Joint Society of Critical Care Medicine-Extracorporeal Life Support Organization Task Force Position Paper on the Role of the Intensivist in the Initiation and Management of Extracorporeal Membrane Oxygenation

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Objectives: To define the role of the intensivist in the initiation and management of patients on extracorporeal membrane oxygenation.
Design: Retrospective review of the literature and expert consensus.
Setting: Series of in-person meetings, conference calls, and emails from January 2018 to March 2019.
Subjects: A multidisciplinary, expert Task Force was appointed and assembled by the Society of Critical Care Medicine and the Extracorporeal Life Support Organization. Experts were identified by their respective societies based on reputation, experience, and contribution to the field.
Interventions: A MEDLINE search was performed and all members of the Task Force reviewed relevant references, summarizing high-quality evidence when available. Consensus was obtained using a modified Delphi process, with agreement determined by voting using the RAND/UCLA scale, with score ranging from 1 to 9.
Measurements and Main Results: The Task Force developed 18 strong and five weak recommendations in five topic areas of extracorporeal membrane oxygenation initiation and management. These recommendations were organized into five areas related to the care of patients on extracorporeal membrane oxygenation: patient selection, management, mitigation of complications, coordination of multidisciplinary care, and communication with surrogate decision-makers. A common theme of the recommendations is extracorporeal membrane oxygenation is best performed by a multidisciplinary team, which intensivists are positioned to engage and lead.
Conclusions: The role of the intensivist in the care of patients on extracorporeal membrane oxygenation continues to evolve and grow, especially when knowledge and familiarity of the issues surrounding extracorporeal membrane oxygenation selection, cannulation, and management are applied. (*Crit Care Med* 2020; 48:838–846)
Key Words: cardiogenic shock; extracorporeal cardiopulmonary resuscitation; extracorporeal life support; extracorporeal membrane oxygenation; respiratory failure

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Extracorporeal membrane oxygenation (ECMO) is a form of respiratory or cardiac life support consisting of a vascular access cannula, a blood pump, and an artificial lung, which removes carbon dioxide and adds oxygen (1). Although ECMO utilization has expanded rapidly since 2009 (2, 3), the majority of ECMO centers remain relatively low-volume centers with a median of 15 cases per year (interquartile range, 5–35 cases per year) (4). The clinical implication is that intensive care clinicians are increasingly likely to be involved in the critical care of patients supported by ECMO, regardless of whether they are part of a large ECMO program. These patients are medically complex, at risk for complications, and resource intensive. Consequently, the Society of Critical Care Medicine (SCCM) established a task force to advance ECMO education and investigation.

The SCCM-ELSO Task Force was appointed as a joint collaboration between the SCCM and the Extracorporeal Life Support Organization (ELSO). The charge of the Task Force was to define the role of the intensivist in the initiation and management of patients on ECMO. We accomplished this charge by reviewing published literature and providing consensus statements written for the intensivist and multidisciplinary ECMO team.

MATERIALS AND METHODS

The Task Force organizing committee convened in January 2018 to define the methodology, select the topics for study, and identify experts in the field. Experts were identified by their respective societies based on reputation, experience, and contribution to the field.

Through a series of emails, conference calls, and in-person discussions, five topics related to the role of the intensivist in the care of adult patients on ECMO were identified. These were the role of the intensivist in patient selection, management, mitigation of complications, coordination of multidisciplinary care, and communication with surrogate decision-makers (SDMs). Experts were tasked with developing recommendations within each topic area for consideration by the entire Task Force.

A MEDLINE search was performed and all members of the Task Force reviewed relevant references, summarizing high-quality evidence when available. In the absence of high-quality evidence, Task Force recommendations were made based on the combination of low-quality evidence and consensus expert opinion among the Task Force. Consensus was obtained using a modified Delphi process, with agreement determined by voting using the RAND/UCLA scale, with score ranging from 1 to 9 (5). Each member of the committee had an equal vote with the highest and lowest scores discarded. Strong agreement required all members to agree with the recommendation with a score of 7 or higher. Weak agreement was achieved when one member ranked the recommendation below 7, but the median was at least a 7. When the committee reached strong agreement statements were characterized as "Recommend" when the committee reached weak agreement statements were characterized as "Consider" (**Table 1**).

For the purposes of this Task Force, an intensivist is a practitioner who is eligible to sit for critical care medicine boards.

RESULTS

The five topics identified by the SCCM-ELSO Task Force are as follows, with recommendations as appropriate (Table 1).

Topic 1: The Role of the Intensivist in the Selection and Timing of ECMO Initiation

ECMO is neither a definitive treatment nor a destination therapy. ECMO can be deployed as a bridge to recovery, transplant, or destination therapy with mechanical circulatory support (MCS) (4, 6–8). Decisions regarding ECMO initiation are best made by a combination of an experienced multidisciplinary team and existing center guidelines (5, 8–10). Due to the many facets of involved in the care of patients on ECMO, a multidisciplinary team consisting of institutional key stakeholders is essential. This team may include intensivists, emergency medicine, anesthesiologists, cardiologists, surgeons, ECMO specialists, pharmacists, nursing, respiratory therapy, rehabilitation team, and palliative care. In emergent situations or circumstances where the entire multidisciplinary team cannot be assembled in an efficient manner, there is value in assembling key personnel.

The timing of ECMO initiation is also complex. ECMO carries substantial risk of complications and uses significant resources (2, 11), but delaying ECMO may risk progressive organ injury and increased risk of mortality (12).

Recommendation: The decision to initiate ECMO and the timing of this decision are complex and should involve a multidisciplinary ECMO team. Intensivists should play a central role in the formation of this team and the discussion about patient selection.

Recommendation: Future research should seek to identify patient criteria that can identify ECMO candidacy and optimal timing for ECMO initiation.

Contraindications for ECMO Support. There are no universally accepted contraindications to ECMO support and we did not achieve consensus on specific contraindications. The American Heart Association, the International ECMO Network and an international group of experts each considered ECMO contraindications (5, 8, 9). ELSO Guidelines have also identified relative contraindications such as end-stage malignancy and unrecoverable CNS damage as well as conditions associated with a poor overall prognosis such as prolonged mechanical ventilation time and prolonged cardiopulmonary resuscitation (CPR) without adequate tissue perfusion. These expert panels suggested that experienced multidisciplinary teams evaluate ECMO candidacy. Patients with chronic organ failure who are not candidates for transplant or a long-term device may be poor candidates for ECMO support.

Recommendation: The decision to withhold ECMO should be made by a multidisciplinary team that includes intensivists.

Recommendation: The decision to withhold ECMO should be based on an evaluation of the prognosis, assessing whether ECMO will improve or worsen the overall prognosis.

ECMO Outcomes and Risk Factors. Hospital mortality for patients receiving ECMO support is approximately 40% for respiratory ECMO (rECMO), 60% for cardiac ECMO (cECMO), and 70% for extracorporeal CPR (ECPR) (2, 12–15). The mortality burden has motivated researchers to identify risk factors and prognostic scores that stratify risk within specific patient populations (16–24).

Recommendation: The multidisciplinary team assessing ECMO candidacy should be aware the factors associated with reduced and improved ECMO survival, consulting with an ECMO expert when possible.

Patient Selection and Timing for rECMO Support

TABLE 1. Recommendations by the Joint Society of Critical Care Medicine-Extracorporeal Life Support Organization Task Force

Strength of Recommendation	Recommendation
The role of the intensivist in the selection and timing of ECMO initiation	
Recommend	The decision to initiate ECMO and the timing of this decision are complex and should involve a multidisciplinary ECMO team. Intensivists should play a central role in the formation of this team and the discussion about patient selection
Recommend	Future research should seek to identify patient criteria that can identify ECMO candidacy and optimal timing for ECMO initiation
Recommend	The decision to withhold ECMO should be made by a multidisciplinary team that includes intensivists
Recommend	The decision to withhold ECMO should be based on an evaluation of the prognosis, assessing whether ECMO will improve or worsen the overall prognosis
Recommend	The multidisciplinary team assessing ECMO candidacy should be aware the factors associated with reduced and improved ECMO survival, consulting with an ECMO expert when possible
Recommend	[a]Patients with respiratory failure should receive optimal mechanical ventilation and prone positioning where appropriate prior to consideration for ECMO
Consider	[a]ECMO can be considered for patients with acute respiratory distress syndrome from a reversible etiology who have received optimized care with P:F ratio $<$ 50 mm Hg for $>$ 3 hr, P:F ratio $<$ 80 mm Hg for $>$ 6 hr with F_{IO_2} $>$ 80% and positive end-expiratory pressure $>$ 10, or arterial pH $<$ 7.25 with $Pa_{CO_2} \geq$ 60 mm Hg for $>$ 6 hr while trying to maintain plateau pressure $<$ 32 despite a respiratory rate of 35 breaths per minute
Recommend	[a]Patients with severe respiratory failure who are not responding to conventional management should undergo early transfer to a hospital with ECMO capabilities if clinically feasible
Recommend	Cardiac ECMO can be considered for patients with cardiogenic shock, especially with signs of poor perfusion and failure of medical therapy, transferring to a specialty center capable of both long-term and short-term support options when clinically appropriate
Consider	ECPR requires emergent, time-sensitive deployment of invasive life support; therefore, we recommend centers offering ECPR establish a multidisciplinary ECMO team with explicit guidelines for patient selection, exclusion, and team member notification. Intensivists should play a central role in the formation of these guidelines and the delivery of subsequent intensive care needs
The role of the intensivist in cannulation for ECMO	
Recommend	Many specialists, including intensivists, can successfully perform cannulation for ECMO. For cases where the intensivist does not cannulate, the intensivist should remain involved in the decisions surrounding cannulation such as timing, configuration, and cannula size, all of which can impact ICU management
Recommend	Intensivists performing cannulation should use percutaneous access in lieu of open cannulation techniques
Avoiding and rescuing patients from ECMO-related complications	
Recommend	Intensivists should be familiar with complications specific to ECMO and should participate in developing institution-specific protocols for preventing and managing these complications
Recommend	Ultrasound, radiography, and/or fluoroscopy should be used to aid in the visualization of vessels, wire, and cannula during cannulation
Recommend	Post-cannulation plain radiographs should be obtained to document cannula positioning
Consider	For bleeding patients on ECMO, the intensivist role is to evaluate if clinically significant bleeding is present, evaluate the patient's ability to form and maintain clot, evaluate the ECMO circuit's clot burden, and assimilate the information to decide if anticoagulation should be reduced or held and assess if bleeding will require further medical or procedural interventions
Consider	Intracranial hemorrhage on ECMO can be life threatening. Potential options for the managing intensivist include holding/decreasing anticoagulation, evaluation for ECMO discontinuation, serial neurologic examination, neuroimaging, and neurosurgical evaluation as appropriate
Consider	The decision to perform any procedure on patients supported by ECMO should be carefully weighed against the risk of hemorrhage and performed by clinicians with significant expertise after a plan has been developed for how anticoagulation will be adjusted

(*Continued*)

TABLE 1. (*Continued*). **Recommendations by the Joint Society of Critical Care Medicine-Extracorporeal Life Support Organization Task Force**

Strength of Recommendation	Recommendation
Recommend	Hospitals should have a ready and rapidly deployable plan for replacing failed ECMO equipment, as well as a protocol for monitoring equipment in order to diminish the risk of failure
Recommend	Intensive evaluation of the distal extremity is necessary with arterial cannulation with attention to any signs of ischemic injury which can be limb threatening
Recommend	Intensivists should be aware of the clinical manifestations of left ventricular distension and develop clinical thresholds and strategies for decompressing the left ventricle
Leading a multidisciplinary team	
Recommend	The establishment of a multidisciplinary care team responsible for daily rounds to provide continuity of care, surveillance of quality metrics, and a mechanism to perform case review at regular intervals is essential
Surrogate decision-maker communication	
Recommend	Established processes should exist for ensuring family-centered communication. Other team members involved in surrogate communications (e.g., palliative care, case management) should be familiar with the unique challenges related to the care of patients receiving ECMO

ECMO = extracorporeal membrane oxygenation, ECPR = extracorporeal cardiopulmonary resuscitation, P:F = ratio of PaO_2/FIO_2.

[a]Denotes a recommendation that is evidence based. All other recommendations are based on expert consensus.

Recommend corresponds to strong agreement Consider corresponds to weak agreement.

Bridge to recovery. Two randomized trials have evaluated the role of ECMO as a bridge to recovery in acute respiratory failure (14, 15). The inclusion criteria of both trials are summarized in **Table 2**. The Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR) trial randomized patients with acute respiratory failure to be transferred to an ECMO center for consideration of ECMO or to remain at a conventional treatment center, with the primary outcome of death or severe disability at 6 months. At 6 months, 33 of 90 patients (37%) cared for at an ECMO capable hospital and 46 of 87 patients (53%) cared for at a non-ECMO capable hospital died or had severe disability (relative risk [RR], 0.69; 95% CI, 0.05–0.97) (13). Of note, the trial was not a comparison of ECMO versus no ECMO, with 22 of 90 patients (24%) randomized to transfer to an ECMO center not receiving ECMO. Also, adherence to standard of care lung-protective ventilation was lower at the non-ECMO capable centers (25).

The Extracorporeal Membrane Oxygenation for Severe Acute Respiratory Distress Syndrome (EOLIA) trial randomized adults with severe acute respiratory distress syndrome (ARDS) who had been intubated for less than 7 days to receive ECMO or conventional ARDS management. The trial design ensured optimized low-volume, low-pressure ventilation with moderate positive end-expiratory pressure (PEEP) and strongly encouraged the use of neuromuscular blockade and prone positioning. At 60 days, 44 of 124 ECMO patients (35%) and 57 of 125 patients (46%) in the control group died (RR, 0.76; 95% CI, 0.55–1.04). Importantly, crossover to ECMO was allowed for predefined refractory hypoxemia, occurring in 35 of 125 patients (28%). A post hoc Bayesian analysis of EOLIA as well as a recent meta-analysis demonstrated a high likelihood of mortality benefit from ECMO in this setting (26, 27).

Although specific recommendations for ECMO initiation are made based on available evidence, the ultimate decision to initiate ECMO is a clinical decision and should be weighed in the context of all available clinical data.

Recommendation: Patients with respiratory failure should receive optimal mechanical ventilation and prone positioning where appropriate prior to consideration for ECMO.

Recommendation: ECMO can be considered for patients with ARDS from a reversible etiology who have received optimized care with ratio of PaO_2/FIO_2 (P:F) less than 50 mm Hg for greater than 3 hours, P:F ratio less than 80 mm Hg for greater than 6 hours with FIO_2 greater than 80% and PEEP greater than 10, or arterial pH less than 7.25 with $PaCO_2$ greater than or equal to 60 mm Hg for greater than 6 hours while trying to maintain plateau pressure less than 32 despite a respiratory rate of 35 breaths per minute.

Recommendation: Patients with severe respiratory failure who are not responding to conventional management should undergo early transfer to a hospital with ECMO capabilities if clinically feasible.

Bridge to transplant. In select cases, clinicians have elected to use ECMO as a bridge to lung transplant. rECMO in this context is used to facilitate reduced sedation, reduced ventilatory support and to promote participation in rehabilitation and ambulation in the pretransplant period (6, 28, 29). The evidence is limited to observational cohort studies or expert opinion.

Patient Selection and Timing for cECMO Support

Bridge to recovery. cECMO uses a venoarterial configuration primarily to support heart failure and cardiogenic shock (1). cECMO as a bridge to recovery is initiated for reversible conditions, such as acute myocardial infarction, refractory ventricular

TABLE 2. Entry Criteria for EOLIA and CESAR Trials

Entry Criteria	EOLIA	CESAR
Severity of lung disease	Acute respiratory distress syndrome + one of the following: 1) Hypoxemia despite optimization of mechanical ventilation (V_T set at 6 mL/kg and trial of PEEP ≥ 10 cm H_2O) and adjunctive therapies (nitric oxide, recruitment maneuvers, prone position, high frequency oscillation ventilation, almitrine infusion) a) P/F < 50 mm Hg with F_{IO_2} ≥ 80% for > 3 hr or b) P/F < 80 mm Hg with F_{IO_2} ≥ 80% for > 6 hr Uncompensated hypercapnia pH < 7.25 with Pa_{CO_2} ≥ 60 mm Hg for > 6 hr despite increasing the respiratory rate increased to 35 breaths per minute while maintain plateau pressure ≤ 32 cm H_2O (first by reducing V_T by steps of 1 mL/kg to 4 mL/kg and second by PEEP reduction to a minimum of 8 cm H_2O)	Acute respiratory failure + one of the following: 1) Murray score ≥ 3 and F_{IO_2} 100% despite optimum conventional treatment The Murray score is the sum of a–d: a) CXR: 0.25 points for each quadrant of CXR consolidation b) P/F: 0.25 points if P/F is 225–299; 0.5 points if P/F is 175–224; 0.75 points if P/F is 100–174; and 1 point if P/F is < 100 c) PEEP: 0.25 points if PEEP is 6–8; 0.5 points if PEEP is 9–11; 0.75 points if PEEP is 12–14; and 1 point if PEEP is ≥ 15 d) Compliance (V_T/driving pressure): 0.25 points if compliance is 60–79; 0.5 points if compliance is 40–59; 0.75 points if compliance is 20–39; and 1 point if compliance is ≤ 19 2) Acidosis: pH < 7.2
Duration of mechanical ventilation	Receipt of mechanical ventilation for < 7 d	Peak inspiratory pressure > 30 cm H_2O or F_{IO_2} > 80% for more than 7 d
Age	≥ 18	18–65
Exclusions	Pregnancy; body mass index > 45; long-term ventilatory insufficiency; cardiac failure resulting in venoarterial ECMO; heparin-induced thrombocytopenia; cancer with life expectancy < 5 yr; coma after cardiac arrest not due to medications; moribund (Simplified Acute Physiology Score > 90); and unable to obtain vascular access for ECMO	Intracranial hemorrhage; contraindication to heparinization; and contraindication to continued therapy

CESAR = Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure, CXR = chest radiograph, ECMO = extracorporeal membrane oxygenation, EOLIA = Extracorporeal Membrane Oxygenation for Severe Acute Respiratory Distress Syndrome. P/F = ratio of Pa_{O_2}/F_{IO_2}, PEEP = positive end-expiratory pressure, V_T = tidal volume.

arrhythmias, pulmonary embolism, acute myocarditis, or postcardiotomy shock (9). The decision to initiate cECMO should include evaluation of the benefits and risks of the other modes of MCS (7).

Recommendation: cECMO can be considered for patients with cardiogenic shock, especially with signs of poor perfusion and failure of medical therapy, transferring to a specialty center capable of both long-term and short-term support options when clinically appropriate.

Bridge to transplant or mechanical circulatory support. cECMO provides a rapidly deployable cardiopulmonary support option that can provide a bridge to a temporary MCS device, heart transplant, or long-term ventricular assist device. cECMO may be advantageous to alternative MCS strategies in biventricular failure, cardiac arrest, or combined cardiopulmonary failure.

Extracorporeal cardiopulmonary resuscitation. ECPR is emergently deployed venoarterial ECMO for circulatory support in a patient who has failed to achieve sustained return of spontaneous circulation with conventional CPR (1). Although trials are ongoing, there are currently no randomized controlled trials that address the efficacy of ECPR. Data from observational studies and entry criteria for ongoing trials suggest that patients with younger age, shockable rhythms, reversible etiologies of arrest, witnessed arrests with bystander CPR, and shorter transition times to definitive care are more like to be considered candidates for ECPR (5, 30).

Recommendation: ECPR requires emergent, time-sensitive deployment of invasive life support; therefore, we recommend centers offering ECPR establish a multidisciplinary ECMO team with explicit guidelines for patient selection, exclusion, and team member notification. Intensivists should play a central role in the formation of these guidelines and the delivery of subsequent intensive care needs.

Topic 2: The Role of the Intensivist in Cannulation for ECMO

Variation exists in the type of clinicians performing cannulation for ECMO. Cardiothoracic surgeons, general surgeons, vascular surgeons, interventional cardiologists, interventional radiologists, emergency medicine physicians, and intensivists have reported effective and safe cannulation for ECMO (31–33). Physicians should practice within their trained skillset and be prepared for life-threatening complications can occur during cannulation. Consequently, there must be a plan to address complications including identifying surgical support for intrathoracic surgical emergencies (9, 34).

Regardless of who performs cannulation, intensivists should be involved in decision-making surrounding cannulation, which will ultimately impact the long-term ICU management of these patients. These decisions include ECMO configuration and anatomic cannulation site selection, access approach strategy, cannula size, the use of distal perfusion catheters, and ventricular venting strategy. At times intensivist involvement may not be possible because ECMO cannulations will occur emergently in the operating room, catheterization suite, or emergency department.

Recommendation: Many specialists, including intensivists, can successfully perform cannulation for ECMO. For cases where the intensivist does not cannulate, the intensivist should remain involved in the decisions surrounding cannulation such as timing, configuration, and cannula size, all of which can impact ICU management.

Recommendation: Intensivists performing cannulation should use percutaneous access in lieu of open cannulation techniques.

Cannulation Decisions Related to rECMO. In rECMO, there are two types of cannulas: single- and dual-lumen cannulas. Single-lumen cannulas require a minimum of two cannulation sites, while dual-lumen cannulas allow for drainage and return of blood from a single site. Relative to dual-lumen cannulas, single-lumen cannulas can be easier to place, but two-site cannulation has the potential for more recirculation than single-site cannulation (35, 36).

Cannulation Decisions Related to cECMO. cECMO may be initiated with central cannulation through a sternotomy site (e.g., when there is an inability to wean from cardiopulmonary bypass) or peripheral cannulation of an artery and vein, usually via the femoral vasculature. Peripheral cannulation for cECMO places the ipsilateral lower extremity at risk for ischemic injury (see cannula-related complications section below).

Section 3: Avoiding and Rescuing Patients From ECMO-Related Complications

Adults receiving ECMO are at risk for patient and mechanical complications (**Table 3**) (2). A role of the intensivist is to attempt to avoid complications when possible, monitor for complications, and manage those complications that occur.

Recommendation: Intensivists should be familiar with complications specific to ECMO and should participate in developing institution-specific protocols for preventing and managing these complications.

Cannulation-Related Complications. There is variability in the tools used to visualize the wire and cannula in the vessels during ECMO cannulation—including ultrasound, echocardiography, radiography, and fluoroscopy (37). These adjunctive modalities can minimize damage to underlying structures, bleeding, and improper cannula placement (38, 39).

Recommendation: Ultrasound, radiography, and/or fluoroscopy should be used to aid in the visualization of vessels, wire, and cannula during cannulation.

Recommendation: Post-cannulation plain radiographs should be obtained to confirm cannula positioning.

Extremity Ischemia and Venous Thrombosis. Arterial cannulation places the cannulated limb at risk of ischemic injury by obstructing distal arterial blood flow, and untreated ischemia can lead to compartment syndromes or amputation (Table 3). The decision to perform arterial ECMO cannulation should be accompanied by a plan to ensure adequate circulation and monitoring of circulation to the distal extremity. Options include end-to-end side graft to the femoral artery, selection of a smaller arterial cannula, or addition of a distal reperfusion cannula (40–43). Intensive neurovascular evaluation of the distal extremity is required. Following removal of venous cannulae, deep venous thromboses can be common.

Recommendation: Intensive evaluation of the distal extremity is necessary with arterial ECMO cannulation, with particular attention to any signs of ischemic injury which can be limb threatening.

Increased Left Ventricular Afterload. cECMO cannulation can be associated with increased left ventricular (LV) distension, particularly in the case of peripheral cECMO, due to retrograde arterial blood flow and increased LV afterload. In the setting of poor LV function, this can lead to LV distension, pulmonary edema, or pulmonary hemorrhage. LV decompression can be considered via a surgically placed left atrial or LV vent, catheter-based septostomy, or peripherally inserted axial flow pump (44, 45).

Recommendation: Intensivists should be aware of the clinical manifestations of LV distension and develop clinical thresholds and strategies for decompressing the LV.

Bleeding. Bleeding is one of the most common complications associated with ECMO (Table 3). A critical role of the intensivist is to manage bleeding risk, monitor for bleeding complications, and respond to bleeding complications. Intracranial hemorrhage can come to clinical recognition incidentally or overtly, but in either case requires timely evaluation and response (46, 47). Intracranial hemorrhage can lead to fatal herniation and brain death. Giani et al (48) provide Guidance on brain death evaluation among ECMO supported patients.

Recommendation: For bleeding patients on ECMO, the intensivist role is to evaluate if clinically significant bleeding is present, evaluate the patient's ability to form and maintain clot, evaluate the ECMO circuit's clot burden, and assimilate the information to decide if anticoagulation should be reduced or held and assess if bleeding will require further medical or procedural interventions.

Recommendation: Intracranial hemorrhage on ECMO can be life threatening. Potential options for the managing

TABLE 3. Adverse Events During Extracorporeal Membrane Oxygenation Among Adults From 2013 to 2017, by Indication

Adverse Event	Respiratory, *n* = 11,507	Cardiac, *n* = 11,920
Patient complications		
Surgical site hemorrhage	808 (7.0)	1,886 (15.8)
Pulmonary hemorrhage	493 (4.3)	297 (2.5)
Intracranial hemorrhage	389 (3.4)	243 (2.0)
CNS infarction	212 (1.8)	441 (3.7)
Seizure electroencephalogram confirmed	46 (0.4)	71 (0.6)
Cardiopulmonary resuscitation required	446 (3.9)	348 (2.9)
Cardiac tamponade due to blood	111 (1.0)	496 (4.2)
Limb amputation	28 (0.2)	68 (0.6)
Mechanical complications		
Pump malfunction	116 (1.0)	72 (0.6)
Oxygenator failure	697 (6.1)	339 (2.8)
Cannula malfunction	590 (5.1)	407 (3.4)

intensivist include holding/decreasing anticoagulation, evaluation for ECMO discontinuation, serial neurologic examination, neuroimaging, and neurosurgical evaluation as appropriate.

There are no consensus recommendations for the optimal anticoagulation strategies, anticoagulation monitoring, or strategies to avoid hemorrhagic complications during ECMO support (49). Potential targets for anticoagulation include activated clotting time, partial thromboplastin time, anti-Xa levels, or thromboelastogram values.

Bleeding can be a complication of procedures performed during ECMO (48). Although procedures commonly performed in the ICU (e.g., tracheostomy or tube thoracostomy) are often well tolerated, they may lead to life-threatening hemorrhage in patients receiving ECMO.

Recommendation: The decision to perform any procedure on patients supported by ECMO should be carefully weighed against the risk of hemorrhage, and performed by clinicians with significant expertise after a plan has been developed for how anticoagulation will be adjusted.

***Thrombosis and Mechanical Failure*.** Thrombosis during ECMO is common and can lead to mechanical inefficiency or failure as well as embolic or thrombotic complications to the patient. Severe mechanical thrombosis can require elective or emergent circuitry replacement (2, 50). A plan for rapidly replacing failed equipment is an essential part of the management plan for ECMO patients.

Recommendation: Hospitals should have a ready and rapidly deployable plan for replacing failed ECMO equipment, as well as a protocol for monitoring equipment in order to diminish the risk of failure.

Topic 4: Leading a Multidisciplinary Team

Expert consensus recommendations suggest ECMO should be delivered with a formalized multidisciplinary team that encourages communication, invites multidisciplinary perspective, and regularly reviews cases for improvement (5, 10, 51, 52). Participants in the ECMO multidisciplinary team may include nurses, physicians, ECMO specialists/perfusionists, nutritionists, pharmacists, respiratory therapists, physical and occupational therapists, hospital administrators, members of the palliative care team, and other key stakeholders at the institution. A process for balancing the expertise of the ECMO multidisciplinary team with the expertise of the remaining critical care team is imperative. The process should address care continuity, emergent decision-making, routine decision-making, and family and team communication.

In the absence of high-quality evidence to guide the care of patients on ECMO, process improvement is an essential part of assessing data and applying it to the care of this specific patient population. Intensivists are in a unique position to lead these multidisciplinary efforts to improve quality of care for patients on ECMO.

Recommendation: The establishment of a multidisciplinary care team responsible for daily rounds to provide continuity of care, surveillance of quality metrics, and a mechanism to perform case review at regular intervals is essential.

Topic 5: Surrogate Decision-Maker Communication

When patients are considered for and managed with ECMO, they often lack decision-making capacity (12), and therefore SDMs usually partner with the medical team for medical decision-making. Although there is limited evidence regarding family communication in the ECMO population, a trial in critically ill patients found that a family support intervention improved SDM ratings of quality of communication (53). We recommend that intensivists have established processes for ensuring effective communication with SDMs. Palliative care physicians, case managers, and ethicists may be helpful partners in facilitating family communications for selected patients requiring ECMO (54, 55).

Recommendation: Established processes should exist for ensuring family-centered communication. Other team members involved in surrogate communications (e.g., palliative care, case management) should be familiar with the unique challenges related to the care of patients receiving ECMO.

DISCUSSION

Although complex and resource intensive, ECMO plays an important role in the care of patients with severe cardiac and respiratory failure. The increasing availability and utilization of ECMO underscores the expanding role that intensivists will be expected to play in the management of patients supported by this technology. As with other aspects of critical care, the provision of ECMO is best performed by a multidisciplinary team, which the intensivist is in a unique position to engage, involve, and lead. However, intensivists can only play this role if they are knowledgeable and familiar with ECMO physiology, indications, and complications. This position paper provides 18 strong and five weak recommendations in five topic areas of ECMO initiation and management.

There are many essential components of care of patients on ECMO to include anticoagulation, pharmacokinetics, and mechanical ventilation. However, although vital to the daily management of these patients, there is limited evidence demonstrating the superiority of any particular approach. Further efforts will be required to collect and consolidate evidence, garner expert opinion, and develop practice guidelines, in order to properly prepare critical care professionals to manage this complex patient population.

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