HHS Public Access
Author manuscript
Crit Care Nurse. Author manuscript; available in PMC 2020 August 01.

Published in final edited form as:
Crit Care Nurse. 2020 June 01; 40(3): 49–57. doi:10.4037/ccn2020918.

Extracorporeal Membrane Oxygenation (ECMO) as a Bridge to Lung Transplantation: Considerations for Critical Care Nursing Practice

Brittany Koons, PhD, RN [Postdoctoral Research Fellow],
Work address: NewCourtland Center for Transitions and Health, University of Pennsylvania School of Nursing, 3615 Chestnut Street, Room 327, Philadelphia, PA 19104, Home address: 4007 N Warner Road, Lafayette Hill, pa 19444

Jennifer Siebert, MSN, RN CCRN [Doctoral Student]
Robert Wood Johnson Foundation Future of Nursing Scholar, Work address: Villanova University, 800 Lancaster Avenue, Villanova, Pa 19085, Home address: 1104 Clark Road, Wyndmoor19038, Pa

Introduction

Lung transplant is increasingly used as a treatment option for end-stage lung disease. The demand for lung transplantation is increasing, but the number of donor lungs is limited. Candidates waiting for lung transplant are sicker now than ever before. Due to the shortage of donor lungs and progression of disease, waitlist mortality rate is high, about 15.1 deaths per 100 patients waitlisted.[1] Extracorporeal membrane oxygenation (ECMO) is an advanced support device increasingly used in patients suffering from heart and/or lung failure. The use of ECMO in patients waiting for lung transplant represents a small but growing portion of the total ECMO patient population. The proportion of patients requiring ECMO as a bridge to lung transplant increased from 3.4% in 2012 to 5.2% in 2017.[1] In the past few years, extracorporeal membrane oxygenation (ECMO) has become a critically important strategy to bridge patients to lung transplantation. Outcomes for patients bridged with ECMO to lung transplantation appear to be improving. The 1-year survival rate for patients who were bridged with ECMO to lung transplantation significantly improved from 25% (2000–2002) to 74.4% (2009 to 2011).[2] There is some evidence that survival rates for patients bridged with ECMO to transplant at high-volume centers are somewhat comparable to non-bridged patients.[3] This improvement may be attributed to improvements in ECMO technology and health care provider training.[4]

Patients who require ECMO as a bridge to transplantation require interdisciplinary care, including attending doctors, surgeons, fellows, nurses, nurse practitioners, physician assistants, and pharmacists from both the intensive care unit and transplant teams, and also physical therapist, social workers, and palliative care specialist. Many ECMO programs,

Correspondence to: Brittany Koons.
No financial disclosures.

both in the U.S. and internationally, are nurse-driven. Under the nurse-driven ECMO care model, nurses are responsible for the clinical needs of the patient, support needs of the family, and the bedside management of the ECMO circuit.[5] This is in contrast to the traditional perfusion-driven care model, in which a perfusionist is present at the bedside to manage the ECMO circuit and the nurse is at the bedside to care for the patient. A recent single center study reported a significant annual cost savings of $366,264 with implementation of a nurse-driven ECMO care model, compared with a perfusion-driven ECMO model, with no differences in patient outcomes.[5] Given the increasing practice of bridging patients with ECMO to lung transplantation and the increasing demands placed on nursing to manage both the patient and the ECMO circuit, it is imperative that nurses have a clear understanding of the unique and technologically complex critical care needs of this patient population.

This review provides critical care nurses with the foundational knowledge essential for delivering quality care to this high acuity patient population who require ECMO as a bridge to lung transplant. This review describes the differences between veno-venous (VV) ECMO and veno-arterial (VA) ECMO, and provides an overview of the indications and contraindications for ECMO. Lastly, the role of clinical bedside nurses in the team-based management of pre-transplant candidates requiring ECMO will be discussed. This review fills a critical gap in knowledge to promote expertise among nurses who care for transplant candidates requiring ECMO as a bridge to lung transplant.

Components of an ECMO Circuit

ECMO is a supportive therapy for patients with severe respiratory failure, cardiac failure, or a combination of both. It was derived from cardiopulmonary bypass and created to be a longer-term supportive therapy that can be managed in the intensive care unit.[6] It is a non-pulsatile device that uses a blood pump and an oxygenator to support circulation, oxygen (O_2) perfusion, and the removal of carbon dioxide (CO_2). There are two basic types of blood pumps, a roller pump and the more commonly used centrifugal pump. The centrifugal pump generates a pressure differential across the pump head via centrifugal force, resulting in negative pressure in the drainage tubing and subsequent blood flow. [7] Blood flow through the pump is sensitive to preload, afterload, and revolutions per minute (RPM). Inadequate preload, resulting from hypovolemia or a mechanical obstruction, such as a kink in the venous cannula, will result in decreased ECMO flows. An increase in afterload can also result in decreased ECMO flows. Increased afterload may result from post-pump obstruction, such as a thrombus in oxygenator or kinks in the arterial cannula, or excessive systemic vascular resistance or mean arterial pressures.[8] A decrease in the RPMs will also decrease the blood flow through the ECMO circuit while an increase in RPMs should increase the blood flow through the ECMO circuit, if not limited by inadequate preload or increased afterload. RPMs can be adjusted with the knob on the pump control console. The pump control console also displays the ECMO flow rate.

Blood pumped through the centrifugal pump is delivered to the oxygenator, a hollow fiber membrane where gas exchange occurs. Oxygen uptake and CO_2 removal depend on the presence of a diffusion gradient and the available surface of the semipermeable O_2

membrane. Fresh gas is delivered to the O_2 membrane, the patient's blood is exposed to the surface membrane, and diffusion occurs. The nurse can adjust the percent oxygen delivered to the oxygenator membrane by adjusting the knob on the gas blender; oxygen delivery can be as low as 21% FiO2 or as high as 100% FiO2. Also, increasing the blood flow through the oxygenator will exposure more of the patient's blood to the surface of the membrane, allowing for greater oxygenation to occur. In contrast, CO_2 elimination is dependent on sweep gas flow rate, a gas flow rate in liters per minute through the oxygen membrane. A flowmeter, which the nurse can adjust, regulates gas flow to the membrane. An increase in the sweep gas flow rate results in a decreased concentration of CO_2 in the fresh gas that is delivered to the membrane, therfore increasing the diffusion gradient and promoting more CO_2 removal from the patient's blood. Alternatively, a decrease in the sweep gas flow rate results in increased concentration of CO_2 in the fresh gas that is delivered to the membrane, therefore decreasing the diffusion gradient and reducing the amount of CO_2 removed from the patient's blood. [8] Oxygenated blood is then returned to the patient via the return cannula.

Types of ECMO and Cannulation Strategies

VV ECMO is used to bridge patients with hypercapnia and/or hypoxemia, despite maximal ventilatory support, and who are without significant hemodynamic compromise.[9] VV ECMO works by removing blood from a vein, circulating blood through the ECMO circuit, where O_2 is delivered and CO_2 is removed, and returns blood to the venous system.[10] There are several VV ECMO cannulation strategies that health care providers need to consider when supporting a patient on ECMO. The traditional cannulation configurations for VV ECMO include femoral-femoral and femoral-jugular cannulation. VV ECMO via a femoral-femoral configuration withdrawals blood from the inferior vena cava (IVC), via a femoral cannula, and returns oxygenated blood to the right atrium, via a femoral cannula. VV ECMO via the femoral-jugular configuration withdrawals blood from the IVC, via the femoral vein, and returns oxygenated blood to the right atrium, via the internal jugular vein. Patients with severe hypoxemia who require >5 liters/min of flow to maintain adequate O_2 levels are best suited for femoral-femoral or femoral-jugular configuration. There are risks associated with these configurations that need to be considered.[9] There is a risk for recirculation, a phenomenon that occurs when the two cannulas migrate too closely to one another, causing oxygenated blood to be withdrawn through the drainage cannula without passing through systemic circulation.[11] Also a disadvantage, these configurations restrict the patient's mobility to bedrest, which is not optimal for patients' pre-transplant functional status.

The preferred VV ECMO approach is a bicaval dual-lumen catheter. This catheter has a single cannula inserted in the jugular vein or subclavian vein under guidance of an echocardiogram or fluoroscopy.[9] The bicaval catheter has three ports: the distal and proximal ports withdraw blood from the IVC and superior vena cava (SVC) and oxygenated blood is returned to the patient via the middle port which rests in the right atrium and directs oxygenated blood towards the tricuspid valve.[4] Advantages of this cannula include a decreased risk for bleeding as only one vessel is punctured, and affords greater patient mobility. This cannula has lower flow rates than the femoral-femoral and femoral-jugular configurations; and therefore primarily used in patients who require CO_2 removal versus patients with severe hypoxemia who require greater flow rates.[9]

For VV ECMO to be effective, patients must have normal right and left sided heart function. Some lung transplant candidates have severe pulmonary hypertension and subsequent compromised right sided heart function that cannot overcome the increased pulmonary pressure.[12] In cases of severe pulmonary hypertension, VA ECMO is the preferred bridging strategy.[4] VA ECMO draws blood from the venous system and returns oxygenated blood to the arterial system, thus fulfilling two functions, gas exchange and circulation.[13] Patients requiring VA ECMO are cannulated either peripherally or centrally. Peripheral VA ECMO cannulas are inserted in the femoral vein and femoral artery or through the femoral artery and internal jugular vein. These cannulation strategies deliver oxygenated blood to the aorta via the femoral artery using retrograde perfusion. Peripheral VA ECMO cannulation can also be achieved through the axillary artery and internal jugular vein. Peripheral VA ECMO via the femoral artery is the easiest approach, but patients cannulated in this manner cannot ambulate, and are at risk for lower limb ischemia because the large cannula placed in the femoral artery can occlude blood flow. Patients cannulated via the axillary artery and the internal jugular vein are better able to ambulate than femoral cannulation, but there is a greater risk for upper extremity ischemia. Additionally, placement of the axillary and internal jugular vein cannulas are more challenging to place than the femoral approach.[4]

Central VA ECMO cannulation requires opening the mediastinum to cannulate the right atrium and the aorta. There are benefits and disadvantages of this cannulation strategy. Patients centrally cannulated are able to ambulate if tolerated, and carry less risk for peripheral ischemia. Use of the central VA ECMO cannulation strategy can support higher ECMO flows allowing for greater cardiac support and oxygenation. However, central cannulation carries higher risks for surgical site infections and scarring at the sternotomy site. In addition, central cannulation requires opening the mediastinum which can lead to profuse bleeding.[4] Health care professionals must consider these clinical factors, and weigh the risks and benefits associated with different cannulation configurations when deciding how to best manage patients requiring ECMO as a bridge to lung transplant.

Candidate Selection

No absolute contraindications to ECMO have been formally established. Patients are evaluated on a case-by-case basis in respect to risks versus potential benefits. However, the Extracorporeal Life Support Organization (ELSO) has identified conditions to be considered as relative contraindications due to their association with poor outcomes despite ECMO support. These include conditions that are incompatible with life and pre-existing conditions effecting the patient’s quality of life such as: severe brain injury and end-stage malignancy. In addition, mechanical ventilation >7 days or prolonged cardiac arrest are also considered relative contraindications. Relative contraindications also include advanced age, recent or expanding hemorrhaging, and patients who cannot be anticoagulated while on ECMO.[14] Health conditions such as peripheral vascular disease, aortic insufficiency, and aortic aneurysm are also relative contraindications because these vascular complications decrease the efficacy of ECMO.[15,16]

Additional factors to consider in the bridge to transplant decision-making process include patients’ nutritional status, presence of an active infection, multi-system organ failure, the patients' functional status, their ability to participate in rehabilitation while on ECMO, and the patients' anticipated time on the waitlist.[4,10] Identifying candidates who may benefit from this supportive bridging strategy is a challenging and complex responsibility of health care providers. Future research is needed to better identify candidates who benefit most from pre-transplant ECMO support as these findings may contribute to the development of patient selection guidelines.

Nursing Practice in Caring for Patients Bridged with ECMO to Lung Transplant

Neurological Considerations

Patients requiring ECMO often require analgesia and sedation for comfort and to reduce oxygen consumption and facilitate ventilator synchrony. Achieving an optimal level of sedation can be challenging. There is growing evidence that changes in pharmacokinetics and pharmacodynamics for some drugs, such as analgesics and sedation, occur in the presence of an ECMO circuit, further complicating analgesic and sedation management in this patient population.[17] This area of research is in its infancy and guidelines based on this evidence have not been established.

Candidates who are bridged with ECMO to lung transplant should be weaned off sedation as tolerated so that they are awake and active participants in their pre-transplant rehabilitation. Candidates who are active participates in their physical therapy and who maintain a good functional status prior to transplant experience better post-transplant outcomes.[4,10] Nurses are on the frontlines of care and able to determine the patient's ability to be weaned off sedation. If hemodynamic stability is compromised, or the patient becomes asynchronous with the ventilator, continued sedation and analgesics may be warranted. If the patient remains sedated, the nurse should check the patient's neurological status at least every four hours due to the increased risk for stroke experienced by patients supported with ECMO. However, nursing practice related to the frequency of neurological checks varies from hospital to hospital, but should be performed at least every four hours, and more frequently if there is a neurological concern.

North-south syndrome is a serious complication of peripheral VA ECMO that can lead to coronary and cerebral ischemia.[18] Peripheral VA ECMO delivers oxygenated blood to the aorta and the great vessels which supply oxygenated blood to the brain, neck, thorax, and upper limbs. This method of delivering oxygenated blood is called retrograde perfusion. Retrograde perfusion competes with native ante-grade circulation. If the heart starts to recover and contract more forcibly, native deoxygenated blood is ejected from the heart to the aorta and mixes with the oxygenated blood delivered from the ECMO circuit to the aorta resulting in hypoxic blood. This complication is called north-south syndrome. Cerebral hypoxia may occur when hypoxic blood circulates to the upper body and the brain via the great vessels. To monitor for this complication, nurses draw arterial blood gases from the right radial arterial line to acquire the most accurate reading of blood oxygenation to the heart and brain. A deceased O_2 level on the right radial arterial line is indicative of north-south syndrome. Given the importance of the right radial arterial line in detecting this serious complication, nurses should advocate that all patients on peripheral VA ECMO have a right radial arterial line. Nurses should also ensure that patients have a pulse oximetry probe placed on their right hand to monitor the O_2 levels delivered to the upper body.[19] Treatment for north-south syndrome includes increasing ECMO flows and increasing the FiO_2 on the ventilator. The team should also consider transitioning the patient to VV ECMO or de-cannulate from VA ECMO if tolerated. In conclusion, nurses play a vital role in managing both the patient and the ECMO circuit. Nurses are the first to detect complications that require intervention, such as the need for sedation, changes in neurological status, and presentation of north-south syndrome.

Oxygenation and Ventilation

A major benefit of ECMO support is that patients can be safely weaned from mechanical ventilation support and be active participants in their care and physical rehabilitation. Weaning patients off mechanical ventilation also decreases the patient's risk for mechanically induced lung injury. In addition, there is some evidence that non-ventilated patients bridged with ECMO have a better 6-month survival rate as compared with non-ECMO patients bridged with mechanical ventilation.[20] Although there is a benefit to weaning patients from mechanical ventilation while supported on ECMO; some patients cannot be safely weaned from mechanical ventilation, and early tracheostomy should be considered. If continued mechanical ventilation is needed, lung protective ventilation strategies should be instituted to prevent lung injury such as barotrauma and volutrauma.[4] The Extracorporeal Life Support Organization (ELSO) recommends low respiratory rates with long inspiratory time, low plateau inspiratory pressure (under 25 cm H_2O), and low FiO2 (<30%) (ELSO< 2017), if the patient tolerates.[14]

Nurses on the frontlines of care play an integral role in assessing the patients' response to both mechanical ventilation and ECMO therapy. Patient-ventilator asynchrony is one complication that can occur in mechanically ventilated patients. This complication can cause increased intrathoracic pressure which can compromise ECMO flow rates. If this occurs, ventilator settings may need to be changed or the patient may need sedative medication. Maintaining adequate flow rates on the ECMO circuit is necessary to sustain adequate PaO_2 levels. Higher flow rates allow for more blood to be pushed through the oxygenator, allowing for greater O_2 delivery to the patient. The O_2 level on arterial blood gases for patients supported by VV ECMO is typically much lower (PaO_2 80–120) compared with the O_2 level for a patient on VA ECMO (PaO_2 200–400). This occurs when patients on VV ECMO have more oxygenated blood and native blood mixing than patients on VA ECMO. Lower than normal arterial blood O_2 levels for patient supported on VV ECMO may be a result of low ECMO flows, an oxygenator failure, recirculation, or a gas leak. Nurses need to monitor for low O_2 levels on arterial blood gases and intervene quickly to prevent the perfusion of deoxygenated blood to the brain and the rest of the body.[3] ECMO also functions to remove CO_2 from patients' blood via the sweep gas flow on the ECMO circuit. Nurses monitor and control CO_2 levels via the sweep function. Increasing the sweep level decreases CO_2 and decreasing the sweep level increases CO_2. It is recommended that nurses adjust sweep flow rates by 0.5 or 1 liters per minute and recheck arterial blood gases 30 to 60 minutes after making changes.

Perfusion, Anticoagulation and Bleeding

The initiation of ECMO is associated with some degree of systemic inflammatory response syndrome. The release of inflammatory mediators results in a cascade of events including activation of the immune response, increased capillary permeability, and activation of the clotting cascade. The consequence of the latter are emboli in the microcirculation which can lead to decreased peripheral and organ perfusion.[21] Furthermore, the large bore cannulation catheter itself can occlude blood flow to the extremities. To ensure adequate distal perfusion to the peripheral extremities, nurses perform hourly peripheral pulse checks by palpation or with a doppler. Nurses also monitor the extremities for temperature, color, and capillary refill. If peripheral ischemia is detected, a small reperfusion cannula, called a superficial femoral artery (SFA) cannula can be placed with a Y connector at the site of the femoral artery cannula. This SFA cannula diverts retrograde blood from the ECMO cannula down through the femoral artery to perfuse the leg and prevent further ischemia.[22]

Clot development can impact the performance of the ECMO oxygenator. Clot formation in the oxygenator can reduce the membrane's ability to deliver O_2 to and remove CO_2 from the blood.[23] Under nurse-driven ECMO programs, nurses are responsible for monitoring the ECMO oxygenator and its tubing for clot development, documenting the presence or absence of clots, and communicating findings with the team. To prevent or reduce clot formation, patients are placed on systemic anticoagulation, typically heparin because of its shorter half-life, availability of a reversal agent, and reduced costs, compared with argatroban, lepirudin, and bivalarudin.[4] Blood tests to monitor anticoagulation levels are dependent on institutional preference which may include the partial thromboplastin time (PTT), activated clotting time (ACT), anti-factor Xa, and thromboelastography (TEG). For example, at some institutions, ACTs are monitored in the operating room by the perfusionists, and nurses in the intensive care unit monitor PTTs every 4 hours to maintain the PTT level goal that the interdisciplinary team establishes. [24]

Anticoagulating patients on ECMO increases the risk for bleeding. Nurses monitor for cannula and IV site bleeding, hematoma development at old puncture sites, retroperitoneal bleeding, gastrointestinal bleeding, and pulmonary hemorrhage.[4] Conservative transfusion policies should be adhered to for patients receiving ECMO as a bridge to transplant. This is because frequent blood product transfusions can elicit an antibody response that may adversely affect the candidate's organ cross-match. It is common practice to not transfuse a patient unless the hemoglobin level drops below 6 g/dL, as long as there is no evidence of hemodynamic compromise.[10] Nurses should consider using pediatric blood tubes when drawling blood samples from transplant candidates supported on ECMO in an effort to reduce blood loss.

Monitoring for and Prevention of Infection

Infection prevention is paramount in patients bridged with ECMO to lung transplant. Presence of an active infection in patients waiting for a lung transplant can result in a "temporary inactive status" on the waiting list, which means that the candidate cannot receive organ offers at that time. Temporary inactivation is associated with increased risk for longer wait times, higher waitlist mortality, and lower rates of transplantation.[25] ECMO increases patients' risk for infection because of the large-bore vascular access and its proximity to areas of potential increased infection (ex. femoral access).[26] At this institution, dressings changes at the site of the ECMO cannula are performed under sterile conditions using chlorhexidine impregnated dressings.[10]

Monitoring for signs of infection in patients supported with ECMO is more challenging because exposure of the patient's blood to the foreign surfaces of the ECMO circuit activate the patient's systemic inflammatory response, even in the absence of an active infection. The usual markers for systemic infection, such as a fever and elevated white blood cell count, are not reliable when a patient is on ECMO. ECMO can mask a patient's fever because when blood is removed from the body it is cooled in the tubing and can result in hypothermia. Typically, an ECMO heater is used to warm the blood to normothermia before delivering the oxygenated blood back to the patient's body. As a result, the ECMO circuit can mask a fever in a patient whose body is trying to mount a febrile response. Patients who are able to generate a fever while on ECMO support are likely experiencing a strong inflammatory response and intervention is needed. Furthermore, white blood cell counts, which are often used as a marker for systemic infection, are more difficult to interrupt in these patients because the systemic inflammatory response is already activated, causing an elevation in white blood cells, even in the absence of active infection. Furthermore, chest x-rays are frequently opacified with pulmonary inflammatory changes often seen in patients on ECMO making this diagnostic tool inadequate to detect pulmonary infection or ventilator associated pneumonia. For these reasons, detection of infection in patients supported with ECMO is complex and difficult. Nurses must closely monitor these patients for specific clinical observations that may indicate presence of an infection, such as increased secretions, purulent drainage from central lines and ECMO cannulas, and hemodynamic instability.[14]

Monitoring for End Organ Damage

Patients supported on ECMO are at risk for developing end-stage kidney or liver failure. Kidney failure can result due to changes in hemodynamics and decreased perfusion to the kidneys, hormonal changes that occur in response to ECMO support, and activation of the systemic inflammatory process. Studies show that patinets on ECMO who develop kidney failure and need renal replacement therapy are at increased risk for failure to wean from ECMO and mortality. Nurses should monitor the patient's urine output and laboratory results for signs of worsening kidney function. Hemolysis, liver hypoperfusion, and activation of the systemic inflammatory response system can increase the risk for liver dysfunction among patients on ECMO. [27] Nurses should monitor patient's liver function tests for signs of liver dysfunction. Preventing end-stage organ failure in patients supported on ECMO while waiting for lung transplantation is of upmost importance because dysfunction of major organs is a contraindication to lung transplantation and could result in patient inactivation on or removal from the wait list. [28]

Physical Therapy

Optimizing patients prior to lung transplantation through physical therapy is critical for post-transplant success. Reduced functional status and increased frailty among lung transplant candidates are significant risk factors for poor post-transplant outcomes, increased length of stay, and mortality.[4,28,29] Patients who are mechanically ventilated are at risk for neuromuscular weakness and deconditioning due to mobility restrictions.[4,30] Patients who are bridged with ECMO to lung transplant can be safely weaned off of sedation and mechanical ventilation and become active participants in pre-transplant physical therapy.

The ideal ECMO cannulation configurations that allow for patient ambulation are the bicaval dual lumen catheter in the right internal jugular and central cannulation. Ambulating a patient supported on ECMO requires a multidisciplinary team of nurses, perfusionists, physical therapists, and respiratory therapists. Active rehabilitation and ambulation for patients bridged to lung transplantation on ECMO can improve deconditioning, muscle atrophy, length of stay, and costs.[30] Mobilization of patients cannulated via the femoral artery or the femoral vein is more complex, and these patients are often restricted to bedrest due to the increased risk of cannula dislodgement that can occur with ambulation. For this reason, patients cannulated via femoral access are at a severe disadvantage in terms of their ability to participate in physical therapy and rehabilitation. Furthermore, restrictions in repositioning and mobility increase patients' risk for pressure injuries.[26] Nurses are responsible for implementing preventive measures to reduce this risk. Nurses should ensure that patients are turned and repositioned frequently.[26] Additionally, the use of a low-air loss mattress, pressure redistribution mattress, or an air fluidized bed should be considered for these patients. Patients' heels should be elevated with a pillow or heel lift boots applied to reduce the risk for pressure ulcers on the heels.[22] Physical therapy should be consulted to perform passive and active range of motion for patients who are restricted to bedrest.[31] When possible, nurses should advocate for the exchange of femoral access ECMO for placement of an bicaval dual lumen catheter so that the patient can better participate in physical therapy and rehabilitation prior to lung transplant.

Palliative Care

Palliative care services aim to improve the quality of life of patients and families affected by critical illnesses by addressing issues related to symptoms and suffering, enhancing communication between patients, families, and healthcare providers, and supporting patient and family decision-making. Palliative care services are not limited to the end of life. Unfortunately, palliative care consults for the lung transplant population are rare and often initiated primarily at the end of life. In one multi-center study of palliative care referrals after lung transplant, the researchers reported that mean survival after palliative care consult was <30 days.[32] Palliative care services need to be better utilized in the transplant population, especially for patients supported with ECMO prior to lung transplant. Patients bridged with ECMO to lung transplant face uncertain outcomes, which is a distressing experience for both the patient and the family. To abate some of the fears, anxiety, and stress that accompany waiting for a transplant and need for ECMO support, nursing units should consider developing and disseminating an ECMO educational resource to guide patients and families through the ECMO and transplant waiting experience.

These critically ill patients and their families could benefit from the palliative care consults that aim to reduce symptoms and suffering, facilitate communication, support difficult decision-making, and improve the overall quality of life for the patient and family during this difficult time. Palliative care providers should be consulted at the initiation of ECMO and their services should be available to the patient and the family members while they wait for a lung transplant.[33] Nurses are well-positioned to advocate for palliative care consults. In some cases, patients are supported on ECMO while the transplant team completes the transplant work-up and decides whether the patients is eligible for transplant listing. In some cases, the patient is not deemed eligible for transplant listing. In this difficult situation, the palliative care team can help support the patient and family and facilitate a goals of care conversation. Some patinets who are bridged with ECMO to transplantation become too sick while waiting for a transplant and may be removed from the waitlist. This is another situation where palliative care can play an important role providing patient and family support and facilitating goals of care discussions. Clearly, palliative care team members can play an important role in the care of patients supported on ECMO. Nurses are well positioned to advocate for palliative care consults at the time ECMO is initiated.

Conclusion

ECMO is among the most advanced critical care technology and its use to bridge patients to lung transplant is increasing. Critical care nurses need to be well-prepared to care for this high acuity patient population. This review article fills a critical knowledge gap related to the care of patients supported on ECMO, specifically as a bridge to lung transplant. Further research on the use of ECMO as a bridging strategy and development of evidence-based guidelines to direct nursing care are needed to improve patient outcomes.

Acknowledgments

Brittany Koons, PhD, RN is supported by the Robert Wood Johnson Foundation Future of Nursing Scholar program and the NewCourtland Center for Transitions and Health (*Individualized Care for At Risk Older Adults* T32NR009356) at the University of Pennsylvania.

Jennifer Siebert, MSN, RN, CCRN is supported by the Robert Wood Johnson Foundation and Villanova University.

Biography

Brittany Koons, PhD, RN is Postdoctoral Research Fellow at the University of Pennsylvania with research interests in lung transplantation. She is also a critical care nurse on the Cardiothoracic Surgical Intensive Care Unit at the Hospital of the University of Pennsylvania.

Jennifer Siebert, MSN, RN, CCRN is a Robert Wood Johnson Foundation Future of Nursing Scholar and doctoral student at Villanova University with research interests in organ transplantation. She is also a critical care nurse on the Cardiothoracic Surgical Intensive Care Unit at the Hospital of the University of Pennsylvania.

References

1. Valapour M, Lehr CJ, Skeans MA, et al. OPTN/SRTR 2016 Annual Data Report: Lung. Am J Transplant. 2018;18 Suppl 1:363–433. [PubMed: 29292602]

2. Hayanga AJ, Aboagye J, Esper S, et al. Extracorporeal membrane oxygenation as a bridge to lung transplantation in the United States: an evolving strategy in the management of rapidly advancing pulmonary disease. J Thorac Cardiovasc Surg. 2015;149(1):291–296. [PubMed: 25524684]

3. Hayes D Jr., Tobias JD, Tumin D. Center Volume and Extracorporeal Membrane Oxygenation Support at Lung Transplantation in the Lung Allocation Score Era. American journal of respiratory and critical care medicine. 2016;194(3):317–326. [PubMed: 26840155]

4. Sharma NS, Hartwig MG, Hayes D Jr. Extracorporeal membrane oxygenation in the pre and post lung transplant period. Ann Transl Med. 2017;5(4):74. [PubMed: 28275619]

5. Cavarocchi NC, Wallace S, Hong EY, et al. A cost-reducing extracorporeal membrane oxygenation (ECMO) program model: a single institution experience. Perfusion. 2015;30(2):148–153. [PubMed: 24825881]

6. Daly KJ, Camporota L, Barrett NA. An international survey: the role of specialist nurses in adult respiratory extracorporeal membrane oxygenation. Nursing in critical care. 2017;22(5):305–311. [PubMed: 27649636]

7. Ventetuolo CE, Muratore CS. Extracorporeal life support in critically ill adults. American journal of respiratory and critical care medicine. 2014;190(5):497–508. [PubMed: 25046529]

8. Chung M, Shiloh AL, Carlese A. Monitoring of the adult patient on venoarterial extracorporeal membrane oxygenation. ScientificWorldJournal. 2014;2014:393258. [PubMed: 24977195]

9. Hashimoto K, Hoetzenecker K, Yeung JC, et al. Intraoperative extracorporeal support during lung transplantation in patients bridged with venovenous extracorporeal membrane oxygenation. The Journal of heart and lung transplantation : the official publication of the International Society for Heart Transplantation. 2018;37(12):1418–1424.

10. Biscotti M, Sonett J, Bacchetta M. ECMO as bridge to lung transplant. Thoracic surgery clinics. 2015;25(1):17–25. [PubMed: 25430426]

11. Darryn Abrams DB. Identification and management of recirculation in venovenous ECMO. https://www.elso.org/Portals/0/Files/ELSO_Recirculation_guideline_May2015.pdf. Published 2015 Accessed decemeber 14 2018.

12. Weinberg A, Mongero L, Armstrong B. ECMO cannulation strategy for pulmonary hypertension: an alternative approach to traditional Veno-Arterial ECMO. Perfusion. 2016;31(7):614–617. [PubMed: 27107037]

13. Pavlushkov E, Berman M, Valchanov K. Cannulation techniques for extracorporeal life support. Ann Transl Med. 2017;5(4):70. [PubMed: 28275615]

14. Organization ELS. ELSO Guidelines for Cardiopulmonary Extracorporeal Life Support. https://www.elso.org/Portals/0/ELSO%20Guidelines%20For%20Adult%20Respiratory%20Failure%201_4.pdf. Published 2017 Accessed.

15. Bisdas T, Beutel G, Warnecke G, et al. Vascular complications in patients undergoing femoral cannulation for extracorporeal membrane oxygenation support. The Annals of thoracic surgery. 2011;92(2):626–631. [PubMed: 21550582]

16. Pappalardo F, Regazzoli D, Mangieri A, et al. Hemodynamic and echocardiographic effects of aortic regurgitation on femoro-femoral veno-arterial ECMO. International journal of cardiology. 2016;202:760–762. [PubMed: 26476028]

17. Dzierba AL, Abrams D, Brodie D. Medicating patients during extracorporeal membrane oxygenation: the evidence is building. Critical care (London, England). 2017;21(1):66.

18. Mosier JM, Kelsey M, Raz Y, et al. Extracorporeal membrane oxygenation (ECMO) for critically ill adults in the emergency department: history, current applications, and future directions. Critical care (London, England). 2015;19:431.

19. Baran DA. Extracorporeal Membrane Oxygenation (ECMO) and the Critical Cardiac Patient. Current transplantation reports. 2017;4(3):218–225. [PubMed: 28932651]

20. Fuehner T, Kuehn C, Hadem J, et al. Extracorporeal membrane oxygenation in awake patients as bridge to lung transplantation. American journal of respiratory and critical care medicine. 2012;185(7):763–768. [PubMed: 22268135]

21. Millar JE, Fanning JP, McDonald CI, McAuley DF, Fraser JF. The inflammatory response to extracorporeal membrane oxygenation (ECMO): a review of the pathophysiology. Critical care (London, England). 2016;20(1):387.

22. Calhoun A ECMO: Nursing Care of Adult Patients on ECMO. Critical care nursing quarterly. 2018;41(4):394–398. [PubMed: 30153183]

23. Dornia C, Philipp A, Bauer S, et al. Analysis of thrombotic deposits in extracorporeal membrane oxygenators by multidetector computed tomography. ASAIO journal (American Society for Artificial Internal Organs : 1992). 2014;60(6):652–656. [PubMed: 25158889]

24. Loor G, Simpson L, Parulekar A. Bridging to lung transplantation with extracorporeal circulatory support: when or when not? J Thorac Dis. 2017;9(9):3352–3361. [PubMed: 29221320]

25. Williams L UNOS transplant waitlist status https://www.kidney.org/transplantation/transaction/TC/winter14/UNOS_Committee. Published 2014 Accessed.

26. Trinsey A Extracorporeal membrane oxygenation: A review. 2017;12(4):16–23.

27. Lyu L, Yao J, Gao G, et al. Incidence, Risk Factors, and Outcomes of Hyperbilirubinemia in Adult Cardiac Patients Supported by Veno-Arterial ECMO. Artificial organs. 2018;42(2):148–154. [PubMed: 28877352]

28. Bain JC, Turner DA, Rehder KJ, et al. Economic Outcomes of Extracorporeal Membrane Oxygenation With and Without Ambulation as a Bridge to Lung Transplantation. Respiratory care. 2016;61(1):1–7. [PubMed: 26264415]

29. Grimm JC, Valero V, 3rd, Kilic A, et al. Preoperative performance status impacts perioperative morbidity and mortality after lung transplantation. The Annals of thoracic surgery. 2015;99(2):482–489. [PubMed: 25528724]

30. Araújo Neto J, Bomfim R, Lima F, Castro D, Moura E, Maia MJCC. Impact of mechanical ventilation on the functional status in patients admitted to the intensive care unit. Crit Care. 2011;15(2):P55.

31. Lowman JD, Kirk TK, Clark DE. Physical therapy management of a patient on portable extracorporeal membrane oxygenation as a bridge to lung transplantation: a case report. Cardiopulmonary physical therapy journal. 2012;23(1):30–35.

32. Song MK, De Vito Dabbs A, Studer SM, Arnold RM. Palliative care referrals after lung transplantation in major transplant centers in the United States. Critical care medicine. 2009;37(4):1288–1292. [PubMed: 19242344]

33. Klinedinst R, O'Connor N, Farabelli J. Walking Across the Bridge to Nowhere: The Role of Palliative Care in the Support of Patients on ECMO (FR400). Journal of Pain and Symptom Management. 2017;53(2):350.