Title EXTRA-CORPOREAL MEMBRANE OXYGENATION DURING CARDIOPULMONARY RESUSCITATION (ECMO-CPR)

1. TARGET AUDIENCE:

This Guideline is intended for medical and nursing staff of the Intensive Care Unit (ICU) and Emergency and Trauma Centre (E&TC).

2. PURPOSE

This guideline outlines the procedures to be followed in the use of Extra-Corporeal Membrane Oxygenation during Cardio-Pulmonary Resuscitation (ECMO-CPR) in the E&TC, ICU, Cardiac Catheterisation Laboratory, Operating Theatre and Ward areas.

3. DEFINITIONS

ECMO-CPR is defined as the provision of an artificial circulation using the pumping of blood from a femoral venous catheter through an oxygenator into a femoral arterial catheter as an alternative to ventilation and external cardiac massage.

4. INDICATIONS

Out-Of-Hospital Cardiac Arrest

Patients in the E&TC with out-of-hospital cardiac arrest which is refractory to standard advanced cardiac life support (ACLS) treatment AND:

- The patient meets the enrolment criteria of the **CHEER** trial, which are
    - Initial cardiac rhythm of ventricular fibrillation; and
    - Chest compressions were commenced at scene within 10 minutes, and
    - The cardiac arrest has been prolonged (i.e. > 30 minutes); and
    - The patient is aged <60 years, and
    - There are no major co-morbidities, and
    - There has been no return of spontaneous circulation despite standard advanced cardiac life support in the field
- The patient is profoundly hypothermic (<32℃) due to accidental exposure
- The patient has taken a significant overdose of a vaso-active drug(s) (i.e. β-Blockers, tricyclic acid, digoxin etc)
- Any other cause where there is likely to be reversibility of the cardiac arrest if an artificial circulation can be provided

In-hospital cardiac arrest

Patients with refractory in-hospital cardiac arrest in whom the cause may be reversible, such as:

- The patient with suspected acute coronary syndrome who arrests in the E&TC (or just prior to arrival) AND does not respond to standard ACLS AND the cause is likely to be reversible with treatment in the cardiac catheterisation laboratory

- The patient in the cardiac catheterisation laboratory undergoing coronary angiography who suffers a cardiac arrest and who does not immediately respond to standard CPR

- The patient with suspected massive pulmonary embolism

- Any other cause where there is likely to be reversibility of the underlying condition if an artificial circulation can be provided

5. EXCLUSIONS:

- Where the prognosis for neurological recovery after prolonged CPR is poor. Examples include out-of-hospital cardiac arrest where the initial cardiac arrest was not witnessed, the initial cardiac rhythm was not ventricular fibrillation and there are no other factors that would have provided neurological protection such as peri-arrest hypothermia

- Where there is no realistic prospect of reversal of the underlying cardiac condition

- Advanced age precludes prolonged intensive care and mechanical support

- Limitation of medical treatment or advanced care plan that precludes further resuscitation

- Outside normal working hours (9am-5pm, Monday-Friday) unless 2 ICU Consultants are present or immediately available

6. ECMO-CPR REQUIREMENTS

There are three key components of ECMO-CPR, all of which must be provided concurrently:

- External cardiac massage using the Autopulse machine, and

- Peri-arrest cooling using a rapid intravenous infusion of large-volume (30mL/kg) ice-cold saline (available from the ECMO area refrigerator). This MUST be administered by the ICU Senior Registrar as an IV bolus during and immediately after prolonged CPR to induce therapeutic hypothermia (32-34℃) for neurological protection, and

- Rapid percutaneous canulation using small cannulae (17F arterial, 19F venous) and connection to the pre-primed ECMO machine.

7. ECMO-CPR EQUIPMENT

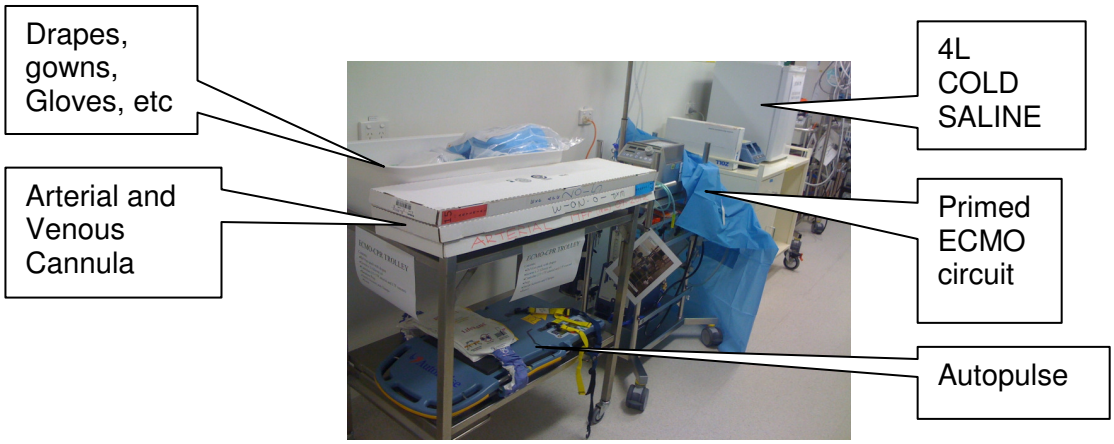
The equipment for ECMO-CPR is held in the ECMO storage area of the ICU (see photo). The key components are:

The “ECMO-CPR trolley”, containing:

- A Devries set (drapes, dishes, instruments)
- 17F and 19F arterial cannulae packs
- 19F venous cannula
- Gowns and gloves (x2)
- Betadine skin prep
- Sterile clamps and scissors

- The Autopulse machine

Photo: ECMO-CPR Equipment



8. ECMO-CPR STAFFING

The key staffing are:

- Two Intensivists who are certified for ECMO cannulation and who are immediately available
- The ICU ECMO Nurse
- A third ICU Consultant or Senior Registrar (experienced in ultrasound) to perform ultrasound of the IVC
- The ICU Senior Registrar on-call for wards to administer cold IV fluid
- In the E&TC, one senior doctor and three nurses

9. ECMO-CPR ACTIVATION

The E&TC

For out-of-hospital cardiac arrest patients, the ambulance service will ring the “Bat-phone” and give approximately 10 minutes warning of the arrival of a cardiac arrest patient (usually on an ambulance Autopulse).

The E&TC nurse answering the telephone will page the ICU Senior Registrar on for wards. The ICU-SR will then have the responsibility of contacting the ICU ECMO-CPR staff including one ECMO nurse and two ICU Consultants who are accredited in ECMO cannulation.

The E&TC nurse also advises the senior E&TC Consultant (or Senior Registrar) of the imminent arrival of a patient with CPR in progress.

The nursing staff prepares a Trauma Bay (preferred) for the reception of the patient.

Hospital wards

At a Code Blue in the ICU, cardiac catheter laboratory or wards, the ICU SR will activate the ECMO-CPR team by telephoning the 2 ICU Consultants on-call AND the ECMO nurse.

10. ECMO-CPR ROLES

In the E&TC, there are 9 staff who each has a specific role:

Emergency Physician (or E&TC Senior Registrar)

- Is the Team Leader for the resuscitation
- Accepts the hand-over from the paramedics
- Supervises the move from the ambulance stretcher to the E&TC bed with Autopulse running
- Commences hand ventilation with 100% oxygen using a bag/valve connected to the ETT
- Does NOT connect the patient to a ventilator until ECMO commences and the Autopulse is switched off

E&TC Nurse 1 ("airway nurse"):

- Assists the Emergency Physician with airway management
- May need to draw up and administer sedation (midazolam 5mg/5ml) and muscle-relaxant (rocuronium 100mg in 10mL) if the patient is spontaneously moving during Autopulse compressions

E&TC Nurse 2 ("circulation nurse")

- Ensures that the pre-hospital IV(s) is patent
- Connects the ambulance defibrillator leads to the ED defibrillator
- Prepares an adrenaline infusion, connects and runs this infusion at 25 microgram/min during Autopulse chest compressions

E&TC Nurse 3 ("scribe")

- Commences documentation

ICU Consultant 1:

- Attends the ECMO area in the ICU and adds the cold saline pack (containing 4L cold saline) from the refrigerator to the ECMO-CPR trolley
- Proceeds to the site of the cardiac arrest with the ECMO-CPR trolley
- Opens the Devries pack and lays out equipment on the trolley, including cannulae
- Scrubs, gowns, preps and drapes
- Cannulates the femoral artery and vein

ICU Consultant 2:

- Proceeds to the site of the arrest with the ultrasound machine (Note: ultrasound machine may be available in ED)
- Gowns and gloves and assists with cannulation and circuit connection

The ICU Senior Registrar

- Administers 40mL/kg ice-saline IV bolus during CPR. This should be administered at >100ml/min
- In the case of ward arrests, delegates this task to another person and then leads the arrest.

ICU Consultant 3/ ICU Senior Registrar 2:

- Proceeds to the site of the arrest
- Images the femoral area with ultrasound and demonstrates the anatomy of the artery and vein prior to draping, then
- Images the IVC to determine correct placement of the venous guide-wire.

The ECMO Nurse:

- Proceeds to the site of the arrest with a pre-primed ECMO circuit
- Monitors the Autopulse machine. In the case of ward arrests, initially arranges the placement of the Autopulse under the patient
- Prepares the ECMO circuit for use
- When cannulae are connected, commences ECMO flow at 3L/min and air flow 3L/min

11. ON-GOING CARDIAC ARREST MANAGEMENT:

The patient on Autopulse must not be connected to a mechanical ventilator but instead be ventilated gently by bag/ valve with 100% oxygen

During cannula insertion, all other procedures and therapies must be delayed, including arterial line placement/ defibrillation/ chest Xray etc.

******DO NOT DEFIBRILLATE DURING ECMO CANNULATION*******

The patient may be fitted with a standard C-spine collar to prevent excessive head movement during Autopulse compressions. This may be removed when on ECMO, unless there has been a significant head strike.

12. COMMENCEMENT OF ECMO-CPR

Cannula insertion:

- The femoral vessels must be imaged with ultrasound
- The femoral artery and vein will be accessed with a needle and the standard guide-wire inserted
- The venous guide wire must be imaged in the IVC and the arterial guide wire must be ascertained as NOT being in the IVC
- A skin incision is required to facilitate dilation
- Smaller ECMO cannulae (17F arterial, 19F venous) are inserted since smaller cannulae are faster and easier to insert, and relatively low ECMO flows (3-4L/minute) only are required during hypothermic arrest
- No femoral artery back-flow cannula is required initially

Commence ECMO perfusion:

Once the cannulae are inserted, the ECMO circuit will be connected and flow will be commenced. The Autopulse will then be switched off.

There is evidence that hyperoxia (pO2 >300mmHg) may be harmful during brain reperfusion after prolonged cardiac arrest. Therefore, the ECMO oxygenator will be suffused with air (if available) at 3-4L/min instead of 100% oxygen at 3-4L/min.

Adequate therapeutic hypothermia (32-34℃) is **imperative** for neurological protection during and after prolonged cardiac arrest. If the temperature is still >34℃ after the 40mL/kg bolus of cold saline and commencement of ECMO, then the heat exchanger will be filled with ice chips/ cold saline, connected to the ECMO oxygenator and the heat-exchanger flow started.

13. MAINTENANCE ON ECMO

Once on ECMO, the subsequent patient management will depend on the clinical setting:

- For patients with presumed cardiac arrest of cardiac cause, transfer to the cardiac catheter laboratory for coronary angiography and possible angioplasty will be required. The Cardiology Registrar on-call should be paged
- For patients with suspected massive pulmonary embolism, consideration should be given to thrombolysis or pulmonary embolectomy
- Patients who have suffered a significant head strike during their collapse should undergo CT brain and C-Spine scanning as soon as possible after stabilisation
- A 5 lumen antibiotic coated central line should be inserted into the right internal jugular vein once the patient is on ECMO, the Autopulse is stopped and the collar has been removed
- Once ECMO flow is established, commence midazolam 1-5mg/ hr IV. Administer a longer acting non-depolarising muscle relaxant (eg rocuronium 50mg IV) for moving/ shivering.
- If the leg with an arterial cannula appears to be ischaemic, then a femoral artery backflow cannula may need to be inserted
- Bladder catheter and naso-pharyngeal temperature probe are inserted and a chest-Xray performed

14. TRANSFER TO THE CARDIAC CATHERISATION LABORATORY

If acute coronary occlusion is suspected, then the patient should be transferred to the cardiac catheterisation laboratory.

The Cardiologist will undertake coronary angiography using the left femoral artery or radial artery approach.

In general, a coronary artery bare-metal stent will be inserted and this will require administration of aspirin, clopidegrel and a heparin infusion.

At the conclusion of coronary angiography, the arterial sheath will be connected to a transducer and this will be used for arterial blood pressure monitoring and arterial blood gas analysis.

15. TRANSFER TO THE INTENSIVE CARE UNIT

After coronary angiography and CT scanning of the brain and C-spine (if head strike), the patient will be transferred to the ICU.

The subsequent treatment follows the usual practice of provision of ECMO and therapeutic hypothermia in the ICU.

Therapeutic Hypothermia

A target temperature of 32.5℃ to 33.5℃ (ideally 33℃) represents the optimal balance between clinical effectiveness and adverse side effects. In addition, at this temperature, there is minimal shivering. This temperature should be maintained for a period of 24 hours post cardiac arrest.

If the patient is on ECMO, the heat exchanger may provide warming but inadequate cooling

Should the core temperature rise to >33.5℃:
- Add the cooling jacket and check that there is cold water flow through the jacket
- Administer further neuromuscular blocking agent as required for shivering

Should the core temperature fall below 32.5℃:
- Switch on ECMO heating circuit
- Check the temperature setting and circulating water temperature on the ECMO circuit

At 24 hours post arrest, rewarm no faster than 3℃ over 12 hours (i.e. 0.25℃ per hour). For this rate of rewarming, set the ECMO heat exchanger or surface temperature control machine temperature to every 4 hours to 1℃ higher than the previous four hours.

Shivering often occurs between 34°C and 35.5°C. This may significantly increase metabolic demand and must be immediately treated with additional muscle relaxant.

Hypotension can occur during rewarming and should be treated immediately with a fluid challenge. If the hypotension continues vasopressor administration may be required. Patients that are particularly unstable may also require the cessation of rewarming until the hypotension has been controlled.

Respiratory:

When cardiac function (and thus pulmonary blood flow) returns, the ventilator must be adjusted to provide arterial blood gases (not corrected for temperature):
- A pO2 of 70-90 mmHg
- A pCO2 of 40mmHg

(Note: These target blood gases require a decrease in minute volume of about 30% i.e. tidal volume of 6ml/kg and a rate of 8/minute should be used as initial settings).

Cardiovascular:

In post-cardiac arrest patients, the systolic blood pressure should be maintained above 100 mmHg if possible. A decreased heart rate (35-50/minute) is a physiological effect of hypothermia and does not require treatment. The electrocardiograph may show prolonged QT interval and Osbourne waves.

If an inotrope is required to increase blood pressure, an adrenaline infusion should be commenced. If the dose exceeds 20mic/min or the lactate level is increasing, then an infusion of noradrenaline should be considered. If a further fluid challenge is required for CVP<12mmHg, infuse a bolus (i.e. 500mL) of 0.9% saline.

If higher ECMO flows are required during and after rewarming, then a second venous cannula should be considered.

Renal/ Electrolytes:

The frequent monitoring and appropriate correction of electrolytes (K+, Mg++, PO4-) is required. In particular, hypokalaemia is usual during cooling, therefore carefully monitor K+ and replacement of potassium to level >4.0 mmol/L is required. During rewarming, the potassium level increases however this generally does not require treatment.

Post cardiac arrest, a mild increase in the creatinine level is common however renal function generally recovers over 48 hours.

Gastrointestinal:

The target feed should be 70% of predicted because of the decreased metabolic rate. Also, gut motility is decreased during hypothermia and high gastric volumes should be expected.

Endocrine:

Hyperglycaemia is common during hypothermia and should be treated according to the usual ICU Insulin infusion protocol.

Calcium infusions are toxic to injured neurones, thus calcium should not be administered to correct asymptomatic hypocalcaemia in patients with neurological injury.

Haemotology

In post cardiac arrest patients on ECMO, full heparinisation should be considered. The APTT should be adjusted as per the usual anticoagulation guideline.

Neurological:

Sedation may be required if there are signs of awakening. However, hypothermia is also sedating therefore modest doses of sedation only should be administered. Options include midazolam/ morphine infusion (maximum 5/5mg/hr) or propofol infusion. The former is preferred if blood pressure is unstable and vasopressors are required.

If shivering occurs despite modest sedation, a longer acting non-depolarising neuromuscular blocking drug (pancuronium 8mg or rocuronium 100mg) should be administered as required.

16. PROGNOSTICATION:

The assessment of neurological recovery after prolonged CPR is generally undertaken at 96 hours (>48 hours after cessation of sedation) and is based largely on the clinical neurological examination. In ECMO-CPR patients, the assessment will follow the standard Alfred ICU pathways

As per usual Alfred ICU policy, organ donation may be considered in patients who meet the criteria for brain death or, if severe neurological injury is diagnosed, then donation after irreversible cessation of circulation (being cessation of ECMO) may be considered.

Diagnosis of brain death:

Brain death may be suspected on the basis of clinical examination of the cranial nerves. However, an apnea test is not possible on ECMO since it is not possible to increase the pCO2 to >60mmHg without concurrent hypoxia. Therefore, a nuclear medicine brain scan should be undertaken if brain death is suspected and organ donation is planned.

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