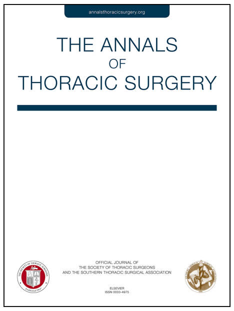

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The management of patients with cardiac and respiratory failure is essential to the critical care training of thoracic surgery residents. When conventional treatments fail, trainees may be called to evaluate these patients for extracorporeal membrane oxygenation (ECMO). Unlike many topics covered in the *How I Teach It* series, the surgical techniques needed to place a patient on ECMO are not particularly challenging. Femoral vessel exposure, central line placement, and interventional and wire skills are all techniques learned early in surgical training. However, the decision-making and management algorithms needed to care for ECMO patients are of equal importance, and often times are overlooked when teaching residents. As the classic saying goes, "A good surgeon knows how to operate, a better one knows when to operate."

Preparation

In our institution, all adult ECMO cannulations are performed by cardiothoracic surgeons, and all consultations for ECMO are initially evaluated by thoracic surgery residents. Therefore, teaching residents about ECMO requires a strong understanding of cardiac and pulmonary physiology, as well as the treatment of cardiopulmonary failure. When approaching a consultation for ECMO, our residents are taught to take a comprehensive and systematic approach. To begin, a thorough history is obtained, paying particular attention to comorbidities, previous operations, and medical therapy received. Prior to cannulation it is critically important to determine the "exit strategy" to successfully transition off of ECMO. If the patient does not have a reversible disease process and is not a candidate for advanced therapies such as left ventricular assist device implantation or heart or lung transplantation, then the patient is not a good candidate for ECMO. To this end, the physical exam should include an expeditious assessment of the patient's neurologic function, as a devastating and unrecoverable neurologic insult is a contraindication to cannulation.

We instruct our residents to quickly assess patient acuity and feasibility of successful cannulation in the current location. Examples of these considerations include whether the patient is on a fluoroscopy-compatible bed, if there is time to perform a femoral cutdown for access, and whether a provider capable of performing trans-esophageal echocardiography (TEE) is present. To help standardize some of these questions, our institution has developed a mobile ECMO team which is capable of cannulating in any location throughout the hospital.

How I Teach It

Venovenous ECMO

Patients with respiratory failure who fail to improve despite optimal medical management may be candidates for venovenous (VV)-ECMO. Prior to initiating ECMO, it is important to consider the overall clinical picture and ensure that conventional therapies to improve respiratory dynamics have been exhausted, including increasing positive end-expiratory pressure, paralysis, or prone positioning. We expect and train our residents to be well-versed in the management of acute respiratory distress syndrome. When a patient remains hypoxic or acidotic despite optimal medical management, we then proceed with VV-ECMO cannulation.

Cannulation techniques vary from internal jugular (IJ) inflow and femoral vein outflow, to femoral-femoral cannulation, to single bicaval cannulation with a dual lumen cannula (Avalon Elite, Getinge AB, Sweden). At our institution we prefer to use a dual lumen cannula via the right IJ as our first-line approach, due to the potential for ambulation and decreased recirculation. Before our residents begin to place large ECMO cannulas in an emergent setting, they first obtain extensive training in the operating room, where they learn wire skills and cannulation techniques in a more controlled environment. We focus on teaching them proper wire control to prevent vascular injury and wire kinking or contamination.

The patient is first evaluated for the ability to cannulate the right IJ using history or cross-sectional imaging, if available. If an IJ catheter is already in place, this can be exchanged over a wire for ECMO access. Using ultrasound guidance, the RIJ is accessed with a needle and an Amplatz Super Stiff wire (Boston Scientific, Marlborough, MA) is then placed using either fluoroscopic or TEE guidance, ensuring that the wire does not cross into the right ventricle. If using fluoroscopy, the wire is observed passing through the right atrium and into the inferior vena cava (IVC) (Figures 1-2). If using TEE, a bicaval view is obtained to demonstrate the wire passing directly from the superior vena cava to the IVC without curling through the tricuspid valve into the right ventricle. Our residents are trained in performance and interpretation of TEE, so they can ensure proper placement. Once the wire is appropriately placed, the IJ is serially dilated, using imaging to ensure that the wire is not becoming displaced. At this point, 25-50 units/kg of intravenous heparin are administered, based on current bleeding status. The cannula is then inserted over the wire and aimed so that the reinfusion port is guided towards the tricuspid valve with the tip of the cannula in the IVC (Figure 3). The cannula is then connected to the ECMO circuit and ECMO is initiated. The final step of placement is to secure the cannula in numerous places to ensure that the position does not change with movement of the patient's head and neck. We use a standard heparin dosing strategy based on concern for bleeding. If the risk of bleeding is prohibitive for systemic anticoagulation (as is often seen in polytrauma patients, patients with recent surgeries, or other contraindications) anticoagulation can be safely held for extended periods of time (from days to months).[1]

After successful VV-ECMO cannulation, mechanical ventilation must be integrated in such a way as to maximize the benefits of ECMO while avoiding additional lung injury. We prefer to use open lung ventilation, where tidal volumes are kept low and PEEP is used to maintain alveolar recruitment.[2] Our goal is to maintain tidal volume around 6cc/kg, plateau pressure less than 30cmH_20, and fraction of inspired oxygen less than 60%. Once patients are stable on a ventilation strategy with ECMO, we then work to reduce any pulmonary edema with aggressive diuresis and renal replacement therapy if needed. During this phase we wean sedation to have the patient awake and participating in physical therapy. It is our goal to have every patient awake and ambulating while on VV-ECMO.

When we have achieved minimal ventilator and ECMO settings, we work towards decannulation. A test of ECMO wean is performed by capping the oxygenator and following blood gases to ensure adequate oxygenation and CO_2 clearance. A final test that can be done is termed the "Cilley" test, which involves turning the FiO_2 to 1.0; if there is rapid increase in the saturation to 100%, then there is likely to be success weaning from ECMO.[3] Once the decision is made to decannulate, the heparin is stopped, the cannula(s) removed, a purse-string placed around the puncture site, and manual compression held.

Venoarterial ECMO

Venoarterial (VA)-ECMO is utilized for patients that require hemodynamic support in addition to respiratory support. In general, VA-ECMO is used in patients with cardiogenic shock, post -cardiotomy shock, graft failure after heart transplantation, or in patients with chronic cardiomyopathy as a bridge to long term support, transplant, or decision. An important decision point that we emphasize with our residents is the distinction between a patient with hypotension caused by hypoxia who needs VV-ECMO and a patient with hypotension caused by cardiac dysfunction who needs VA-ECMO. Occasionally it is not immediately clear which modality of ECMO is indicated. In these situations, the clinical scenario, medical history, and echocardiography can help.

The sites that are considered for VA-ECMO in adults include central cannulation of the right atrium and ascending aorta, an ambulatory configuration consisting of the axillary artery and internal jugular vein, or the femoral vessels. In general, we prefer femoral cannulation in emergent or urgent cases of cardiogenic shock, axillary artery and internal jugular vein cannulation for bridge-to-transplant patients who we plan on ambulating, and central cannulation in patients with post-cardiotomy shock.

Femoral cannulation for VA-ECMO is similar to the technique used in other procedures, such as minimally invasive cardiac surgery and transfemoral transcatheter valve replacement. We teach femoral cannulation either percutaneously or via a surgical cutdown, based on the clinical scenario and patient acuity. When patients are actively coding, we feel the percutaneous approach is faster, safer, and easier to perform during chest compressions. With the percutaneous approach, the femoral vein is accessed and a stiff wire is passed into the right atrium and distal SVC under TEE guidance (Figure 4). Once the wire is in the correct position, the vein is dilated and the cannula placed. The common femoral artery is accessed, dilated, and cannulated. The cannulas are then connected to the ECMO circuit, a dose of 25-50 units/kg heparin is given, ECMO is initiated, and the cannulas are secured.

In patients who require urgent but not emergent cannulation, we prefer a femoral cutdown. This technique has the following advantages over percutaneous cannulation: better vessel visualization and more accurate placement of cannulas, allows repair of potential injuries, and facilitates future decannulation. However, it does take more time, instruments, and personnel to cannulate via a cutdown approach. At our institution we have found it safe to perform surgical cutdowns in the intensive care unit, but this may not be the case at every ECMO center. The cutdown technique is similar to the percutaneous approach, except that the artery and vein are directly cannulated after exposure and placement of pursestring sutures.

Given the high rate of lower extremity ischemia with VA-ECMO, we prefer to routinely place a distal perfusion catheter. This practice is supported by recent data demonstrating that lack of a distal perfusion cannula is an independent risk factor for developing acute limb ischemia with femoral VA-ECMO.[4] For percutaneous cannulation, we place a 6F or 8F vascular sheath in the superficial femoral artery (SFA) using a micropuncture kit (Cook Medical, Bloomington, IN) and ultrasound guidance. The sidearm from the sheath is connected to a luer lock connector on the arterial limb of the ECMO circuit (Figure 5). Given the tendency for the sheath to kink, we prefer to use a wire-reinforced cannula when a femoral cutdown is performed. An additional 5-0 prolene pursestring suture is placed in the SFA using the same incision, and an 8F cannula is placed for perfusion of the leg (Bio-Medicus NextGen, Medtronic Inc, Minneapolis, MN).

After initiating VA-ECMO, vasoactive agents are titrated accordingly, and lactate acid levels are followed to assess end-organ perfusion. Cardiac recovery is monitored by serial echocardiography and vasopressor/inotrope requirements. It is important for the trainee to remember that VA-ECMO delivers retrograde flow and that this can have deleterious effects on the patient's physiology. In brief, blood that is ejected from the left ventricle (LV) will encounter resistance from the retrograde ECMO flow. While the ECMO circuit will generally protect the right ventricle (RV) by decreasing preload, reducing RV output, and reducing pulmonary circulation, the effects are quite different on the LV. Blood delivered retrograde will cause an increase in the mean arterial pressure and thereby increase afterload. This increase in afterload can then cause reduction in LV stroke volume. This effect is intensified as ECMO support is increased, and can lead to LV distention, decreased coronary blood flow, and reduced subendocardial perfusion. Options for decreasing this afterload, by venting the LV, include an intra-aortic balloon pump, percutaneous ventricular assist device, surgically placed vent via a mini-left thoracotomy, or transseptal atrial cannulation. LV unloading has been shown to decrease mortality associated with VA-ECMO in a recent meta-analysis.[5]

Another complication of peripheral VA-ECMO which requires special consideration is the North-South, or Harlequin syndrome. This syndrome stems from concomitant lung disease, which results in poorly oxygenated blood being ejected from the LV to the coronary and cerebral circulations. The extent of this malperfusion depends on the degree of LV output and the location of the watershed region between LV output and ECMO flow. Use of a right radial arterial line, which can monitor for pulsatility and be used to check PaO_2 of the upper extremities, facilitates recognition of the North-South syndrome and can be a surrogate for coronary and carotid blood flow and oxygen delivery. Options for management of North-South syndrome include optimizing mechanical ventilation to improve oxygenation of blood through the lungs, improving venous drainage to minimize blood flow through the heart (VVA configuration), or returning oxygenated blood into the SVC to allow oxygenated blood to enter the pulmonary circulation (VAV configuration).[6]

Comment

In summary, patients in extremis from respiratory or cardiac failure can be rescued by specialized teams through the use of ECMO. The care of these patients is incredibly complex in all phases of their course, but this is an excellent opportunity for our trainees to learn advanced cardiopulmonary physiology and critical care skills. The management of patients on ECMO should be an essential component of every thoracic surgery training program.

REFERENCES

1. Muellenbach RM, Kredel M, Kunze E, et al. Prolonged heparin-free extracorporeal membrane oxygenation in multiple injured acute respiratory distress syndrome patients with traumatic brain injury. J Trauma Acute Care Surg. 2012 May;72(5):1444-7.
2. Gattinoni L, Tonetti T, Quintel M. How best to set the ventilator on extracorporeal membrane lung oxygenation. Curr Opin Crit Care. 2017 Feb;23(1):66-72.
3. ELSO Guidelines for Cardiopulmonary Extracorporeal Life Support Extracorporeal Life Support Organization, Version 1.4 August 2017. Retrieved from http://www.elso.org
4. Kaufeld T, Beckmann E, Ius F, et al. Risk factors for critical limb ischemia in patients undergoing femoral cannulation for venoarterial extracorporeal membrane oxygenation: Is distal limb perfusion a mandatory approach? Perfusion. 2019 Sep; 34(6): 453-459.
5. Rao P, Khalpey Z, Smith R, et al. Venoarterial Extracorporeal Membrane Oxygenation for Cardiogenic Shock and Cardiac Arrest. Circ Heart Fail. 2018 Sep;11(9):e004905.
6. Russo JJ, Aleksova N, Pitcher I, et al. Left Ventricular Unloading During Extracorporeal Membrane Oxygenation in Patients With Cardiogenic Shock. J Am Coll Cardiol. 2019 Feb 19;73(6):654-662.

Figure Legends

Figure 1. VV-ECMO cannulation through the right IJ with an Avalon cannula. with the wire bowing across the tricuspid valve and into the right ventricle during advancement of the cannula. Black arrow = wire; TEE = transesophageal echo probe.

Figure 2. Repositioning of the wire so that it is now properly placed into the IVC.

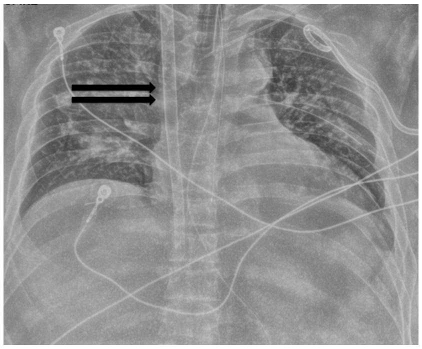
Figure 3. Correct placement of the Avalon cannula in the right atrium with the tip in the IVC and the side port directed to the tricuspid valve. Double black arrow = Avalon cannula.

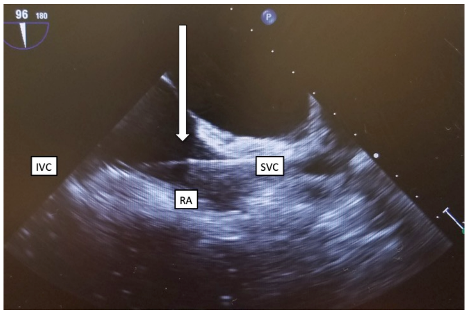
Figure 4. Venous cannulation for ECMO through the femoral vein using TEE guidance.

- IVC = inferior vena cava; SVC = superior vena cava; RA = right atrium; white arrow = Amplatz stiff wire

Figure 5. Final set up of percutaneous VA-ECMO cannulation through the femoral vessels. Demonstrated here is the securing of the cannulas and the positioning of the distal perfusion catheter (DPC).

- FVC = femoral venous cannula; FAC = femoral artery cannula; DPC = distal perfusion cannula

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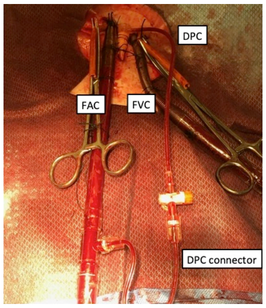
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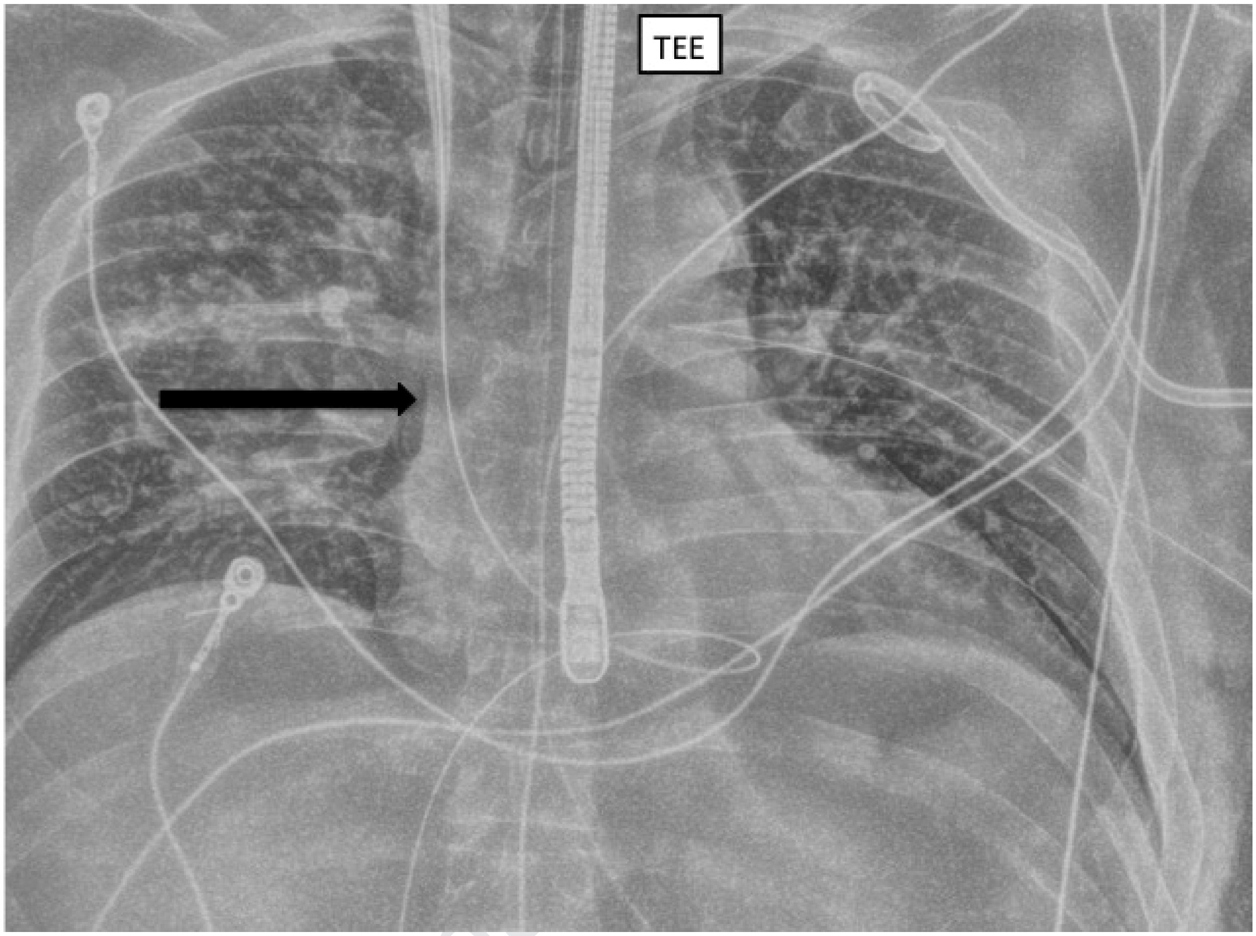
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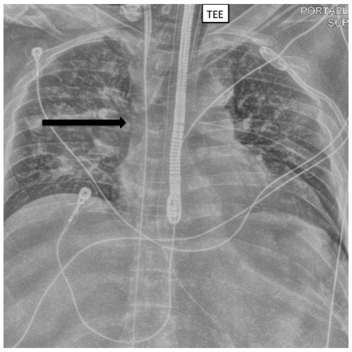
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