Extracorporeal Membrane Oxygenation (ECMO)

Extracorporeal membrane oxygenation (ECMO) is used for both cardiac and pulmonary failure when conventional measures (i.e., mechanical ventilation, intraaortic balloon pump) are inadequate to support life. While not treatment for the underlying disease process, ECMO delivers oxygen-rich blood to vital organs, which gives the heart and lungs time to repair. During ECMO, blood is drained from the patient's vascular system and then circulated outside the body by a mechanical pump through an oxygenator and heat exchanger. Carbon dioxide (CO_2) is removed, and oxygen-saturated blood is returned to the body.

At facilities without ECMO capabilities, intentional planning for early transfer to an ECMO center should occur. Prolonged time on mechanical ventilation pre-ECMO is associated with worsening mortality after ECMO (Tonna, 2021).

Types of ECMO

Also known as extracorporeal life support or extracorporeal lung assist, there are two primary types: venovenous (VV) and venoarterial (VA) ECMO. The table below shows a comparison of the two.

Types of ECMO		
	Venovenous (VV) ECMO	**Arteriovenous (AV) ECMO**
Level of support (Manaker, 2023)	• Typically used for patients in respiratory failure; provides respiratory support, but no cardiac/hemodynamic support. • Blood is extracted from the vena cava or right atrium, oxygenated, and returned to the right atrium.	• Typically used for patients in cardiac failure; provides both respiratory and cardiac/hemodynamic support. • Blood is extracted from the right atrium and returned to the arterial system, bypassing the heart and lungs.
Indications (Calhoun, 2018; Manaker, 2023)	• Reversible conditions such as acute respiratory distress syndrome (ARDS), pulmonary infection, severe asthma or COPD exacerbation, or acute pulmonary embolism, causing one or more of the following despite optimal ventilator management: ○ Severe hypoxemic respiratory failure (ratio of arterial oxygen tension to fraction of inspired oxygen [PaO_2/FiO_2] of less than 100 mm Hg) ○ Hypercapnic respiratory failure with an arterial pH less than 7.20	• Inadequate tissue perfusion resulting from a low cardiac output state despite volume resuscitation, inotrope/vasopressor support, and mechanical support if appropriate. Clinical examples include: ○ Decompensating heart failure ○ Mixed cardiopulmonary failure ○ Right ventricular failure ○ Myocarditis ○ Malignant cardiac arrhythmias ○ Cardiac arrest ○ Septic shock • Failure to wean from cardiopulmonary bypass during heart surgery

	○ Persistently elevated lung plateau pressures • Refractory hypoxemia or hypercarbia in a pre-lung transplant patient or primary graft dysfunction post lung transplant	• Bridge to permanent device, such as left ventricular assist device (LVAD) • Bridge to heart transplant
Cannulation (Manaker, 2023)	Major veins are cannulated to drain and return blood to the body. • Right or left common femoral vein (drainage) and right internal jugular vein (return/infusion) • Femoral vein and femoral vein • Bi-cava, double lumen in internal jugular	Major veins (drainage) and arteries (return) are cannulated. • Inferior vena cava or right atrium (drainage) to right femoral artery (return/infusion) • Femoral vein to femoral artery • Right common carotid artery or subclavian may be used, but high risk for cerebral infarction
Blood flow (Manaker, 2023)	Set near-maximum flow rates to optimize oxygen delivery.	Set flow rate high enough to provide adequate perfusion and oxygen saturation, but low enough to provide enough preload to maintain left ventricular output.

Relative Contraindications (Manaker, 2023)

- Uncontrolled bleeding
- Poor prognosis from primary condition

The only absolute contraindication to ECMO is a pre-existing condition that is irrecoverable or incurable, such as severe neurologic injury or end-stage cancer.

Initiation of ECMO Therapy

Once it has been determined that ECMO will be instituted, the patient is anticoagulated, typically with intravenous (IV) heparin. Cannulation of the vessels is performed; the patient is connected to the ECMO device and blood flow is increased until respiratory and hemodynamic targets are met. These targets may include (Manaker, 2023):

- Arterial oxyhemoglobin saturation greater than 90% for VA ECMO, or greater than 75% for VV ECMO
- Venous oxyhemoglobin saturation 20-25% lower than the arterial saturation, measured on the venous line
- Adequate tissue perfusion, as evidenced by arterial blood pressure, venous oxygen saturation, and blood lactate level

Nursing Considerations (Manaker, 2023; Naddour et al., 2019)

- Hemodynamics
    - When the target parameters have been met, blood flow is maintained at the set rate and oxygen status is assessed by continuous venous oximetry.
    - If oxygenation drops below the target range, consider increasing blood flow, intravascular volume, or hemoglobin concentration (Manaker, 2023). Decreasing patient's temperature to reduce oxygen consumption may be beneficial as well.
    - Left ventricular output may worsen with VA ECMO; inotropes (i.e., dobutamine, milrinone) may be used to increase contractility and intra-aortic balloon pump (IABP) will reduce afterload and support left ventricular cardiac output.
    - Monitor central venous pressure and fluid status.
- Anticoagulation and laboratory
    - Maintain anticoagulation with a continuous IV infusion of unfractionated heparin or direct thrombin inhibitor to achieve an activated clotting time (ACT) of 180 to 210 seconds. Reduce the ACT target if bleeding occurs.
    - Monitor platelet counts and maintain level above 50,000/mL.
    - Monitor hemoglobin and maintain level within normal range.
- Ventilator management
    - Adjust ventilator settings to prevent barotrauma, ventilator-induced lung injury, and oxygen toxicity. Typical ventilator settings are FiO_2 less than 50%, positive end expiratory pressure (PEEP) at 5 cm H_2O, tidal volume at 4 mL/kg, respiratory rate at 2 to 5 breaths per minute, and plateau pressure maintained less than 20 cm H_2O (Manaker, 2023; Naddour et al., 2019).
    - Perform strict pulmonary hygiene to prevent ventilator-associated pneumonia.
- Renal management
    - Diuretics are often administered to reduce fluid overload.
    - Ultrafiltration can be added to the ECMO circuit if patients are not able to produce enough urine for diuresis.
    - Oliguric and polyuric phases of acute tubular necrosis are common on ECMO, and continuous renal replacement therapy (CRRT) may be required.
- Monitor for signs of infection and poor perfusion such as increased lactic acid level, metabolic acidosis, decreased urine output and increased liver enzymes.
- Assess for lower limb ischemia: check dorsalis pedis and posterior tibial pulses and assess for coolness or mottling of feet.
- Use RASS (Richmond Agitation-Sedation Scale) scoring to titrate sedating medications to promote adequate analgesia, maintain ventilator synchrony and prevent agitation (Dreucean et al., 2022).
- Conduct daily wakeup and hourly pupil checks to monitor neurological status.
- Practice diligent patient repositioning to prevent skin breakdown.
- Staffing considerations (O'Connor & Smith, 2018):
    - ECMO is usually delivered in an intensive care unit setting.
    - Staffing models will vary from facility to facility based on staffing experience and ECMO patient volumes; some centers require two staff per one ECMO patient.

  - Pediatric/neonatal patients on ECMO are typically managed by an ECMO specialist. These specialists may include:
    - Registered nurse (RN)
    - Registered respiratory therapist (RRT)
    - Clinical perfusionist
    - Physician with advanced training in ECMO
  - An alternative staffing model may include a core team of RNs and RRTs within ECMO centers who develop expertise in caring for complex patients.
  - Specialized training will include:
    - Management of the ECMO circuit such as priming the circuit for cannulation and titration of blood flow and sweep gas flow
    - Coordination of fluid, blood, and sedation management

Complications (Manaker, 2023; Naddour et al., 2019)

There are several common complications from ECMO therapy that are associated with significant morbidity and mortality.

- Bleeding
  - Due to anticoagulation and platelet dysfunction
  - Can occur at multiple sites such as insertion site, surgical site, intra-abdominally, and intracranially
- Thromboembolism
  - Blood clot formation in membrane oxygenator and tubing connections; monitor for changes in the circuit such as dark or white areas around the gas exchange device; a primed replacement circuit should be readily available at the bedside
  - Pulmonary embolism
  - Deep vein thrombosis
- Hemolysis
  - Hemolysis is the destruction of RBCs leading to the release of hemoglobin found within RBCs into the plasma, causing anemia, renal injury and multiorgan failure
  - Monitor urine output and urine color (pink tinged urine is an early sign of hemolysis)
  - Monitor labs including CBC and LDH
- Heparin-induced thrombocytopenia (HIT) – replace heparin with a non-heparin anticoagulant, such as argatroban.
- Cannulation-related complications
  - Vessel perforation with hemorrhage
  - Arterial dissection
  - Limb ischemia
  - Incorrect location (i.e., venous cannula located within the artery)
  - Venous cannulas too close causing recirculation of blood
- Mechanical complications
  - Oxygenator failure
  - Pump failure
- Neurologic complications

  - Stroke, seizures and intracranial hemorrhage occur in up to 10% of patients on ECMO (Bergeron, 2020).
  - Perform frequent neurologic assessments and notify the provider of any changes.
- VA ECMO-specific complications
  - Pulmonary hemorrhage
  - Cardiac thrombosis
  - Coronary or cerebral hypoxia

Weaning from ECMO (Manaker, 2023)

Before weaning from ECMO can begin, several criteria should be met. For patients with respiratory failure, monitor for improvement in chest X-ray appearance, pulmonary compliance, and arterial oxyhemoglobin saturation. In patients with cardiac failure, assess for improved left ventricular output. A transthoracic echocardiogram may be performed to evaluate heart function. Trials should be performed before discontinuing ECMO permanently. When the patient is ready, stop the heparin drip 30 to 60 minutes before the cannulas are removed. Following cannula removal, apply pressure to the insertion sites. For VA ECMO, compression should be applied to the arterial site for a minimum of thirty minutes.

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