Extracorporeal membrane oxygenation: A review

By Ashley Trinsey, MSN, RN, CCRN, ACCNS-AG

Abstract: Extracorporeal membrane oxygenation (ECMO) is a mechanical circulatory support device that is used when the heart and/or lung functions are affected by severe disease or organ dysfunction. ECMO therapy provides temporary, lifesaving support to the body until surgical intervention or other permanent treatments can be provided. This article reviews the two main types of ECMO therapy along with therapeutic indications, function, and how to manage critically ill adult patients using ECMO.

Keywords: acute respiratory distress syndrome, ARDS, cardiogenic shock, ECMO, extracorporeal membrane oxygenation, life support, mechanical circulatory support, oxygenation

Extracorporeal membrane oxygenation (ECMO) is a device that provides cardiac and/or respiratory support to patients with severely impaired heart and lung function. ECMO is a form of cardiopulmonary bypass (CPB) that is used as a bridge to organ recovery, transplantation, or further mechanical circulatory support such as a ventricular assist device. ECMO is most commonly used in an urgent or emergent setting when other interventions have been unsuccessful.

ECMO therapy is not often seen in community hospital settings because of the complexity of the device and patient acuity. Patients are often referred to tertiary academic medical centers for advanced interventions prior to ECMO or specifically for ECMO support. Because of the specialized experience and expertise required to manage this patient population, the majority of nurses and other medical disciplines are rarely exposed to ECMO.

With the increase of referrals for ECMO therapy, a knowledge gap has been identified among healthcare personnel who do not primarily care for this complex patient population. Often, this knowledge gap is related to simply not knowing what ECMO is, how it functions, and/or how it may
improve patient outcomes in certain clinical conditions. Increasing awareness and knowledge of ECMO therapy among nurses and other medical professionals will help them understand the importance of early ECMO therapy and how it could help their patients.

**Background**

CPB is used in the OR during cardiac surgical cases as mechanical circulatory and oxygenation support for organ preservation. Modern-day CPB was introduced in the 1950s, and the development of adult ECMO support for respiratory distress began in the 1970s. ECMO therapy is often associated with poor outcomes and survival rates; however, in recent years, improved technology and patient management have shown that ECMO therapy is beneficial in adult patients with cardiac failure and acute respiratory distress syndrome (ARDS).

ECMO therapy can provide cardiac and/or respiratory support to patients with severely diseased hearts and/or lungs. ECMO has the ability to pump blood when heart function is decreased and can also provide increased oxygen support and carbon dioxide removal when the lungs are compromised and traditional mechanical ventilation is unsuccessful.

**Device**

The ECMO pump is controlled by a console and runs in rotations per minute to provide blood flow through the patient’s system (see ECMO device). In order to perform ECMO therapy, two vascular accesses must be obtained (see Configuration of ECMO support). The ECMO pump removes blood from the body via one access point; the blood flows through the centrifugal pump portion of the device, then on to the “oxygenator” component of the device. The oxygenator contains fibrous material encapsulated in plastic that has the ability to provide oxygen and remove carbon dioxide when regulated by an oxygen and medical air blender and oxygen flow meter. This component has the ability to provide oxygen and reduce carbon dioxide, similar to a mechanical ventilator. Once the blood has passed through both major components of the system, it is returned to the body via the other vascular access site. A heater is applied to the ECMO circuit to maintain normothermia, as the extracorporeal removal of the blood will reduce the patient’s body temperature.

The type of ECMO support needed will determine the settings for each component of the ECMO system and where the vascular access points are established. The managing physician, usually a cardiac anesthesiologist or cardiac surgeon, will determine the type of access needed and individual goals for blood flow and oxygenation.

**Types of ECMO therapy**

There are two main types of ECMO therapy: venoarterial ECMO (V-A ECMO) and veno-venous ECMO (V-V ECMO). Simply put, V-A ECMO provides cardiac and respiratory support while V-V ECMO provides primarily respiratory support to the body.

The primary function of V-A ECMO is to provide oxygen and carbon dioxide gas exchange as well as circulatory and hemodynamic support. In V-A ECMO, vascular access is obtained by the placement of a large cannula in a large central vein such as the...
Configuration of ECMO support

(A) Veno-venous (V-V) ECMO. Extracorporeal gas exchange occurs in venous blood, which is then returned to the venous circulation. V-V ECMO provides no direct hemodynamic support. (B) Veno-arterial (V-A) ECMO. Venous blood is actively pumped into the system circulation, effectively bypassing the cardiorespiratory system. V-A ECMO is partial CPB.

V-V ECMO therapy can also be delivered using a bicaval cannulation technique. Using a specially designed cannula, vascular access can be obtained in one area instead of two. The cannula has two lumens that can pull blood from the inferior and superior vena cava to be delivered from the body to the pump and returned back to the body into the right atrium. Bicaval V-V ECMO cannulation can provide increased mobility in the awake patient. For this procedure, minimal sedation and analgesia are used for comfort and pain management; the goal is for the patient to be fully awake and oriented shortly after the procedure. Both types of V-V ECMO cannulation only allow for minimal ventilatory support and organ rest for the lungs.

Assessment

Clinical conditions, indications, and contraindications can vary from one institution to another. The Extracorporeal Life Support Organization provides indications and contraindications related to ECMO therapy based on current research and outcomes. It is best to separate V-A and V-V ECMO when presenting indications because their functions and clinical conditions differ. The clinical condition of the patient at consultation for ECMO therapy is important in
determining the type of ECMO therapy needed and the anticipated outcome or goal of therapy. [See Clinical conditions and indications in adults for ECMO by type.]

All potential contraindications to ECMO therapy should be discussed with the patient (if awake) and family and consent should be obtained prior to initiation. Contraindications may also vary from one ECMO provider or institution to another.

Contraindications to ECMO therapy may be relative and dependent on the patient’s current clinical condition, comorbidities, and past medical history. They may also be absolute, meaning ECMO therapy is not considered beneficial in patients with certain clinical conditions. [See Contraindications in adults to ECMO by type.] Again, contraindications are separated by type of ECMO therapy because the type of therapy and its indications differ.

Treatment

The ultimate goal of ECMO therapy is to promote organ recovery or function as a bridge to transplantation/implanted circulatory support. The goals of care and long-term outcomes should be discussed with the interdisciplinary team when considering a patient for ECMO therapy because it may not be the appropriate therapy in all clinical situations. Providers should discuss relative and absolute contraindications and consult an ECMO provider to determine the benefits and outcomes ECMO may provide. [See Key points for referral to an ECMO institution.]

As discussed, the goals of ECMO therapy include bridge to transplantation, implanted mechanical circulatory support, and organ recovery. Organ transplantation includes primarily heart and/or lung transplantation, but may include other organs such as the kidneys or liver.

Implanted mechanical circulatory support generally refers to ventricular assist devices to optimize heart function and quality of life, or provide a bridge to transplantation at a later date.

A goal of organ recovery would mean that ECMO support will eventually be weaned and removed. This process may vary based on the institution, but in general ECMO support is reduced to assess organ function. For V-V ECMO, the amount of oxygen or FiO2 provided by the therapy is reduced to allow the patient’s lungs to control oxygenation and carbon dioxide management. Success is measured by adequate tissue oxygenation. For V-A ECMO, the amount of blood flow the therapy is providing is limited to allow the patient’s heart to pump blood throughout the body. Success of V-A ECMO weaning is measured by the patient’s ejection fraction via echocardiography.

Patient management

Patient management during ECMO therapy is multidisciplinary because of the complex clinical condition of the patient. The multidisciplinary team includes surgical and intensivist providers who play a large role in the day-to-day management of the patient receiving ECMO therapy along with critical care nurses, respiratory therapists, perfusionists, pharmacists, dietitians, physical and occupational therapists, and palliative care providers.

### Clinical conditions and indications in adults for ECMO by type

<table>
<thead>
<tr>
<th>V-A ECMO</th>
<th>V-V ECMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cardiogenic shock</td>
<td>• ARDS (pneumonia, aspiration)</td>
</tr>
<tr>
<td>• Acute coronary syndrome</td>
<td>• Respiratory failure (as a bridge to recovery or lung transplantation)</td>
</tr>
<tr>
<td>• Myocarditis</td>
<td>• Primary graft dysfunction after lung transplantation</td>
</tr>
<tr>
<td>• Failure to wean from CPB</td>
<td>• Pulmonary embolism</td>
</tr>
<tr>
<td>• Intractable dysrhythm</td>
<td>• Traumatic lung injury (contusion, airway obstruction, smoke inhalation)</td>
</tr>
<tr>
<td>• Postcardiac arrest</td>
<td></td>
</tr>
<tr>
<td>• Pulmonary hypertension</td>
<td></td>
</tr>
<tr>
<td>• Cardiomyopathy (as a bridge to further mechanical support, organ recovery, or transplantation)</td>
<td></td>
</tr>
<tr>
<td>• Primary graft dysfunction after heart transplantation</td>
<td></td>
</tr>
<tr>
<td>• Conditions causing cardiac depression (drug toxicity, sepsis)</td>
<td></td>
</tr>
<tr>
<td>• Traumatic cardiac injury</td>
<td></td>
</tr>
</tbody>
</table>
### Contraindications in adults for ECMO by type\(^1,4,5,8\)

<table>
<thead>
<tr>
<th>Type</th>
<th>V-A ECMO</th>
<th>V-V ECMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative</td>
<td>• Organ dysfunction</td>
<td>• Mechanical ventilation at high settings</td>
</tr>
<tr>
<td></td>
<td>• Advanced age</td>
<td>• Advanced age</td>
</tr>
<tr>
<td></td>
<td>• Prolonged mechanical ventilation</td>
<td>• Prolonged mechanical ventilation</td>
</tr>
<tr>
<td></td>
<td>• Obesity</td>
<td>• Obesity</td>
</tr>
<tr>
<td></td>
<td>• Peripheral vascular disease (may present challenges with obtaining vascular access for ECMO cannulation)</td>
<td>• Peripheral vascular disease (may present challenges with obtaining vascular access for ECMO cannulation)</td>
</tr>
<tr>
<td>Absolute</td>
<td>• Unlikely organ recovery and not a candidate for transplant or implantable mechanical circulatory support</td>
<td>• Unlikely organ recovery and not a candidate for transplant</td>
</tr>
<tr>
<td></td>
<td>• Multiorgan failure</td>
<td>• Multiorgan failure</td>
</tr>
<tr>
<td></td>
<td>• Prolonged cardiopulmonary resuscitation</td>
<td>• Malignancy (advanced or metastatic disease)</td>
</tr>
<tr>
<td></td>
<td>• Malignancy (advanced or metastatic disease)</td>
<td>• Severe brain injury</td>
</tr>
<tr>
<td></td>
<td>• Severe brain injury</td>
<td>• Severe aortic regurgitation</td>
</tr>
</tbody>
</table>

The palliative care provider is commonly involved early in the care of patients receiving ECMO therapy because of their critical condition and plays a pivotal role. Because these patients are critically ill for an extended period of time, palliative care providers provide the psychosocial and emotional support for the families of these patients as well as the patient themselves (if they are able to participate). The palliative care team assists with medication management to optimize quality of life. Palliative care providers may also play a key role in facilitating goals-of-care conversations with patients and families during clinical condition changes.

Specific pharmacologic management includes anticoagulation therapy to prevent clot formation in the ECMO system. Sedation management is important initially to promote organ recovery. Once the patient is hemodynamically stable, sedation and analgesia medications may be weaned as tolerated. Vasopressor support is often needed at the initiation of ECMO therapy. Patients receiving V-A ECMO therapy are often on inotropic and vasopressor support prior to the initiation of ECMO.

In patients on either V-A or V-V ECMO, once a patient is hemodynamically stable, nutritional support is provided and vasopressors and sedation are weaned. Physical and occupational therapy is also provided once the patient is able to participate.

Initial ventilatory support is dependent on the type of ECMO a patient requires. In both V-A and V-V ECMO, 100% oxygen is provided through the ECMO device. Oxygen titration and carbon dioxide removal are managed by titrating the oxygen flow and medical air provided to the oxygenator. The use of a ventilator for patients with ECMO is generally to support mechanical function of the lungs with minimal oxygen support.\(^7,9\) Ventilatory support is weaned as tolerated by the patient.

Goals for ventilatory support are specific to the patient, the type of ECMO therapy, and the goals of therapy (organ recovery versus organ transplantation, for example). In V-A ECMO, patients often remain intubated and on ventilator support until weaned from ECMO therapy. The ventilator is weaned to the minimal support tolerated by the patient.\(^1\) For patients on V-V ECMO, the ventilator is often weaned at a quicker rate to achieve extubation.\(^7,9,10\) If the V-V ECMO patient's goals are lung recovery, low-stretch ventilator settings initially may be used to promote organ rest while maintaining mechanical function.\(^7,9,11-13\)

### Nursing considerations

Nursing management includes optimization of pharmacologic support with collaboration from providers and the pharmacist. Infection and pressure injury prevention are key interventions provided by nursing staff caring for these patients. Patients receiving ECMO therapy are most commonly placed in a 1:1 nursing assignment; at times, 2:1 nurse-to-patient

---

[1] www.nursingcriticalcare.com
ratios are required with the increased acuity of these patients. Patients receiving ECMO therapy are usually managed in a cardiothoracic ICU; however, this is specific to the ECMO center. Depending on the institution, perfusionists or specially trained ECMO technicians remain at the bedside. Some institutions have developed nurse-run ECMO programs where nurses are specially trained to care for patients receiving ECMO therapy and manage the ECMO system on a daily basis and during clinical emergencies. The time limitations for ECMO therapy are patient-dependent and dependent on the goals of therapy.

A key consideration for this patient population is the impact of working with patients and families. The high-acuity patient receiving ECMO is a psychosocial and emotional challenge to manage. Patients often remain on ECMO therapy and in the ICU for an extended period of time; nurses may develop a close supportive relationship with these patients and their families. A palliative care team can provide critical resources and emotional support for the interdisciplinary staff as needed.

Complications
Due to the acuity and nature of ECMO therapy, the risk of potential complications is high. Common complications include bleeding and embolic events; infection, sepsis, and multiorgan failure; pressure injuries related to skin integrity from immobility; and organ or tissue malperfusion.1,8 Regular and frequent assessments by the healthcare team are key to preventing any potential complications in patients receiving ECMO therapy.

Bleeding occurs because of the large-bore vascular access required for the ECMO system as well as necessary anticoagulation therapy required to prevent clot formation throughout the system. Thromboembolism is also seen in patients receiving ECMO therapy.1,4,5,8 Clot formation in the ECMO system can pose a potential risk for an embolic event elsewhere in the body.

Infection is another major complication for patients receiving ECMO therapy. This is a result of the large-bore vascular access required to perform it and the proximity of the access to areas of potential increased infection (femoral access, for example). Infection prevention in patients receiving ECMO therapy is important to patient survival. Sepsis is a common complication, and it may cause organ dysfunction and multiorgan failure, which can lead to death. Following the guidelines recommended by the Surviving Sepsis Campaign can help to identify and treat sepsis early in patients receiving ECMO therapy.14,15

Pressure injuries to the skin are prevented as much as possible through frequent turning and repositioning.16 Patients who are hemodynamically unstable may be too unstable to reposition or turn. Additional nursing considerations such as specialty surfaces and therapies for patient beds, including rotation therapy and weight pressure redistribution, can aid in the prevention of skin breakdown. These efforts may also include repositioning devices such as wedge pillows, fluidized positioners, and heel offloading devices.16

Organ or tissue malperfusion can be caused by cannula placement during ECMO therapy or pre-existing organ dysfunction. Frequent neurovascular assessments of limbs below cannulation sites will help prevent tissue and limb malperfusion. If tissue and/or limb malperfusion are identified early, ECMO cannulation sites can be revised or relocated to a different location to improve peripheral circulation.

Improving outcomes
Outcomes are continuing to improve with research, advances in technology, and patient management.
Early intervention with ECMO therapy has been shown to improve patient outcomes as well. Based on reports provided by the Extracorporeal Life Support Organization, 71% of patients receiving ECMO therapy were weaned from therapy, and 59% of all patients receiving ECMO therapy are eventually discharged or transferred for further rehabilitation.4,5

Outcomes can be impacted by the patient's health and functional status prior to the need for ECMO therapy along with the condition requiring ECMO support. It also may vary depending on the goals and duration of therapy.

**Conclusion**

ECMO therapy is a continually evolving option that can provide life support to patients with severely diseased hearts and lungs. ECMO is an alternative treatment for patients whose condition has failed to improve using traditional cardiac and respiratory therapies. Care of patients receiving ECMO therapy is limited to medical centers with the appropriate resources. While patients are frequently referred to these centers for care, nurses and other healthcare professionals are not often exposed to ECMO therapy and may not understand its function and goals. With proper understanding, nurses can advocate for their patients earlier and promote the potential benefits of ECMO therapy.

---

**REFERENCES**


Ashley Trinsky is a full-time Clinical Nurse Specialist in the Heart and Vascular Intensive Care Unit at the Hospital of the University of Pennsylvania, Philadelphia, PA.

The author has disclosed that she has no financial relationships related to this article.

DOI: 10.1097/0.CCM.0000528427/5d942a2

---

**Call for manuscripts**

Wherever you care for patients, *Nursing2017 Critical Care* will provide you with the very latest practical, clinical, and professional information. But we can't do it without your help!

We are seeking submissions from qualified nurses writing on topics relevant to acute and critical care. Our editors are ready to guide you through the process!

For more information, e-mail nursingcriticalcare@wolterskluwer.com.

---

www.nursingcriticalcare.com

July | *Nursing2017 Critical Care* | 23