/minute
- Patient stable with flow < 2.5 L/min is a good indicator of success.
- Minimum pump flow is 1 L/min do not go below this level
- If successful, the patient should remain on 2.5 L/min for a further 12 to 24 hours.
- Optimise ventilator settings aim for spontaneous breathing if possible and wean.
- The Sweep gas flow rate and FIO2 should be reduced in tandem with the increase in ventilator support during the weaning process.

Decannulation:

- Removal of veno-arterial ECLS should be done in theatre, and preceded by a clamping test, these can been done on the ward prior to theatre.
- Just before moving to theatre, simplify circuit by removing the reperfusion line if present that connects the luer from the return cannula to the leg reperfusion cannula.
- Ensure the reperfusion cannula is saline locked
- Always clamp as close to patient as possible.
- Discontinue sweep gas to avoid risk of air embolism
- Consider stopping heparin infusion
- Venous cannula inserted by seldinger. Direct pressure over wound for 30 minutes then place a mattress suture to close skin wound. Patient supine for 4 hours post removal. 15 minute observations of insertion site.
- Femoral Arterial cannula to be removed and formally repaired by vascular team or cardiac surgical team.
- Ensure cannulae tips are sent for culture.
- Post cannula removal the insertion site wounds should be observed for bleeding every 15 minutes for 2 hours post removal. The area should NOT be covered over by a sheet during this time.
- Venous duplex 24-48 hours following the removal of cannulae to assess for the presence of deep vein thrombosis (it is estimated to occur in up to 20% of patients)
- Dorsalis pedis or Posterior tibial reperfusion cannula can be removed on the ward after the main arterial cannula has been taken out. It is important to aspirate then flush and “lock” these cannulae. Direct pressure over the access site as per removal of the venous lines works well.

Emergency Complications with ECLS care

Emergency complications involving the ECLS circuit demand immediate responses.

Emergency ECLS responses however are fortunately rare. They are largely preventable and a commitment to a thorough system of checking the circuit and rehearsing potential emergency responses should make them manageable for our patients.

Possible complications are:

- Haemolysis
- Off pump emergencies.
- Pump Failure
- Decannulation
- Circuit Rupture
- Air Embolism
- Cardiac Arrest
- Oxygenator Failure

Haemolysis

Many potential causes in an ICU patient but can be a specific issue with ECLS patients due to mechanical trauma to the blood from the pump or circuit.

Signs of haemolysis: Increased bilirubin,LDH and plasma free haemoglobin- these should be measured at least every 12 hours. Blood film demonstrating fragments. Red (or dark brown in extreme cases) urine- check with bedside urine dipstick which will be positive for haematuria, high serum potassium, renal failure; jaundice (late sign).

Signs of **drainage cannula** insufficiency: Insufficiency occurs when flow into the circuit from the patient is inadequate for the pump speed settings. This may occur if the venous return is insufficient or there is obstruction near the inlet of the cannulae. Blood flow into the circuit becomes episodic and pressure swings can be very large resulting in damage to red blood cells. The drainage line tubing may visibly shake or have a palpable “kick”. Continuous monitoring the drainage line is a major part of routine nursing care of a patient on ECLS.

Management of haemolysis:

Increase volume state and review pump settings (if signs of drainage insufficiency present)
TTE to ensure cannula not obstructed
Consider changing the circuit
Reset anticoagulation targets. May need to be higher- but consider change of circuit first.

Emergency Complications of ECLS

Pump failure
This is a no flow state due to failure of the electrical pump to drive pump head. It leads to hypoxia / hypercarbia and haemodynamic collapse may occur as a result of hypoxia in VV ECLS and loss of cardiovascular support in VA ECLS.

Causes
- Pump head disengagement: eg. accidental contact with pump-head or incorrect initial placement of pump head or pump head adaptor
- Electrical motor failure
- Battery failure (no AC power connected)

Prevention
- Always maintain the pump head in a position to minimise the risk of contact especially with devices such as portable x-ray and CVVH
- Minimise time on battery
- When the console is not in use, it needs to be plugged into AC power
- A blinking plug icon confirms that AC power is on (levitronix)

Response
- Call for help including perfusionist and ICU consultant
- Assign roles for **concurrent patient and circuit management**

Patient Management
- Re-establish full ventilation using C circuit with FIO2 of 1.0 or SIMV 400 x 20; PEEP 10cmH20 & FIO2 1.0. These should always be prescribed on daily ECLS rounds.
- Resuscitative measures

Circuit Management
- Examine circuit: identify pump head disengagement; exclude torsion, kinking or compression of tubing
- clamp the return line and turn pump off,
- Pump head disengagement
- Re-engage pump head
- Turn pump on and ensure rpm set to 0
- Increase rpm 1500 rpm and remove clamp
- Gradually increase rpm to previous setting

Electrical motor failure
- Clamp return line and turn off pump
- Place pump head into back up motor(levitronix)
- Adjust RPM based on systemic saturation, pre and post membrane pressure
- Re-engage pump head in new blood pump
- Turn pump on and ensure rpm set to 0
- Turn on blood pump to 1500 rpm and remove clamp
- Gradually increase rpm to previous settings

Emergency Off Pump Drill

If there is no flow in the ECLS system for even a short period of time then clotting and thrombosis may become a major problem. In general if a patient is going to be "off pump" for more than 5 minutes then efforts to maintain cannula patency should be undertaken with urgency. Changing a circuit is far less of a problem then having to change the cannulae and for this reason we always have an aseptically prepared and primed emergency ECLS circuit ready for use. Focus on maintaining cannula patency during off ECLS emergencies becomes an important goal.

Causes

- Recurrent Circuit air embolus
- Circuit rupture
- Decannulation

Response

- Call for help including perfusionist and ICU consultant
- Assign roles for **concurrent patient and cannula management**

Patient Management

- Re-establish full ventilation using C circuit with FIO2 of 1.0 or SIMV 400 x 20; PEEP 10cmH20 & FIO2 1.0. These should always be prescribed on daily ECLS rounds.
- Resuscitative measures as required

Equipment

- 4 tubing clamps
- One dispensing pin
- 500mls bag of plasmalyte 148
- One 50ml luer lock syringe
- 5000 units of unfractionated heparin

Cannula management- note difference between drainage and return cannula

- Place clamp distal to luer port on return cannula
- Place clamp closest to patient onto the plastic compressible part of the drainage cannula
- Give 2500u unfractionated heparin via central line or increase Argatroban by 0.05 micrograms/kg/minute
- For return cannula use the luer port to attach the 50ml luer syringe
- Aspirate blood and flush with Plasmalyte solution 50mls.
- Change the circuit as soon as perfusion attend.

Emergency Complications of ECLS

Decannulation
This is the partial or complete removal of either the drainage or return cannula. It will result in hypoxaemia and/or haemodynamic collapse of varying severity (depending on underlying cardiac and respiratory reserve) and mode of ECLS. The large cannulas also mean that large rapid blood loss from cannulation site can occur.

Causes
- Extreme tension being placed on tubing and hence cannulae and cannulation sites

Prevention
- Anchoring the cannulae to the patient correctly
- Use of a spotter to ensure that lines remain free during patient manoeuvres
- The only responsibility of the spotter is to ensure cannula and line integrity, they should not be involved in helping to physically position the patient.
- Ensure the patient is appropriately sedated
- Patient is never left unattended

Response
- Call for help including perfusionist and ICU consultant
- Assign roles for **concurrent patient and circuit management**

Patient Management
- Re-establish full ventilation using C circuit with FIO2 of 1.0 or SIMV 400 x 20; PEEP 10cmH20 & FIO2 1.0. These should always be prescribed on daily ECLS rounds.
- Give blood to replace blood loss and activate major haemorrhage protocol if indicated

Circuit Management
- If cannula completely removed then clamp the return line and turn pump off, apply pressure to the cannula site
- If cannula partially removed and no native lung function then push the cannula back in until the side holes are covered

Other
- Consider prophylactic antibiotics
- Consider replacement of cannula
- Consider imaging to review cannula positions

Emergency Complications of ECLS

Circuit Rupture

This is the disruption of any part of the circuit which will lead to large and rapid blood loss, possible air embolus, haemodynamic collapse and hypoxia of varying severity (depending on underlying cardiac and respiratory reserve) and mode of ECLS.

Causes

- Fracture and breakdown of polycarbonate components after being cleaned with alcohol
- Broken three way tap
- Accidental cutting or puncturing of circuit tubing

Prevention

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

Response

- Call for help including perfusionist and ICU consultant
- Assign roles for **concurrent patient and circuit management**

Patient Management

- Re-establish full ventilation using C circuit with FIO2 of 1.0 or SIMV 400 x 20; PEEP 10cmH20 & FIO2 1.0. These should always be prescribed on daily ECLS rounds.
- Give blood to replace blood loss and activate major haemorrhage protocol if indicated
- Other inopressors as required

Circuit Management

- Clamp the circuit on either side of the circuit disruption, stop pump
- Manage as per off pump emergencies
- Circuit change

Emergency Complications of ECLS

Circuit Air Embolism-
Is the introduction of air into the ECLS circuit. Massive air embolus into the pump head will de-prime the pump and stop it pumping. This will lead to haemodynamic collapse and hypoxaemia of varying severity (depending on underlying cardiac and respiratory reserve) and mode of ECLS. There is also the risk of air embolus into the patient. **Prevention is the key intervention** and as such no access to the negative (pre pump) side of the ECLS circuit is allowed. All central lines should be placed by a Consultant. It may be useful during key stages to transiently reduce the RPM on the centrifugal pump to reduce the chance of air entrainment. It is likely using our minimal access circuit that major air embolus will reflect a problem that cannot be solved by simply de-airing the circuit and a new circuit with pump and oxygenator will be required however some massive air problems can be solved with the below drill..

Causes
- Introduction of air into the circuit via a cannulation site
- Fracture of connector on the inlet side of the pump

Prevention
- Only ECLS trained consultants to perform ECLS cannulation
- Only perfusionist to manipulate the drainage (inlet) side of the pump
- Do not allow connectors to come into contact with alcohol or organic solvents

Response
- Call for help including perfusionist and ICU consultant
- Assign roles for **concurrent patient and circuit management**

Patient Management
- Re-establish full ventilation using C circuit with FIO2 of 1.0 or SIMV 400 x 20; PEEP 10cmH20 & FIO2 1.0. These should always be prescribed on daily ECLS rounds.
- Give blood to replace blood loss and activate major haemorrhage protocol if indicated

If air into patient's circulation:
- Position patient head down
- Inotropic support to maintain MAP
- Consider aspiration of the right heart using existing lines

Circuit Management- gross air before the oxygenator
- Clamp return line then drainage line near to patient.
- Switch off pump to prevent further introduction of air into the patient
- Release pump head from drive
- Walk air through the pump head and leave on floor keeping pump outlet at 12 O'clock
- Attach 50ml syringe to de-airing pigtail and open it
- Open up pressurised plasmalyte bag to re priming pigtail
- Tap oxygenator to get air to top of oxygenator
- Gently aspirate air from top of oxygenator until tubing post pump and oxygenator de-aired

- Reinsert pump head and restart pump at 1500 RPM
- Check no air after the oxygenator. If so move onto gross air post oxygenator drill
- Release return clamp
- Release drainage clamp.
- If this recurs immediately consider coming off pump and changing circuit.

Circuit Management- gross air after the oxygenator

- Clamp return line after the luer connector then drainage line near to patient
- Switch off pump to prevent further introduction of air into the patient
- Once pump and oxygenator de aired in manner above attach luer lock syringe onto the return luer to collect the fluid and air- keep this upright.
- Release drainage clamp
- Switch on pump to 1500 RPM
- Once de-aired remove return line clamp and restart ECLS
- If this recurs immediately consider coming off pump and changing circuit.

Emergency Complications of ECLS

Oxygenator failure

Definitions:
Gradual oxygenator failure: over time thrombus may build up in the oxygenator. It is acceptable to have some thrombus in the oxygenator, particularly in the corners where flow is lower. The transmembrane pressure should be <50mmHg. With impending oxygenator failure two features predominate**: worsening gas exchange** and **increasing transmembrane pressure (>150mmHg)**.

Rapid oxygenator failure is rare, causes include:

- Water leak external (heat exchanger rupture)
- Blood to water leak

Effects:
Gradual failure: decreasing O2 transfer. Trans-membrane pressure >150mmHg
Heat Exchanger Rupture: Water leaking, loss of ability to control blood temperature through oxygenator

Causes

- Thrombus in oxygenator.
- Heat Exchanger Rupture
- Manufacturing defect

Prevention
Gradual failure: monitor transmembrane pressures and oxygenator for thrombus (visual inspection), notify ICU consultant and perfusionist if pre oxygenator pressure rising at same flow rate and thrombus visualised. If transmembrane pressure is also >150mmHg then likely need to change out oxygenator. The Perfusionist will perform daily and as required post oxygenator blood gases. If the post oxygenator PaO_2 is < 20kPa then electively change the oxygenator. Ensure that no equipment is rolled over or obstructs the heater cooler hoses attached to the oxygenator

Response

- Gradual failure: It is likely that the oxygenator will need to be changed (depending on the clinical situation) - contact perfusionist and ICU Consultant

- Heat exchanger rupture: Turn off heater cooler, clamp water lines and detach from oxygenator use warming blanket to control patient temperature, consider changing oxygenator when convenient.

Emergency Complications of ECLS

Cardiac arrest

Definitions:
Loss of cardiac output due to cessation of cardiac function

Effects:
VV ECLS: hypotension, hypoxaemia, shock
VA ECLS: may have minimal effects but note risk of thrombus in LV during ventricular standstill, with back pressure and pulmonary haemorrhage.

Causes
- Ischaemic heart disease
- Hypoxaemia
- Bleeding- covert or overt
- Cardiac tamponade
- Tension pneumothorax

Prevention
- Vigilance for the development of complications

Response
- Call for help including perfusionist and ICU consultant
- Assign roles for **concurrent patient and circuit management**
- **Look for and treat the cause**

Patient Management
- For VV ECLS:Re-establish full ventilation using C circuit with FIO2 of 1.0 or SIMV 400 x 20; PEEP 10cmH20 & FIO2 1.0. These should always be prescribed on daily ECLS rounds.
- Follow standard ACLS protocols
- **Defibrillation**-This can be safely done during ECLS
- The patient's haemodynamic stability should be carefully monitored during this time.
- Ensure rpm and flow of ECLS return to baseline

Circuit Management

- This has inherent dangers in a fully heparinised patient with large cannulae in the heart which may become dislodged or entrain air.
- ECLS Nurse watches circuit for air entrainment and looks after pump.
- Do not clamp off ECLS unless air entrained during CPR.
- Switch on back-up pump in case of unanticipated pump failure.
- Be aware that significant increase in afterload secondary to high dose adrenaline will increase the resistance that the pump has to work against therefore rpm may need to be increased significantly until this has worn off.

Emergency Complications of ECLS

Tamponade/Haemothorax/Pneumothorax

Pericardial tamponade and tension haemothorax and/or pneumothorax show a similar pathophysiology of increasing intrapericardial pressure and decreasing venous return. With decreased venous return to the heart, pulmonary blood flow is decreased, cardiac output is decreased and peripheral perfusion is decreased. Peripheral perfusion is initially maintained by the non-pulsatile flow of the VA ECLS circuit but not with VV ECLS.

During ECLS

Features of Tamponade VV ECLS	Management of Tamponade VV ECLS
Increasing Heart rate	Call for help early
Increased CVP	Maintain flows, may need volume/pressors
No change in circuit flow	Sedate & paralyse
Increased Svo2	ECHO and thoracic ultrasound
Decreasing perfusion	CXR
Decreased pulse pressure	Correct coagulopathy
Late sign decreasing BP	Definitive treatment

Features of Tamponade VA ECLS	Management of Tamponade VA ECLS
Increasing Heart rate	Call for help early
Increased CVP	Maintain flows, may need volume
Falling ECLS circuit flow	Sedate & paralyse
Decreased Svo2	ECHO and thoracic ultrasound
Decreasing perfusion	CXR
Decreased pulse pressure	Correct coagulopathy
Late sign decreasing BP	Definitive treatment

Patients with a tension pneumothorax will have a similar pathophysiology of increasing intrathoracic pressure and decreasing venous return. Where haemodynamic instability is absent pneumothorax can be managed by a period of CPAP, acute instability will necessitate emergency drainage which should be undertaken with caution due to the risk of bleeding. Minimal dissection and liberal use of electrocautery is required.

Emergency Complications of ECLS

Changing the circuit

Change the whole circuit in the event of either an oxygenator or pump failure.
It should take less than 60 seconds to cut and change the tubing.
Changing the circuit is the role of the perfusionist. Both perfusionist and ICU consultant should be present.

Indications

- Increasing transmembrane pressure gradient; (it should be <50 mmHg normally, consider change when >150mmHg, or earlier depending on clinical circumstances)
- Oxygen transfer across membrane significantly less than rated
- Heat exchanger rupture
- Increased noise from pump head
- Large thrombus formation within pump head
- Development of haemolysis

Method

- Call for help – ICU consultant and perfusionist
- Re-establish full ventilation using C circuit with FIO2 of 1.0 or SIMV 400 x 20; PEEP 10cmH20 & FIO2 1.0. These should always be prescribed on daily ECLS rounds.
- Apply defib pads (some patients will arrest due to hypoxia)
- Prime the new ECLS circuit.
- Double-clamp the new patient loop, divide it between the clamps, insert a straight heparin bonded ⅜" connector into each end and prime the connectors with a syringe of saline.
- Disconnect the heater-cooler tubing from the old oxygenator.
- Disconnect the gas line from the old oxygenator.
- Position one person on each side to cut and change the tubing.
- Stop the old pump slowly and double clamp the return and drainage lines (5-6 cm apart) close to the patient.
- Divide the lines between the clamps and fill the tubing ends using a syringe of saline.
- Connect the new lines to the ends of the old lines.
- Prewarm circuit if time allows
- Connect the fresh gas line to the new oxygenator.
- Unclamp the lines and slowly increase flow back to normal level.
- Connect the heater-cooler tubing to the new oxygenator (if not already done)
- Apply gun-ties to the new connections in the lines.
- Transfuse patient to target Hb

Miscellaneous Equipment to stay by ECLS patient bedside at all times

- 4 tubing clamps
- Sterile heavy duty scissors tuff cuts
- Two sterile 50ml luer lock syringes
- 500mls of Plasmalyte 148
- Two dispensing pins
- 2 sterile 50ml catheter tipped syringes
- 2 sterile 50ml luer lock syringes
- 5000u of unfractionated heparin
- Torch for examining circuit for clot
- Perfusionist's contact details
- Heparin bonded 3/8" male to male connectors x4
- Non alcoholic betadine
- Full D size oxygen cylinder with flowmeter regulator and oxygen tubing on ECLS trolley

Extracorporeal Life Support Competency Training Document		
ECLS Specialist Name:	Date of Previous Assessment :	
Assessors Name:	Todays Date :	
Competency demonstrated	**PASS**	**FAIL**
Names all parts of and connections of the levitronix machine		
Demonstrates a battery check and measures to ensure keeping it charged		
Demonstrates attaching and zeroing the P1 and P2 pressures and attaching the flow probe		
Demonstrates setting the pressure and flow limit alarms		
Names all parts of the ECLS circuit		
Demonstrates correct clamping sequence of the ECLS circuit		
Demonstrates correct connection of the gas blender and controls.		
Demonstrates a circuit walkthrough check		
Demonstrates knowledge of causes and detection of haemolysis		
Demonstrates knowledge, detection and procedure of “coughing” the oxygenator		
Demonstrates de-airing drill of pre-oxygenator air		
Demonstrates de-airing drill of post oxygenator air		
Demonstrates electrical or pump failure drill		
Demonstrates off pump emergency drill		
Demonstrates knowledge of hypoxia causes on VV and VA ECLS		
Demonstrates knowledge of decreased or fluctuating ECLS flows & appropriate response		
Demonstrates knowledge of preventing retrograde circuit flow during VA ECLS		
Demonstrates knowledge of oxygenator failure		
Demonstrates knowledge of decannulation & circuit rupture drill		
Demonstrates knowledge of cardiac arrest on ECLS		
Demonstrates knowledge of cannulation procedure and expected roles		
Demonstrates knowledge of size & type of cannulas used in ECLS		

Venovenous Cannula positioning

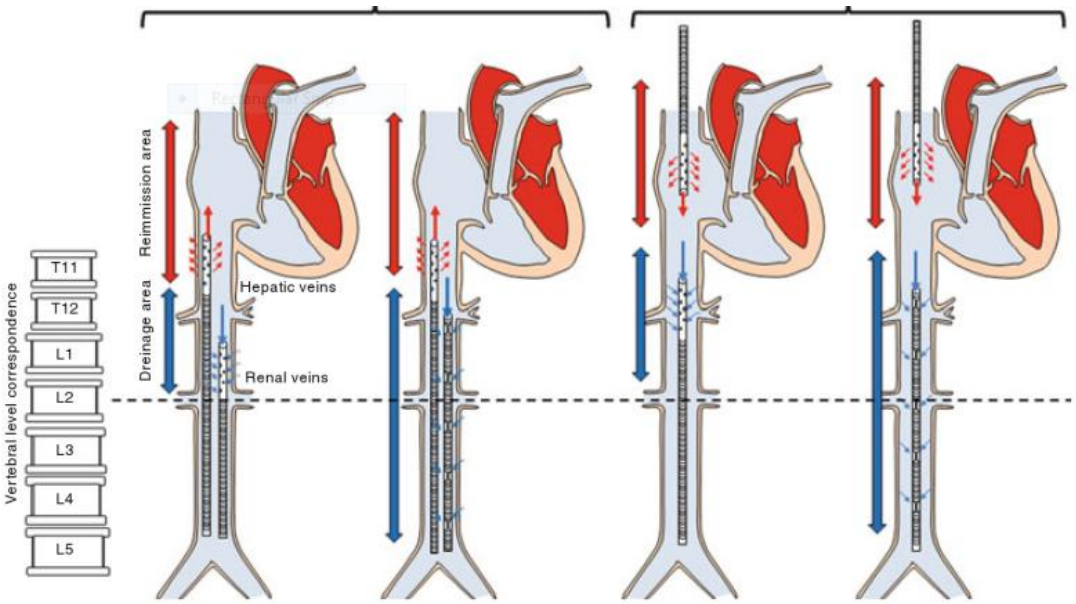


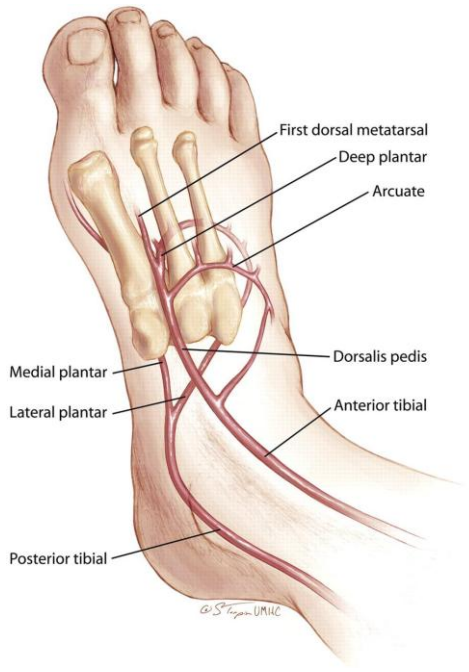
Fig. 4.2 Possible VV cannula configuration according to the type of drainage cannula (multistage side holes or cannula with side holes close to the tip) and to VV configuration (femoro-femoral or femoro-jugular). Correspondence between inferior vena cava main branches (hepatic and renal veins) and vertebral bodies is drawn. Independently from the reimmission cannula, tip of the drainage cannula should be positioned above renal veins, possibly in the intrahepatic portion of inferior vena cava. Multistage cannula should be used for drainage only especially in the femoro-femoral approach to minimize blood flow recirculation

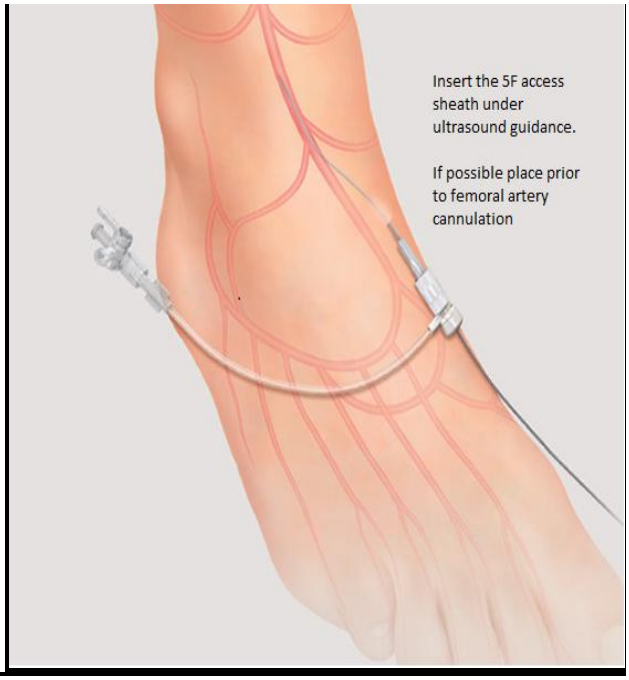
Venous cannula length guide

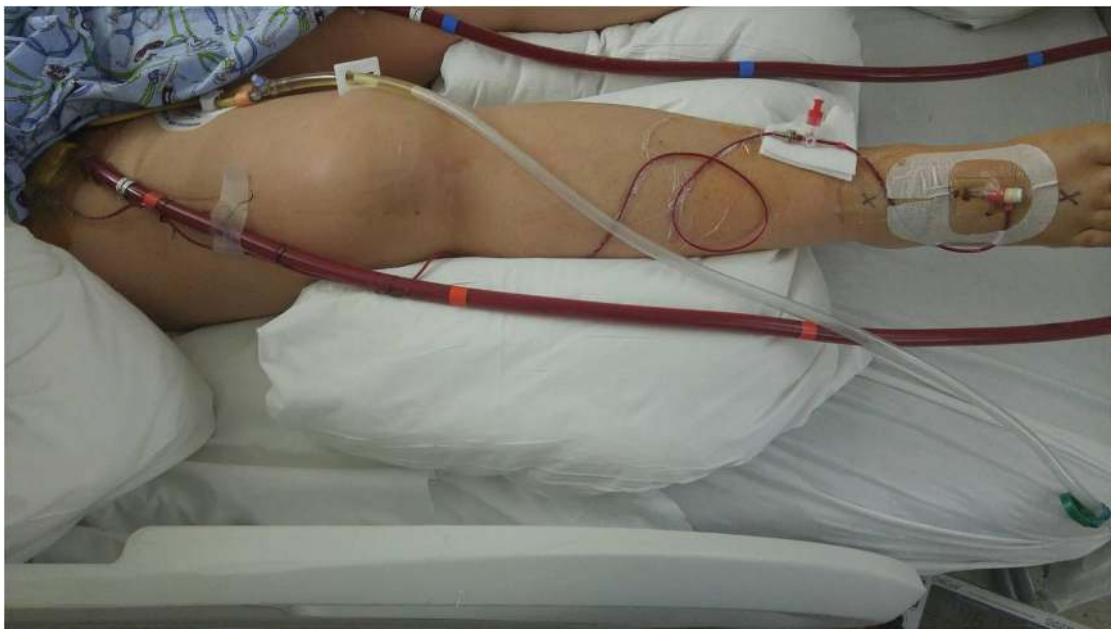
Femoral Insertion length guide for femoral venous drainage catheter insertion						
Measure from the femoral vein insertion point to the umbilicus then xiphisternum as a rough guide. Final position to be determined by fluoroscopy and TTE to keep tip below the hepatic vein. On fluoroscopy the tip should be below the Diaphragm and at the T11/T12 POSITION.						
Patient Height in cm		<140cm	140 to 150cm	150 to 180cm	180cm to 190cm	>190cm
25F, 38cm	Right Femoral vein	30cm	31cm to 35	35 to 40cm	40 to 45cm	45 to 50cm
25F, 55cm	Left Femoral vein	35cm	36cm to 40cm	40 to 45cm	45 to 50cm	50cm

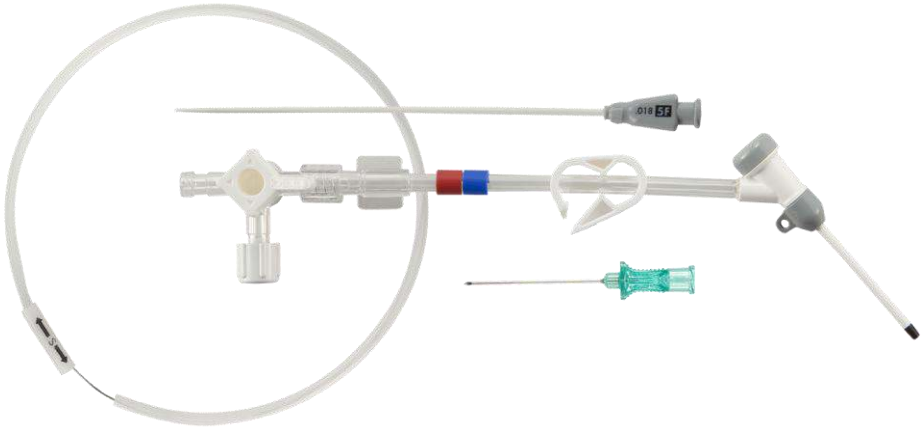
Veno-arterial cannula with reperfusion cannula options

We have 2 options for reperfusion cannula- accessing the ipsilateral posterior tibial OR dorsalis pedis artery to perfuse the leg in a *retrograde* manner (below) or accessing the superficial femoral artery (above) to perfuse the leg in an *antegrade* manner. Both techniques can be done as a percutaneous or open procedure. Our preferred technique is the same as that from the home of ECMO, University of Michigan and is the retrograde technique below.









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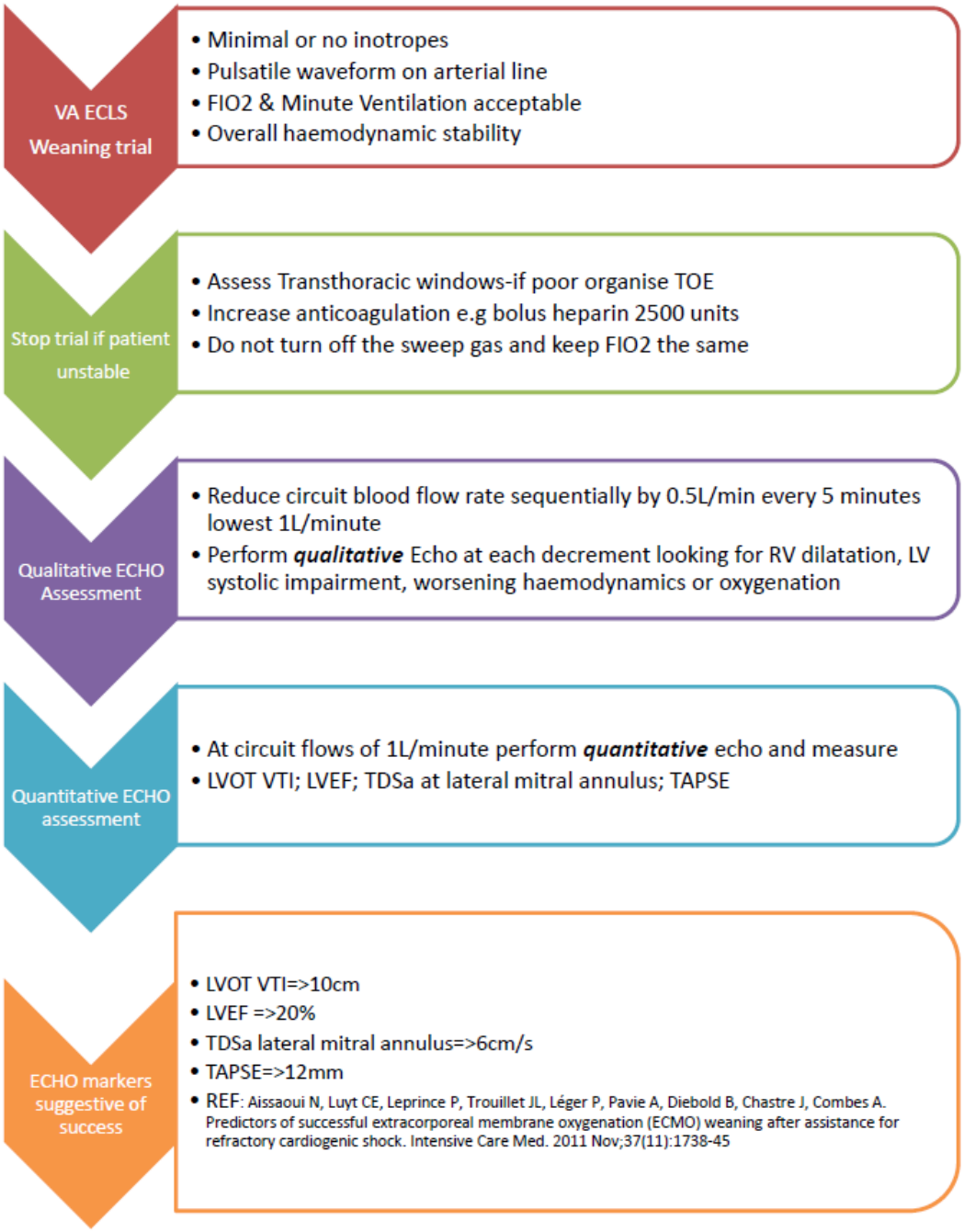
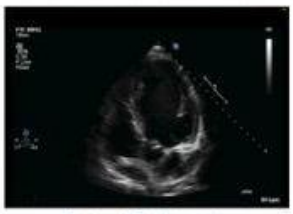
Reviewed on:19/05/2021	**Next review : 22/04/2023**

VA Weaning process

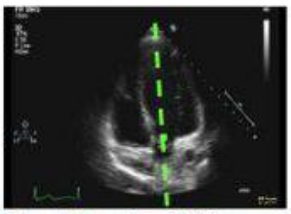


How to measure LVOT VTI & TAPSE

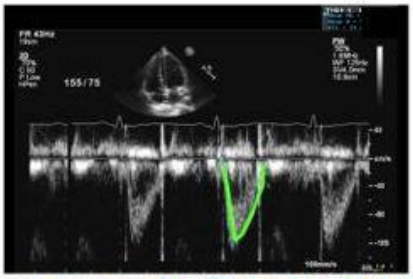
The amount of blood going through the LVOT is given by the VTI (velocity time integral) of the flow, obtained by tracing the signal's envelope:



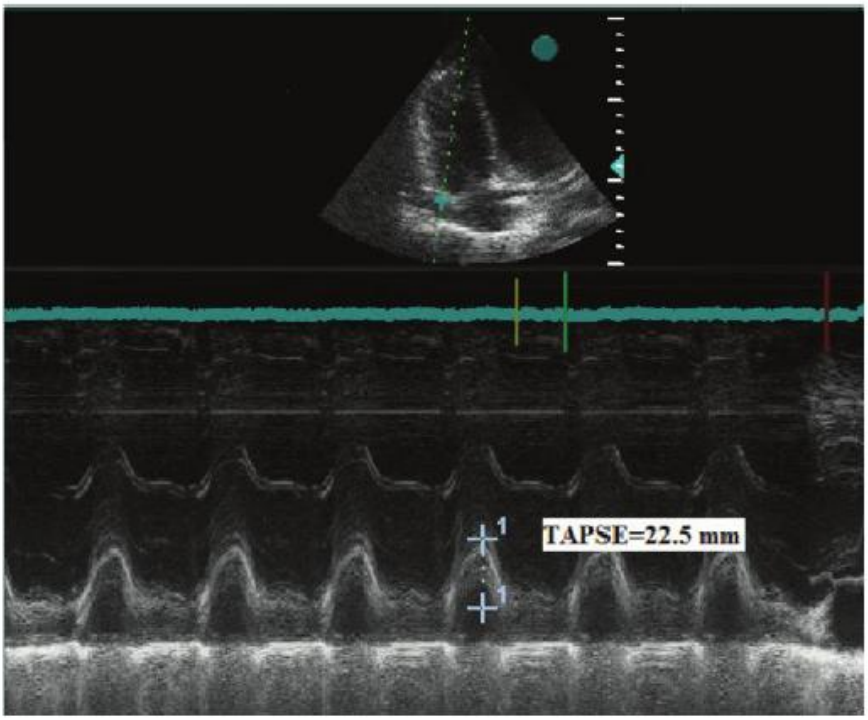
Apical 5 chamber



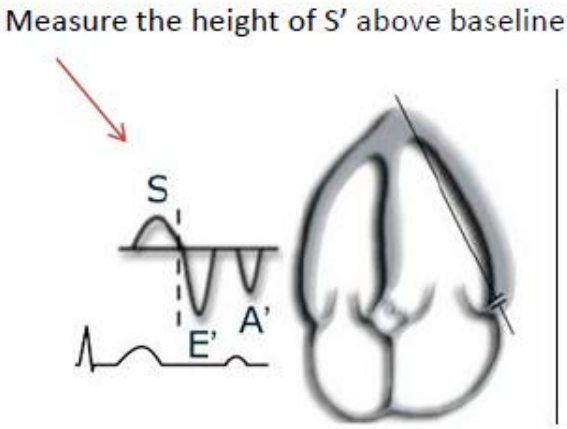
Pulsed Doppler (PW) sample in LVOT
+++ Doppler beam MUST be aligned with the LV outflow +++

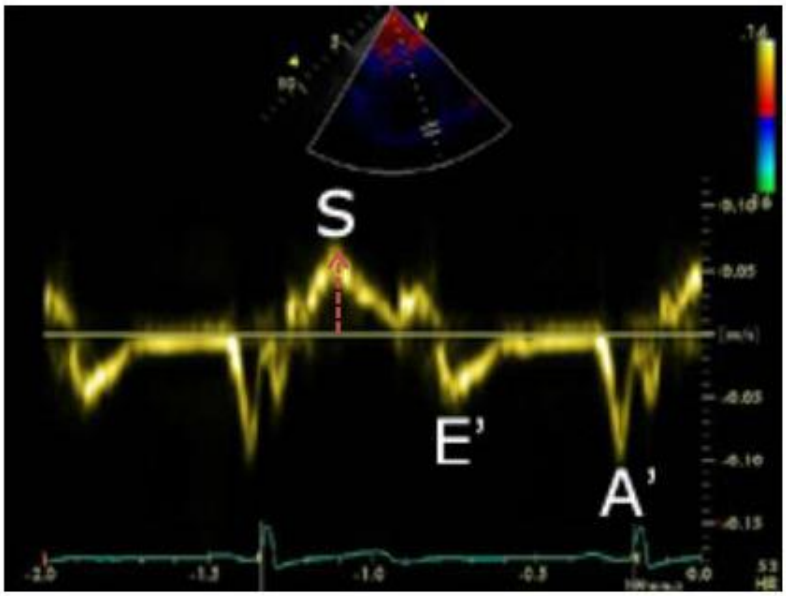


Trace envelope of LVOT flow → VTI of LVOT



Tissue doppler at the lateral mitral annulus





Patient label

VA ECMO Weaning Trial

Haemodynamic ECHO Chart

Prerequisites:

1. Circuit Blood flow rate at 1L/minute
2. Haemodynamically stable patient
3. Adequate TTE apical views OR TOE
4. Anticoagulation increased for duration of weaning trial eg 2500 units heparin at start

Measurement	Value	Markers of success
RV/LV ratio:	≤0.6 □ ≥ 1.0	≤1.0
TAPSE:	**=** **mm**	>12mm
LVOT VTI	**=** **cm**	**>**10cm
LVEF	**=** **%**	>20%
TDSa lateral mitral	**=** **cm/s**	>6cm/s

PRE ECLS CHECKLIST

Question	Response tick for confirmation
Correct patient?	
Haemoglobin over 100g/dl?	
Cross matched 2 units of blood?	
What is the PT?	
What is the APTT?	
Are the platelets over 100?	
What type of ECLS VV or VA?	
Where is drainage cannula going?	
Where is return cannula going?	
Is the ECLS machine present and safety checked?	Circuit primed with plasmalyte 148?
	Smart sites on all access ports?
	Pressure tranduscers primed and zeroed?
	Oxygen connected to oxygenator?
	FULL D size oxygen tank + regulator attached to ECLS trolley with green oxygen tubing
	Mains plugged into levitronix?
	Battery charged on levitronix?
	X4 tubing clamps available?
Is the BEDSIDE ECLS equipment present?	Non alcoholic betadine 500mls
	4 tubing clamps sterile
	1 pair Sterile heavy duty scissors
	500mls of Plasmalyte 148
	2 dispensing pins
	2 sterile 50ml catheter tipped syringes
	2 sterile 50ml luer lock syringes
	5000u of unfractionated heparin
	Torch for examining circuit for clot
	4 Heparin bonded 3/8” male to male connectors

Nursing handover ECLS safety checklist

Question	Response tick for confirmation
What type of ECLS VV or VA?	
What is the Hb	
Cross matched 2 units of blood available?	
What is the APTT?	
Are the platelets in agreed range	
Any clots/fibrin noted?	
Where is return cannula going?	
Where is drainage cannula going?	
Contact details up to date?	
Is the ECLS machine present and safety checked?	Circuit primed with plasmalyte 148?
	Smart sites on all access ports?
	Pressure tranduscers primed and zeroed?
	Oxygen connected to oxygenator?
	FULL D size oxygen tank + regulator attached to ECLS trolley with green oxygen tubing
	Mains plugged into levitronix?
	Battery charged on levitronix?
	X4 tubing clamps available?
Is the BEDSIDE ECLS equipment present?	Non alcoholic betadine 500mls
	4 tubing clamps sterile
	1 pair Sterile heavy duty scissors
	500mls of Plasmalyte 148
	2 dispensing pins
	2 sterile 50ml catheter tipped syringes
	2 sterile 50ml luer lock syringes
	5000u of unfractionated heparin
	Torch for examining circuit for clot
	4 Heparin bonded 3/8” male to male connectors

****FOR INTENSIVE CARE USE ONLY ****

Adult Heparin Infusion Chart for VA ECMO

Consultant		Name of Patient	
Hospital / Ward		CHI Number	
Weight (kg)		DOB	

Medicine (Approved Name)	Final Concentration	Total Dose	Volume	Route	Prescribed / Transcribed By Sign & print name
Heparin	**1000 units/ml**	**40,000 units**	40 mls	IV	

*Please note that in NHS Lothian heparin sodium solution for infusion is available in a ready concentration of 1000units/ml so further dilution is not required. If in doubt, contact pharmacy for advice.

Initiation of therapy

- **Check baseline FBC, coagulation screen, urea, creatinine**
- Prescribe continuous infusion on the patient main prescription chart. **No loading dose is given.**
- Start continuous infusion of heparin **10 units/kg/hour** (maximum 1250 units/hour). Use actual body weight capped at 125kg.
- For patients with a high risk of thrombosis (eg pulmonary embolism or circuit thrombosis) consider a higher starting rate.
- For patients with a high risk of bleeding, a lower starting rate may be required

Infusion Rate Instructions

	Date	Time	Rate ml/hr	Prescribed by	Adjusted by	UFH Anti-Xa level (units/ml)	Reason for Change/Comment
Initial Rate							
Change 1							
Change 2							
Change 3							
Change 4							
Change 5							
Change 6							

Dose Adjustment Instructions

TARGET UFH: **Anti-Xa LEVEL 0.3-0.7 units/ml (VA ECMO)**

Anti-Xa level	**INFUSION ADJUSTMENT:**	**REPEAT UFH Anti-Xa level:**
>1.2	Stop for 1 hour and decrease rate by 500 units (0.5ml)/hr	2 hours
0.9-1.2	Decrease infusion rate by 300 units (0.3ml)/hr	6 hours
0.71-0.9	Decrease infusion rate by 200 units (0.2ml)/hr	6 hours
0.3-0.7	No change in infusion rate	6 hours or after 3 consecutive levels 0.3-0.7, 12 hours
0.15-0.29	Increase infusion rate by 100 units (0.1ml)/hr	6 hours
0.06-0.14	Increase infusion rate by 200 units (0.2ml)/hr	6 hours
<0.06	Increase infusion rate by 400 units (0.4ml)/hr and administer bolus of 80 units /kg (maximum 10,000 units)	6 hours

Other Instructions

- UFH stands for unfractionated heparin (iv heparin)
- UFH-anti-Xa levels are taken in a green citrated tube; fill tube to the level, send to haematology
- To order on TRAK: go to "search for order", click on "order item" then enter "heparin", then click on "Unfractionated Heparin assay All sites": call RIE laboratory to inform sample is coming; WGH and SJH sites must courier samples to RIE lab.(ext 26093, OOH page 6550)
- Check UFH Anti-Xa level 6 hours after initiation, then adjust rate to achieve therapeutic range of **0.3-0.7 units/ml** using the **dose adjustment table** above. Measure the UFH-anti-Xa level 6 hours after each dose change
- Monitor FBC daily and be vigilant for heparin-induced thrombocytopenia
- If therapeutic range for UFH-anti-Xa level is not reached within 24 hours, seek advice from haematology
- Do not stop the heparin infusion to check the UFH-anti-Xa sample
- Do not take the UFH-anti-Xa sample from the limb with the infusion (or the same line in the case of central lines)

Medicine	Heparin	**Infusion Device Type**		**Name of Patient**	
Concentration	1000 units/ml	**Device Service Number**		**Patient Number**	Or affix patient label
Expected Completion Time				**DOB**	

Preparation Details	**Batch Number**	**Quantity**	*Prepared By*	**Checked By**
Heparin				
			Date:	Time:

Check infusion device 15 mins after set up and then every hour thereafter. **Sign box when the device has been checked.**

A	B	C	D	E	F	G	H	I	J
Date	Time	Site check	Rate (ml/hr)	Volume (ml) remaining in syringe – visual check	Volume (ml) infused since last check – calculated from E	Total volume (ml) infused – calculated from E	Total volume (ml) infused – device reading	Initials (two to set up / change rate)	Comments

Use a new page with every new syringe prepared, or if the infusion device is changed.
Syringe pumps must have the line purged and the volume recorded in column E. Start-up time may affect volume actually given to the patient.

****FOR INTENSIVE CARE USE ONLY ****

Adult Heparin Infusion Chart for VV ECMO

Consultant		Name of Patient	
Hospital / Ward		CHI Number	
Weight (kg)		DOB	

Medicine (Approved Name)	Final Concentration	Total Dose	Volume	Route	Prescribed / Transcribed By Sign & print name
Heparin	**1000 units/ml**	**40,000 units**	40 mls	IV	

*Please note that in NHS Lothian heparin sodium solution for infusion is available in a ready concentration of 1000units/ml so further dilution is not required. If in doubt, contact pharmacy for advice.

Initiation of therapy

- **Check baseline FBC, coagulation screen, urea, creatinine**
- Prescribe continuous infusion on the patient main prescription chart. **No loading dose is given.**
- Start continuous infusion of heparin **10 units /kg/hour** (maximum 1250 units/hour). Use actual body weight capped at 125kg.
- For patients with a high risk of thrombosis (eg circuit thrombosis) consider a higher starting rate.
- For patients with a high risk of bleeding, a lower starting rate may be required.
- ***If Pulmonary Embolism then use VA protocol***

Infusion Rate Instructions

	Date	Time	Rate ml/hr	**Prescribed by**	**Adjusted by**	UFH Anti-Xa level (units/ml)	Reason for Change/Comment
Initial Rate							
Change 1							
Change 2							
Change 3							
Change 4							
Change 5							
Change 6							

Dose Adjustment Instructions

TARGET UFH: **Anti-Xa LEVEL 0.2-0.4 units/ml (VV ECMO)**

Anti-Xa level	**INFUSION ADJUSTMENT:**	**REPEAT UFH Anti-Xa level:**
>1.2	Stop for 1 hour and decrease rate by 500 units (0.5ml)/hr	2 hours
0.81-1.2	Stop for 1 hour and decrease rate by 300 units (0.3ml)/hr	2 hours
0.61-0.8	Decrease infusion rate by 200 units (0.2ml)/hr	6 hours
0.41-0.6	Decrease infusion rate by 100 units (0.1ml)/hr	6 hours
0.2-0.4	No change in infusion rate	6 hours or after 3 consecutive levels 0.2-0.7, 12 hours
0.1-0.19	Increase infusion rate by 100 units (0.1ml)/hr	6 hours
0.06-0.09	Increase infusion rate by 200 units (0.2ml)/hr	6 hours
<0.06	Increase infusion rate by 300 units (0.3ml)/hr	6 hours

Other Instructions

- UFH stands for unfractionated heparin (iv heparin)
- UFH-anti-Xa levels are taken in a green citrated tube; fill tube to the level, send to haematology
- To order on TRAK: go to "search for order", click on "order item" then enter "heparin", then click on "Unfractionated Heparin assay All sites": call RIE laboratory to inform sample is coming; WGH and SJH sites must courier samples to RIE lab.(ext 26093, OOH page 6550)
- Check UFH Anti-Xa level 6 hours after initiation, then adjust rate to achieve therapeutic range of **0.2-0.4 units/ml** using the **dose adjustment table** above. Measure the UFH-anti-Xa level 6 hours after each dose change
- Monitor FBC daily and be vigilant for heparin-induced thrombocytopenia
- If therapeutic range for UFH-anti-Xa level is not reached within 24 hours, seek advice from haematology
- Do not stop the heparin infusion to check the UFH-anti-Xa sample
- Do not take the UFH-anti-Xa sample from the limb with the infusion (or the same line in the case of central lines)

Medicine	Heparin	**Infusion Device Type**		**Name of Patient**	
Concentration	1000 units/ml	**Device Service Number**		**Patient Number**	Or affix patient label
Expected Completion Time				**DOB**	

Preparation Details	**Batch Number**	**Quantity**	*Prepared By*	**Checked By**
Heparin				
			Date:	Time:

Check infusion device 15 mins after set up and then every hour thereafter. **Sign box when the device has been checked.**

A	B	C	D	E	F	G	H	I	J
Date	Time	Site check	Rate (ml/hr)	Volume (ml) remaining in syringe – visual check	Volume (ml) infused since last check – calculated from E	Total volume (ml) infused – calculated from E	Total volume (ml) infused – device reading	Initials (two to set up / change rate)	Comments

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