Extracorporeal Life Support Organization (ELSO)

Guidelines for ECMO Transport

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This document is scheduled to expire by May 2018. After this date, users are encouraged to contact the ELSO Guidelines Editorial Board to confirm that this document remains in effect.

Disclaimer

These guidelines describe useful and safe practice for extracorporeal life support (ECLS, ECMO) but these are not necessarily consensus recommendations. These guidelines are not intended as a standard of care, and are revised at regular intervals as new information, devices, medications, and techniques become available. These guidelines are intended for educational use to build the knowledge of physicians and other health professionals in assessing the conditions and managing the treatment of patients undergoing ECLS / ECMO. These guidelines are not a substitute for a health-care provider's professional judgment and must be interpreted with regard to specific information about the patient and in consultation with other medical authorities as appropriate. In no event will ELSO be liable for any decision made or action taken in reliance upon the information provided through these guidelines.

Key words: mobile ECMO, ECMO transport, ECLS, Extracorporeal membrane oxygenation, extracorporeal life support

PURPOSE

The "*ELSO Guidelines for ECMO Transport*" is a document developed by the Extracorporeal Life Support Organization (ELSO) as a reference for current and future mobile extracorporeal membrane oxygenation (ECMO) programs. It is to be used as a guideline for designing and establishing an inter-facility ECMO transport program by centers already performing in-house ECMO. It is assumed that each center considering mobile ECMO is already an established ECMO referral facility with established non-ECMO inter-facility critical care transport, and complies with existing ELSO Guidelines. It is also assumed that any patient being considered for ECMO transport has already been separately evaluated for the need for extracorporeal support. This guideline addresses the candidacy for and execution of extracorporeal transport, not ECMO candidacy in general. Institutional and personnel requirements for ECMO programs are addressed in the ELSO documents, "*Guidelines for ECMO Centers*" and "*Guidelines for Training and Continuing Education of ECMO Specialists*."
For the purpose of this document, the term ECMO comprises all modes of extracorporeal circulation, whether being provided for oxygenation or circulatory support.

CLINICAL FACTORS IMPACTING DECISION FOR ECMO TRANSPORT

A. ECMO inter-facility transports are defined in the following manner:
    1. "*Primary Transports*" - - situations in which the transport team is required to perform cannulation for ECMO support at the referring facility and then transport the patient to an ECMO center
    2. "*Secondary Transports*" - - situations in which the patient is already supported with ECMO at the referring facility and needs to be transported to another center for one of several reasons

B. Clinical factors that impact a patient's candidacy for ECMO transport mirror the combined criteria for any ECMO support (See Criteria for Neonatal/Pediatric/Adult ECMO support) and interfacility transfer.

    1. Refractory hypoxemia/hypercapnia (failure of mechanical ventilator support)
        i. Unacceptable risk of deterioration during conventional transport in the best clinical judgment of managing physicians
        ii. Inability to maintain acceptable oxygenation/ventilation without high frequency oscillatory ventilation (HFOV) (*although high frequency modes of ventilation during transport are possible in select patient populations, HFOV transport is not currently feasible*)
        iii. Dependence upon inhaled nitric oxide (iNO) in treatment of hypoxemic respiratory failure is *not* an absolute contraindication to conventional transport, as iNO can be safely administered during transport
        iv. Presence of air leak syndrome(s) likely to worsen with continued high levels of positive airway pressure and altitude
    2. Refractory septic/cardiogenic shock despite aggressive inotropic/pressor support

i. ECMO support for refractory septic shock may be considered as an indication for ECMO transport primarily in neonatal and pediatric patients
ii. Degree of pre-transport hypoperfusion/hypotension/acidosis coupled with risk of further deterioration during transport (expected duration of transport) must be considered

3. Specific clinical scenarios which may necessitate ECMO transport:
    i. Worsening acute respiratory distress syndrome (ARDS) or other etiology of acute refractory respiratory failure at a center not capable of providing ECMO
    ii. ECMO support initiated at referring center for primary cardiac failure and patient needs transport to transplant center for evaluation for possible orthotopic heart transplantation (OHT) or other cardiac intervention
    iii. Patient who is a possible candidate for lung transplantation requires ECMO for safe transfer to transplant center
    iv. Patient placed emergently and unexpectedly on ECMO support at center without resources to maintain patient on long-term ECMO support

C. Choice of cannulation type. All patients should have a careful evaluation of their hemodynamical status before cannulation, comprising an echocardiography to assess their myocardial function and evaluate their cardiac output.

1. Venovenous (VV) ECMO may be used for transport of patients with severe respiratory failure who have clinical and echocardiographic evidence of adequate cardiac function at the time of transport
2. Venoarterial (VA) ECMO should be considered for transport of hemodynamically unstable patients and/or in cases of significant cardiac dysfunction

D. CONTRAINDICATIONS to mobile ECMO. Clinical factors that would render the patient not a suitable candidate for ECMO transport mirror those factors which would make initiation or continuation of ECMO support in general inappropriate. However, a patient who does not require extracorporeal support at the referring center may benefit from ECMO transport if transfer is required and the patient is too labile for safe conventional transport. The additional logistical requirements of supporting an ECMO transport cannot be underestimated and may render a given patient movement infeasible.

OTHER FACTORS IMPORTANT IN PLANNING FOR ECMO TRANSPORT

A. General
    1. The transport mission includes transport of the ECMO team to the referring facility, followed by transport of the patient to an ECMO center
        i. The receiving facility is usually the transport team's own facility.
        ii. In some instances, the receiving facility may be another center to which the patient is referred for a variety of reasons (*e.g. availability of specialized care, proximity to family support*)

2. A major priority in planning a *Primary Transport* (patient requires cannulation and initiation of ECMO) is expediting the arrival of the ECMO team at the referring facility.
    i. For *Secondary Transports* (patient already supported with ECMO), the timeliness of the team's arrival at the referring facility may not be as critical
3. The overriding priority in transporting the patient to the ECMO center is patient safety.
    i. Time required for patient stabilization prior to moving (*i.e. "ground time"*) may be lengthy and is of secondary priority to patient safety during the transport.
    ii. When a prolonged ground time at the referring facility is anticipated, additional supplies, personnel, and equipment may be required and must be allocated.
4. For practical reasons the same transport vehicle is most often used in both directions. However, in some instances of *Primary Transport*, when a suitable return vehicle is not readily available, the transport team may choose to use a different vehicle to rapidly reach the patient and initiate ECMO support, while the transport return is being organized.

B. Geographic Factors
    1. Distance between referral center and ECMO center, and therefore duration of the mission, plays a large role in dictating the mode of transport. In each case, geographic considerations must be viewed in the context of clinical, weather, and resource priorities. If the duration of *en route* care is expected to exceed 3-4 hours by ground, then air transport should be considered. General distance references include:
        i. Ground ambulance feasible for distances approximately ≤ 250 miles (400 km)
        ii. Helicopter feasible for distances approximately ≤ 400 miles (650 km)
        iii. Fixed wing aircraft usually necessary for missions > 400 miles (650 km)

C. Weather-related Issues
    1. Great impact on air transport (helicopter and fixed wing)
    2. Ice/snow or other hazardous road conditions may impact the feasibility of ground transport
    3. Some helicopters and all commercial fixed wing air ambulances are capable of flight in Instrument Flight Rules (IFR) conditions
        i. IFR mission usually necessitates arrival/departure from local airport rather than hospital-to-hospital directly
    4. The impact of weather on the suitability of air transport for a given mission should **always** be a pilot decision with no input from the medical team

D. Aircraft/Vehicle Availability and Capabilities

	Ground Ambulance	**Helicopter**	**Fixed Wing Aircraft**
Space for team and equipment	Sufficient (4-5 team members)	More limited (3-5 team members)	Variable (≥ 4 team members)
Noise	Relatively Little	Very loud	Loud
Distance range for reasonable transport times	Up to 250-300 miles (400 km)	Up to 300–400 miles (650 km)	Any distance

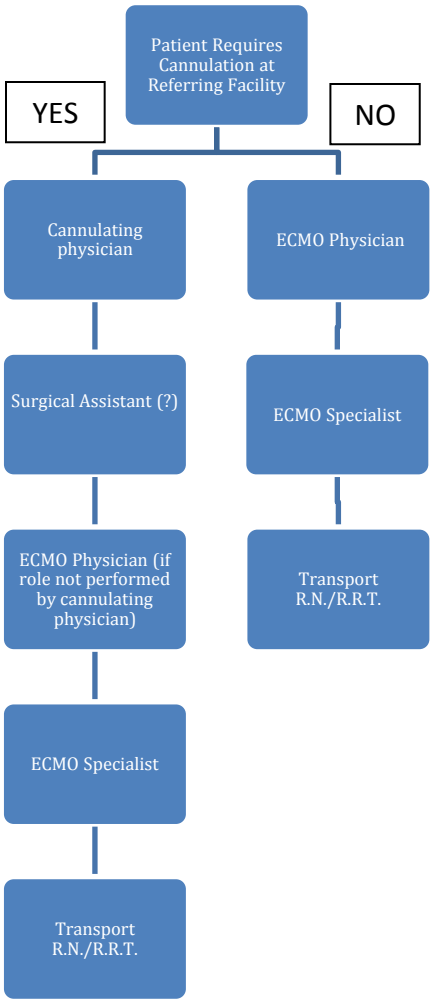
Weight Limitations	Unlimited	(depending on aircraft and weather) Limited (impacted by distance and weather)	Variable (depending on aircraft and conditions)
Loading and securing equipment and ECMO circuit/patient	Relatively easy	Relatively easy	Variable (depending on equipment and aircraft model)
Cost	++	+++	++++

1. Any vehicle/aircraft must have appropriate electrical supply capability for ECMO and all other equipment for the duration of the mission
2. Climate control
3. Reliable oxygen supply (other than transport cylinders)
4. Suction
5. Compressed Air
6. Adequate Lighting
7. Adequate space for necessary team members and equipment

E. Personnel/Team Composition

1. Team Roles/Responsibilities

   The responsibilities of the transport team are listed below. The exact composition of the team and the specificity of team member roles may vary among centers. However, these minimum responsibilities must be met by experienced personnel. The clinical scenario, cannulation setting, and the duration or complexity of the transport may dictate the inclusion of additional team members, such as additional nurses or physicians. Intercontinental ECMO transports represent a unique level of complexity, coordination, and personnel demand, and the potential for physiologic stress and fatigue must not be underestimated. The commitment of experienced personnel to the transport mission must not compromise the center's ability to provide care at home. Below is an example of a common team composition.



i. Cannulating Physician
   1. Primary responsibility is safe and proper placement of ECMO cannula(s)
   2. For neonatal/pediatric ECMO, this is typically a pediatric surgeon or pediatric cardiovascular surgeon
   3. For adult ECMO, this may be general surgeon, vascular surgeon, cardiovascular surgeon, or intensivist
   4. In some circumstances, ECMO team may choose to work with a surgeon and surgical team from the referring hospital if such collaboration facilitates timely patient transfer

ii. ECMO Physician
   a. Must have substantial experience in management of ECMO patients

b. On arrival at referring facility, promptly assesses patient and pertinent clinical data while ECMO Specialist and other team members prepare for cannulation or change to transport ECMO circuit.
c. In rare cases, the patient's condition may have deteriorated between the time of referral call and arrival of ECMO team to the point that ECMO support may no longer be appropriate (*e.g. prolonged cardiac arrest with clinical evidence of severe neurologic injury*). In these rare but difficult circumstances, the ECMO physician must have sufficient clinical experience and judgment to stop ECMO initiation and to discuss with referring physician, hospital staff, and the patient's family. Conversely, the patient may have demonstrated interval improvement, making ECMO initiation unnecessary and allowing safe conventional transport.
d. Obtains informed consent for ECLS and for transport from next-of-kin
e. Assumes and directs medical management of the patient during cannulation/change of ECMO circuit, and throughout the transport
    - Administration of heparin bolus at time of cannulation
    - Administration of any needed deep sedation/analgesia
    - Management of mechanical ventilation, vasoactive infusions, etc

iii. <u>ECMO Specialist</u>
a. Primary responsibility for ensuring all equipment on checklist is functional and loaded at time of departure
b. Primary responsibility for communication of blood product requirements with referring hospital staff prior to ECMO transport team's departure
c. Primary responsibility for priming/preparation of transport ECMO circuit upon team's arrival at referring hospital
d. Primary responsibility for management of ECMO circuit during all phases of transport
e. Must possess extensive experience in ECMO circuit/patient management

iv. <u>Transport Nurse</u>
i. Administers medications, fluids, and blood products, and assists in patient assessment
ii. Primary responsibility for patient nursing care during all phases of transport
iii. To allow cross-tasking, it is strongly recommended that the transport nurse also has experience with ECMO patient/circuit management

v. <u>Transport Respiratory Therapist</u>
a. If aircraft/vehicle space allows, ideally a transport respiratory therapist will accompany ECMO transport team
b. Primary responsibility for ventilator set-up and management, gas connection/disconnection, ventilator trouble-shooting
c. Assists with blood gas analysis, circuit blood sampling per team policy
d. If space/team configuration does not allow, then transport nurse, ECMO specialist, and/or medical physician must be able to execute these tasks competently

EQUIPMENT FOR ECMO TRANSPORT

A. A checklist should be completed before departure.

B. The circuits and equipment utilized for mobile ECMO are the same as components used for in-house support. However, unique aspects and limitations of the transport environment impose specific requirements for transport equipment. If used for air transport, all individual equipment components must meet air worthiness criteria, as established by relevant state, national, or international regulatory agencies. These requirements include the ability to function appropriately and safely throughout exposure to the thermal, vibrational, and acceleration/deceleration forces of the flight environment. The emission of Electromagnetic Interference (EMI) must be low enough so as not to compromise aircraft flight equipment and controls. In some cases, modification with EMI shielding is necessary to make an item safe for use in flight. Such shielding adds weight and can affect equipment portability and use.

C. A mobile ECMO system shall consist of the following minimum components:
    1. Suitable blood pump, centrifugal or roller
    2. Membrane oxygenator, appropriate for the patient size
    3. Device(s) for heating and regulating circuit blood temperature (less critical for adult transports)
    4. Medical gas tanks, regulators, hoses, connectors, flow meters, and blenders for provision and adjustment of blended sweep gas to the oxygenator
    5. Venous and arterial pressure monitoring device(s), according to center-specific practices
    6. Point-of-care anticoagulation monitoring equipment (e.g., Activated Clotting Time)
    7. Emergency pump or manual control menchanism in the event of primary pump failure or power failure
    8. Uninterruptable power source(s) capable of meeting the electrical power needs of all equipment during transfer between vehicles and in the event of vehicle power source failure.
    9. Portable ultrasound machine, if not provided by the referring facility.

D. Mobile ECMO personnel must be familiar with the voltage, current, and power requirements of all equipment. Checklists should include this information for rapid reference prior to and throughout the patient transfer

E. Additional components that can improve the safety of mobile ECMO include:
    1. System for servo-regulation of flow to balance venous drainage rate from the patient and blood return to the patient
    2. Blood flow rate monitor (may be internal or external to the blood circuit)
    3. Monitor(s) for circuit blood temperature, blood gas, oxygen saturation, and hemoglobin (may be internal or external to the blood circuit)
    4. Capacitance “bladder” incorporated into the circuit
    5. Bubble detector with or without automatic pump regulation function

6. Portable air compressor with hoses, for provision of blended gas without reliance upon air cylinders

F. Transport equipment, separate from the ECMO system, shall include:
    1. Patient ventilator, appropriate for the patient's size and clinical needs
    2. Medical gas tanks, regulators, hoses, connectors, flow meters, and blenders for provision and adjustment of blended gas to the patient ventilator
        i. optional air compressor (contingent upon vehicle capabilities)
        ii. optional portable liquid or gaseous oxygen source (contingent upon vehicle capabilities)
    3. Point-of-care device for monitoring blood gases, electrolytes, glucose, hemoglobin
    4. Medication and fluid infusion pumps
        i. Backup components of critical items must be available
        ii. Centers shall ensure that in-house patient safety is not compromised by the utilization of ECMO components for transport, and vice versa. This is best accomplished by maintaining equipment specifically dedicated for transport use, above and beyond that needed to meet the in-house ECMO workload
        iii. Patient/ECMO transport cart. Potentially significant engineering and modification of the patient transport sled may be required to safely accommodate the additional equipment and supplies required for ECMO. Centers may choose to use a comprehensive transport cart that is permanently configured to carry the patient and house all transport and ECMO components, to include securing the blood circuit to avoid kinking and damage

G. Patient. The cart will enable the safe movement of the patient, in compliance with accepted patient transport standards. Specifically, the cart shall:
    1. Incorporate adequate patient restraints
    2. Have the strength and ballast necessary to support the patient's size and weight for prolonged period
    3. Be large enough to completely contain the patient within the cart perimeter
    4. Be secured to a wheeled sled that enables nonturbulent patient movement and transition to/from any vehicles used throughout the transfer.
    5. For neonates, a neutral thermal enclosure is optional. Regulation of circulating ECMO blood temperature typically obviates the need for a patient enclosure to provide neutral thermal environment.

H. Equipment. Each component item must be mounted or housed so as to:
    1. Securely stabilize the component against vibration, acceleration, and deceleration forces in all directions
    2. Avoid potential impact or interference with other components
    3. Allow fixation and removal for repair, scheduled maintenance, and exchange
    4. Incorporate power cords and connecting cables securely, including mitigation against spark/fire risks. Critical components must be plugged in to uninterruptable power source(s) within amperage limits of the circuitry

5. If the oxygenator is secured above the patient, a risk of air embolus exists if accidental stoppage of the pump occurs. This risk is minimized by securing the oxygenator at a level below that of the patient.

SUPPLIES

A. In addition to transport supplies necessary to meet patient care needs throughout transport, the team must be self-sufficient with respect to ECMO supplies. Supplies specific to the cannulation and sustainment of ECMO care throughout the transport duration are required. Potential delays and complications must be anticipated and an appropriate surplus and redundancy of supplies carried. Examples include spare ECMO circuits, spare ventilator circuits, additional IV tubing, needles, syringes, diapers, etc.
SEE ATTACHMENT #1 FOR SAMPLE SUPPLY LIST

B. If cannulation is intended at the referring center, all necessary instrument sets shall be either carried or made available from the referring facility:
   1. Cannulation surgical set / vascular surgery set
   2. Head lamp(s)
   3. Electrical cautery system
   4. Additional suction set-up for dedicated surgical use
   5. Operating room back table, kick bucket, tray tables, etc
   6. Optional bedside ultrasound device for assistance with cannulation

BLOOD PRODUCTS

A. In most cases the referring facility will provide blood products for circuit preparation, cannulation and ECMO initiation in the case of a *Primary Transport*. Required product volumes will vary with patient size, center-specific circuit volume, and priming protocols.

B. The transport team must provide the referring center with a list of requirements as early as possible, to ensure blood products are available in a timely manner. Bringing a blood product cooler will enable transportation of products for use on the return leg.

C. Blood products that commonly are required to be available for ECMO initiation include:
   1. 4 units packed red blood cells (PRBC) – *as fresh as reasonably possible*
   2. 1 unit pheresed platelets
   3. 1 unit fresh frozen plasma

MEDICATIONS

A. The concept of redundancy applies to medications as well. Appropriate preparation includes planning for anticipatable en route complications. These will be individualized to the clinical circumstances and transport parameters, but the risk of cardiopulmonary arrest is very real whenever ECMO is initiated; this

risk is amplified by the addition of destabilizing patient movement. Medications will vary with team preference and formulary inventory, and will require case-by-case tailoring to the patient's needs. *SEE ATTACHMENT #2 FOR SAMPLE NEONATAL/PEDIATRIC MEDICATION LIST*

VEHICLES

A. ECMO transport requires special consideration of vehicle capabilities and characteristics. Transitions between hospital and ambulance, and ambulance and aircraft, represent unique risk and require expert coordination to mitigate these risks. Potential complications include:
    2. Sudden vertical or horizontal movement, altering patient position
    3. Cannula movement, affecting surgical site integrity or cannula tip position
    4. Circuit kinking, compression, or catching
    5. Equipment movement or trauma

B. The use of roller pumps for ECMO transport is not recommended. The improved functionality and safety of modern centrifugal pumps, combined with their non-occlusive mechanism and shorter circuit length make them safer and more ideally suited for the transport environment. However, if roller pumps are used, compression or kinking of venous circuit tubing will result in cavitation and creation of large air bubbles. During roller pump transport, medication and fluid administration should occur post-pump, as inadvertent venous cavitation will result in the rapid entrainment of any medications or fluids being administered pre-pump.

C. Ambulance. In addition to standard ACLS and safety requirements, ambulances used for movement of ECMO patients require additional features.
    1. Adequate internal space to accommodate a potentially larger medical team and equipment. Additional ceiling height will maximize the safety of patient loading and offloading.
    2. High load capacity fixation mechanism appropriate for the increased weight of the transport cart and all components
    3. Independent oxygen source
        i. Independent compressed air source optional for short transfers; necessary for longer duration transports, to preserve portable air tanks for critical phases of transfer
    4. Power source with the voltage, current, and wattage needed to sustain all electrical components throughout the duration of the transfer. It is incumbent upon ECMO team members to be familiar with the power requirements of their equipment. In cases of international transports, appropriate electrical and gas converters are necessary.
    5. Special consideration and planning is necessary to ensure controlled and safe patient loading and unloading without relying upon heavy lifting by the ECMO team members.
        i. A powered lift platform with 1000-pound (450 kg) or greater as necessary
        ii. A non-slip ramp with appropriate weight capacity. This is reasonable for neonates in smaller self-contained incubators.
        iii. Patients being transported on collapsible gurneys should be able to on-load and offload directly at ambulance floor height.

iv. Optional pneumatic shocks on the rear axle allow minor adjustments of the ambulance height, further facilitating smooth transfer to and from the ground, loading dock, or aircraft.

D. Aircraft. Specific consideration must be given to the flight environment's effects on ECMO circulation and care. Flight altitude should be carefully planned. Higher flight level provides for shorter transport time, less turbulence, and less fuel consumption. However, at lower barometric pressure, care must be taken to avoid hyper-oxygenation of the circuit, as oxygen will bubble out of solution at a lower PO_2. Aircraft configuration and interface requirements include:
    1. Adequate internal space for personnel, equipment and supplies, and in-flight access to the patient and equipment
    2. Configuration such that loading and offloading the patient and transport cart is safe and controlled without relying upon heavy lifting by team members. This may require modification of the fuselage door or development of a specific loading ramp.
    3. Dedicated access to ample oxygen, air, and suction throughout the duration of the flight.
        i. Oxygen may be provided by high volume gas tanks, liquid oxygen, or portable liquid oxygen units
        ii. Air may be provided by high volume gas tanks or portable flight-approved air compressor. Some commercially-available aeromedical support units provide connections for oxygen tanks, entrained compressed air, suction vacuum, and outlets for compatible power.
    4. Power source or inverter to provide uninterrupted power to all ECMO and transport equipment throughout the flight
    5. Adequate lighting and temperature regulation
    6. Vibration and noise mitigation
    7. In-flight communication system to allow bidirectional communication with pilots and aircraft crew.