Extracorporeal Life Support Organization Guideline for Transport and Retrieval of Adult and Pediatric Patients with ECMO Support

AHMED LABIB,* ERIN AUGUST,† CARA AGERSTRAND,‡ BJORN FRENCKNER,§ DE'ANN LAUFENBERG,¶ GERALD LAVANDOSKY,‖ CHRISTIAN FAJARDO,# JASON A. GLUCK,** AND DANIEL BRODIE††
REVIEWERS: THOMAS MULLER,‡‡ CHRIS HARVEY,§§ GILES PEEK,¶¶ PETA ALEXANDER,‖‖ PHILLIP MASON,## AND ROBERT BARTLETT***

Disclaimer: This guideline for the preparation for and undertaking of transport and retrieval of patients on extracorporeal membrane oxygenation (ECMO) is 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 and describe what are believed to be useful and safe practice for extracorporeal life support (ECLS, ECMO) but these are not necessarily consensus recommendations. The aim of clinical guidelines are to help clinicians to make informed decisions about their patients. However, adherence to a guideline does not guarantee a successful outcome. Ultimately, healthcare professionals must make their own treatment decisions about care on a case-by-case basis, after consultation with their patients, using their clinical judgement, knowledge and expertise. These guidelines do not take the place of physicians' and other health professionals' judgment in diagnosing and treatment of particular patients. These guidelines are not intended to and should not be interpreted as setting a standard of care or be deemed inclusive of all proper methods of care nor exclusive of other methods of care reasonably directed to obtaining the same results. The ultimate judgment must be made by the physician and other health professionals and the patient in light of all the circumstances presented by the individual patient, and the known variability and biological behavior of the clinical condition. These guidelines reflect the data at the time the guidelines were prepared; the results of subsequent studies or other information may cause revisions to the recommendations in these guidelines to be prudent to reflect new data, but ELSO is under no obligation to provide updates. In no event will ELSO be liable for any decision made or action taken in reliance upon the information provided through these guidelines.

From the *Department of Medicine, Hamad General Hospital, Hamad Medical Corporation, Doha, Qatar; †Adult ECMO Department, Memorial Regional Hospital, Hollywood, Florida; ‡Department of Medicine, Division of Pulmonary, Allergy, & Critical Care Medicine, Columbia University, New York; §Department of Surgery, Karolinska Institute, Sweden; ¶Pediatric Cardiovascular Intensive Care Unit (CVICU), Joe DiMaggio Children's Hospital, Hollywood, Florida; ‖Department of Pediatric Critical Care, Joe DiMaggio Children's Hospital, Hollywood, Florida; #Department of Cardiothoracic Surgery, Clínica las Condes, Chile; **Department of Medicine, Division of Cardiology, Hartford Hospital, Hartford, Connecticut; ††Department of Medicine, Division of Pulmonary, Allergy, and Critical Care Medicine, Columbia University, New York; ‡‡University Hospital Regensburg, Regensburg, Germany; §§University Hospitals of Leicester NHS Trust, Leicester, England, UK; ¶¶University of Florida Health, Gainesville, Florida; ‖‖Boston Children's Hospital, Boston, Massachusetts; ##Brooke Army Medical Center, San Antonio, Texas; and ***Professor Emeritus, Michigan Medicine, Ann Arbor, Michigan.

Submitted for consideration December 2021; accepted for publication in revised form December 2021.

Disclosures: The authors have no funding or conflicts of interest to report.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML and PDF versions of this article on the journal's Web site (www.asaiojournal.com).

Correspondence: Ahmed Labib, MBBCh (Hons), FRCA, Department of Medicine, Hamad General Hospital, Hamad Medical Corporation, Al-Ryann Road. Po Box 3050
Doha, Qatar. Email: ashehatta@hamad.qa

DOI: 10.1097/MAT.0000000000001653

Introduction

As the indications for extracorporeal membrane oxygenation (ECMO) exponentially expand, transportation of patients on ECMO support or the rescue of patients at outside facilities with ECMO implantation adds an additional degree of complexity to the already complicated task of transporting critically ill patients. Mobile ECMO requires a unique skill set focused on the care of a patient requiring ECMO. This guideline aims to provide ECMO centers with a practical reference for providing primary and secondary mobile ECMO services. The same principles apply to the transport of patients with other modes of extracorporeal life support for example, extracorporeal carbon dioxide removal.

Transport of ECMO patients requires coordination and careful considerations of potential risks and benefits of transport and is typically accomplished *via* ground or air. In most cases, the circuit and equipment utilized for mobile ECMO are the same as the components used for in-house ECMO support with adaptation for the unique aspects of mobile care. Regardless of transport mode or equipment, safety of the patient, transport team, and public is paramount during ECMO transport. There is little evidence guiding the transport of patients supported with ECMO; however, it is recommended that transport be performed by well-equipped teams acquainted with mobile transport.[1–3] Several case series describe safe transportation of patients supported with ECMO using different models and team structures.[4–13] This guideline is predominantly based on expert opinion.

Section I: Types of ECMO Transportation

There are several types of ECMO transportation defined by where the patient is retrieved from, transported to, and by which facility's ECMO team. This section contains common types with a description of defining criteria. This may be helpful in determining team responsibility, authority, and other policy and operational implications.

a. **Primary ECMO transportation**. A mobile ECMO team initiates ECMO at an outside facility and, after initial stabilization the patient is transferred to an ECMO center.

   1. Patient is a good ECMO candidate; determined by the referring and accepting ECMO team.
   2. Timely response is essential.
   3. Adequate preparedness is paramount to avoid delays and optimize patient outcomes.

b. **Secondary ECMO transportation.** A patient is currently supported with ECMO but must be transferred to another facility on ECMO support.

   1. Patient may require specialized management such as transplant or durable mechanical circulatory support.
   2. Patient may require another center's medical expertise.
   3. Family request.

c. **Tertiary ECMO transportation.** Hospital A has a patient with ECMO indication and a mobile ECMO team from Hospital B goes to Hospital A. The ECMO team from Hospital B puts the patient on ECMO and transports the patient to Hospital C with ECMO capacity.

   1. In periods of high demand there may be a Hospital C without mobile ECMO but with ECMO capacity.
   2. A hospital with mobile ECMO team capabilities, but without the capacity to receive a patient, could carry out this transport.
   3. Preparation and coordination between the three institutions is required.

d. **Intra-facility ECMO transfer.** A patient is currently supported with ECMO but must be moved within an institution.

   1. Possible reasons for intra-facility transfer: patient may require a diagnostic test (*e.g.*, CT scan), may require a procedure, or be transferring to a different floor.

Section II: Mobile ECMO Specific Considerations

Transport preparation is critical. It is important to consider the type and urgency of ECMO transport being performed, the equipment required, and develop prespecified processes for communicating and documenting salient clinical information. Well-delineated processes can increase efficiency and minimize the risk of transport.

a. Communication and documentation.

   1. Documentation of clinical information should be performed in an efficient and timely manner.

      i. Consider the use of electronic medical record tools and standardized formats.
      ii. Consider the use of a standardized referral form (see Figure 1, Supplemental Digital Content 1, http://links.lww.com/ASAIO/A775).
      iii. Develop a standardized referral process utilizing a centralized transfer or care logistics center when available.
      iv. Pretransport team huddle is recommended.

b. Equipment.

   1. Mobile ECMO team should be self-sufficient in terms of medication, equipment, monitoring, and diagnostic devices. An equipment checklist should be completed by the mobile ECMO team before departure. (see Figure 2, Supplemental Digital Content 1, http://links.lww.com/ASAIO/A775).
   2. Pre-prepared, stocked, and checked ECMO bag(s) are recommended for rapid team mobilization.

      i. Equipment should be standardized and available for restock upon completion of the mission.

   3. A standardized checklist should be sent to the referring hospital detailing equipment and supplies to have ready before the transport team's arrival.

      i. Supplies should be standard and basic (central line kit, drapes, gowns, gloves, *etc.*).
      ii. Medications available at bedside (heparin, fluids, pressors/inotropes, *etc.*).
      iii. Blood products.

c. The mobile ECMO specific equipment should consist of the following components:

   1. Blood pump (centrifugal is recommended) capable of providing sufficient blood flow2 with considerations listed below:

      a. The enhanced performance of modern centrifugal pumps with a nonocclusive mechanism seems a safer choice than roller pumps for mobile ECMO.
      b. Roller pumps have a higher potential for kinking.
      c. Inadvertent compression of venous tubing can result in cavitation.

   2. Membrane oxygenator.
   3. Appropriate cannulas and tubing for connections.
   4. Medical gas tanks and compatible hoses, pressure regulators, connectors, and flow meters for provision and adjustment of sweep gas.
   5. Back-up console, back-up motor and/or hand crank (depending on console type).
   6. Back-up circuit, circuit components, and priming fluids.
   7. Appropriate clamps for circuit emergencies.
   8. Point-of-care lab capabilities.

      a. Anticoagulation (*i.e.*, ACT).
      b. Blood gas analysis.
      c. Hemoglobin/hematocrit.
      d. Basic electrolytes.

   9. Special considerations for pediatric patients.

      a. May need to request blood for blood priming (2 units of packed red blood cells).
      b. Consider regulating blood flow based on patient weight:

         1. Consider bringing equipment for a bridge if one is expected.
         2. Consider the use of a Hoffman clamp for flow regulation.

d. Additional ECMO equipment that can be considered includes the following:

1. Heater-cooler unit (if sufficient power for operation).
2. Medical air/portable air compressor.
3. Blender.
4. Pre-and post-pump pressure monitoring.
5. Bubble detector.

e. Additional critical care transport equipment recommended:

1. Transport ventilator appropriate for patient size and clinical needs.
2. Transport monitor for vitals including end-tidal CO_2 and invasive monitoring when able (arterial, central venous/pulmonary artery lines).
3. Portable Point-of-Care Ultrasound (POCUS) capable of vascular imaging and transthoracic echocardiography.
4. Infusion pumps for medication and fluid infusion.
5. Electrical adapters may be necessary because the plugs may be different at the destination. ECMO Transport team should check before leaving.

f. All equipment should be mounted, strapped, locked-in, housed, or otherwise secured for transport.

1. Stabilize against vibration, acceleration, deceleration, turbulence, rough roads, inclement weather, *etc.*, as unsecured equipment can become a projectile in the event of sudden acceleration/deceleration.
2. Account for forces in all directions.
3. Cannulas should be well secured to avoid movement during horizontal and vertical movements associated with emergency medical service (EMS) travel.
4. Circuit tubing length should be as short as possible to avoid the potential for snagging and inadvertent compression.
    i. Circuit tubing should be long enough to allow for safe loading and unloading of the patient.
    ii. Overly long circuit tubing may increase the risk of kinking or compression.
5. ECMO lines should be carefully traced before, after, and during movement to ensure the absence of kinks, compression, hazard for catching or pulling that could result in hemodynamic instability including cardiac arrest and death.
6. Allow for ready access to back-up systems in case of equipment or power failure.
7. The membrane oxygenator/pump should be secured at the level of the patient, if able.
    i. When below the patient, the oxygenator can accentuate ECMO flow fluctuation and G-forces due to the impact of gravity.
    ii. When higher than the patient, the oxygenator can increase the risk of air entrapment and pump stoppage.

g. Sufficient power and back-up power should be secured for all electrical equipment (ECMO console, infusion pumps, ventilator, defibrillator/monitor, *etc.*).

1. Consider uninterruptable power source (UPS) use for sensitive powered equipment.
2. Transport ECMO team must be familiar with electric specifications of all transport equipment particularly during international transfer.

h. Ensure sufficient medical gas for the transport.

1. Availability of twice the anticipated medical gas requirements is recommended.
2. Consider the use of oxygen concentration equipment.

i. Any equipment used during air transport should meet Civil Aviation Authority, Federal Aviation Administration, or equivalent airworthiness requirements as established by the relevant state, national, or international regulatory agencies.

1. High emission of electromagnetic (EM) or radio-frequency interference may affect the performance of aircraft equipment.
2. Mobile ECMO equipment modification with EM shielding may be required for flight safety.
3. Such shielding adds weight and can affect equipment portability.

j. ECMO transport team preparedness planning includes:

1. Conduct preplanning and simulation of mobile setup and layout.
2. Establish communication and coordination regarding the optimal transportation method for both insertion and retrieval of the team (they may be different) with consideration of:
    i. Patient size and weight,
    ii. Crew size and weight,
    ii. Equipment weight, and
    iv. Modes of transportation available (ground, rotor wing, fixed wing, *etc.*).
3. Ensure adequate patient restraint such as a 5-point harness or straps.
4. Ensure adequate stretcher strength for both patient and equipment.
5. Secure all equipment and pressurized tanks (O_2, air).
6. Establish adequate pressure point protection for overweight patients.
7. Ensure visualization and access to indwelling lines, tubes, and catheters.
8. Ensure adequate power for all equipment.
9. Plan for adequate attention and mitigation for managing patient temperature.
    i. Consider use of heater-cooler,
    ii. Consider use of blankets, and.
    iii. Consider use of thermal enclosure.

Section III: Mobile ECMO Team Structure and Responsibilities

The composition of teams is variable but should be composed of no less than: team lead; cannulating provider (for primary ECMO missions, can be the same person as 1) ECMO specialist; and medical transport team/EMS. Definitions for each team member are as follows:

a. Team lead.
    1. Responsible for overall planning, execution, and oversight of the mission.
    2. Often also performing one of the other team roles, in addition to team lead.

b. Cannulating provider (for primary ECMO missions).
    1. Should be an experienced cannulation expert.
    2. Should have comfort with POCUS (both vascular and echocardiographic).
    3. Responsible for safe and appropriate placement/connection of ECMO cannula(s).
    4. Often works in collaboration with an on-site medical team.
    5. Ensure appropriate environment for ECMO implant (bedside, move to OR, interventional lab, *etc.*).

c. ECMO provider.
    1. Can be the same as cannulating provider.
    2. Should be an experienced ECMO clinician.
    3. Should have comfort with POCUS (both vascular and echocardiographic).
    4. Upon arrival to bedside, should assess/reassess the patient and pertinent data, confirm candidacy, and assist with medical stabilization.
        i. Patient's clinical status may have changed between acceptance and arrival.
        ii. Some patients may be transported without an ECMO implant.
        iii. Some patients may not be suitable for ECMO upon further review and be best left in the care of the local treating team.
    5. Provide clinical update to the patient/family while establishing expectations of ECMO and ECMO process.
    6. Obtain informed consent.
    7. Assumes direct medical oversight of the patient once cannulated and throughout transport.

d. ECMO specialist.
    1. Can be a perfusionist, nurse, respiratory therapist, or medical provider.
    2. Should be an experienced ECMO practitioner.
    3. Responsible for set up and priming of ECMO circuit.
    4. Responsible for ECMO circuit management from implant to arrival at destination center.

e. Medical transport team.
    1. Paramedic or equivalent level of care to supplement the implant team.
    2. Can include nurse or respiratory therapists.
    3. Responsible for:
        i. Patient movement and handling,
        ii. Coordination and communication with command center/dispatch,
        iii. Patient loading and offloading from transport vehicles, and
        iv. Oversight and securing of mobile medical equipment.
    4. Cross-training is recommended (nurse/critical care paramedic, respiratory therapist/critical care paramedic, etc.).
    5. If the medical transport team is unable to perform critical duties such as ventilator management, supplementation of the team with appropriate medical staff to ensure safe transport is recommended.

f. ECMO transport and retrieval teams should have the skills and competencies to perform patient assessment, cannulation, initiation/maintenance of ECMO support, and safe transportation.

g. Team training with medical simulation in the following mobile-specific areas are recommended:
    1. Mock calls for testing the communication system.
    2. Team simulation in the common transport environments the team expects to utilize for transports (ground ambulance, rotor-wing air ambulance, fixed wing air ambulance); and.
    3. High fidelity simulation of common and high-risk low-frequency events, such as:
        i. Transfer of a patient from hospital stretcher to ambulance stretcher,
        ii. Suction events,
        iii. Bleeding,
        iv. Hypotension,
        v. Arrhythmia,
        vi. Catastrophic ECMO system failure/power failure,
        vii. Cannula dislodgement,
        viii. Ambulance malfunction, and
        ix. Air entrainment.

Section IV: Mobile Mission-Specific Guidelines

ECMO centers should collaborate with EMS and establish Standard Operation Procedures (SOPs) for the activation, prioritization, and mobilization of the mobile ECMO transport team. Specific phases of ECMO transport are identified below with appropriate considerations for each phase.

a. Activation and mobilization.
    1. Requesting ECMO.
        i. The use of a clinical information form (either electronic or paper based) that can be easily shared by the ECMO team is recommended for efficient transfer of critical information from requestor to the team.
        ii. Information that should be included in this form includes:
            1. Requisition center/provider demographics,
            2. Patient demographics,
            3. Identification of person making medical decisions (patient or family) and indication if patient/family is aware ECMO consideration,
            4. Basic clinical history,

5. Current medication list,
6. Recent vital signs and vent settings if currently intubated,
7. Basic and relevant recent laboratory review,
8. Review of relevant imaging studies, and
9. Current lines and access.

2. Communication among ECMO team members – a standard method of activating and communicating within the ECMO team should be established by the mobile ECMO center.
3. A standard system of communicating relevant information back to the requesting center should be established. Documented information includes:

i. Acceptance or deferral of ECMO team activation,
ii. Names and credentials of the responding team,
iii. Patient-specific recommendations,
iv. Patient and staff preparation instructions for ECMO team arrival, and
v. Estimated time of arrival.

4. A centralized dispatch/communication center is preferred for documentation and time keeping purposes.

b. Mobilizing the ECMO team.

1. Utilizing the tools noted above, a multidisciplinary team briefing should occur for the identification and initiation of mission-specific items.

i. Identify and secure transportation, and
ii. Assembly location for both personnel and equipment should be identified.

2. Data tracking/Key Performance Indicators (KPIs) should be recorded and used for quality improvement.

i. A standardized registry repository of key data should be established and reposed for clinical research and quality improvement.
ii. KPIs should include both clinical (outcomes, morbidity, mortality, *etc*.) and performance (time from referral to ECMO team mobilization, time from assembly to patient contact, *etc*.) indicators.

3. Preparation.

i. The use of standardized and checked mobile bags is recommended.
ii. The use of a premission checklist is recommended to ensure accounting for all necessary equipment and supplies.

c. Post-cannulation.

1. Stabilization of the patient by the ECMO team postimplant should occur with consideration of the transportation needs.

i. Gradual and not sudden changes in clinical support (hemodynamic, ventilation, *etc*.) are recommended to avoid overcorrection, particularly during transport.
ii. Minimize nonessential medications.
iii. Ensure adequate hemodynamics for transport.
iv. Ensure adequate supply of medications for transport.
v. Ensure blood product availability as needed for transport.
vi. Optimize ECMO and ventilator settings as clinically appropriate.
vii. Awareness of clinical changes likely to occur during the transport is important with planning for needed interventions en route to destination center (point-of-care labs, *etc*.).

2. Transfer to the transport stretcher includes:

i. Secure patient,
ii. Secure equipment, and
iii. Ensure no equipment is left behind.

3. A standardized pretransport checklist should be completed before leaving the sending facility.

d. Transport mode selection: ideal mode of transport should be evaluated on a case-by-case basis.

1. General considerations:

i. Geographical factors and distance.
ii. Traffic conditions.
iii. Urgency.
iv. Weather condition.
v. Experience.
vi. Availability and cost.
vii. Weight of patient, crew, and equipment.

2. Patient-specific considerations.

i. Type of ECMO.
ii. Patient clinical status.
iii. Patient height and weight.

3. General/nonmode specific transport considerations:

i. Appropriate stretcher weight capacity for patient and equipment.
ii. A nonslip area for loading and unloading as available.
iii. Ability to load/unload at ambulance floor height (powered lift platform if available).
iv. Electrical inverter checked before each mission.
v. Adequate oxygen.
vi. Adequate lighting.
vii. Adequate temperature regulation.
viii. Communication method for critical information to receiving center; we require two communication methods to avoid issues, which is why we recommend redundancy and planning for transport.

4. Mode specific considerations:

i. Ground (Figure 1a, b, and c).

1. Most common and available.
2. Multiple sizes – larger patient care areas (preferentially with 360-degree access to the patient) are preferred when available.
3. Can accommodate larger teams.

ii. Air transportation, in general:

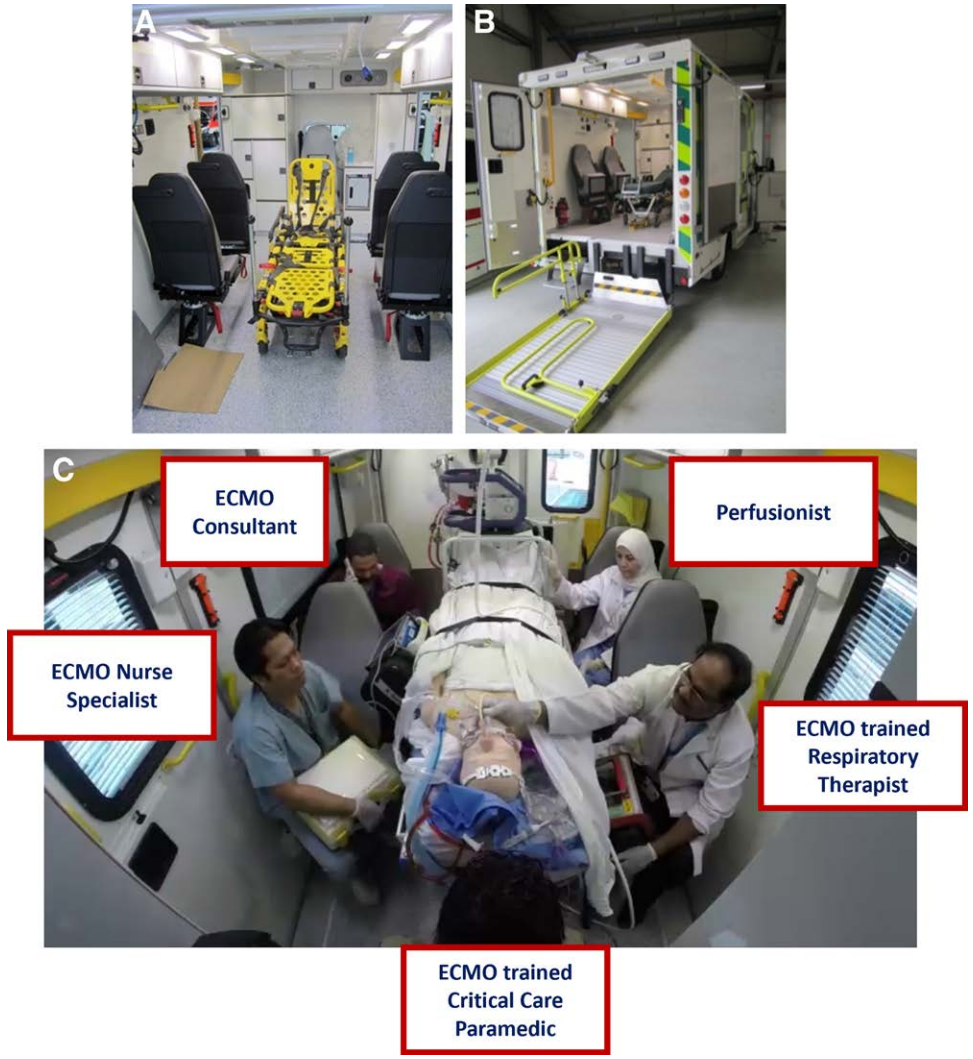

Figure 1. (A, B, and C). Spacious ICU ambulance with 360° access to patient. Seating for 5 medical personnel. Note sealed cabinet and floor for easy cleaning and infection control.

1. Pilot flying time must be considered, as time is often regulated and may impact transportation options.
2. Weather and aircraft will be coordinated with air travel regulatory agencies which may impact timing.

iii. Rotor wing (helicopter) (Figure 2).

1. Smaller cabin space has limited crew capacity.
2. More weather-dependent than ground units.
3. Flexible landing and take-off locations with vertical assent capability.
4. Helipads are available at many medical centers.
5. Not affected by road traffic.
6. Need to consider altitude within the treatment plan.
7. Often use liquid oxygen which can have variable flow at different temperatures.
8. Should factor in vibration and noise mitigation for patient, crew, and equipment. Alarms can be hard to hear.
9. In-flight communication system to allow communication with flight crew and pilot is recommended.

iv. Fixed wing (airplane) (Figure 3a, b, and c).

1. Capable of long transport distances.
2. Requires multiple transfers of the patient:
   a. Hospital bed to transport stretcher,
   b. Transport stretcher to aircraft stretcher,
   c. Aircraft stretcher to transport stretcher, and
   d. Transport stretcher to the hospital bed.
3. Consider altitude within the treatment plan.
   a. High altitude provides for shorter flight, less turbulence, and less fuel consumption.
   b. At low barometric pressure (higher altitudes), extra care must be taken to avoid hyper-oxygenation of the circuit as oxygen can bubble out of solution at lower pO_2 (rare in pressurized cabins).
   c. Effect of barometric pressure on endotracheal tube cuff.

Figure 2. Helicopter lay out. Note limited space and access to patient and equipment.

4. Liquid oxygen which can have variable flow at different temperatures.
5. UPS systems for power where available.
6. Should factor in vibration and noise mitigation for patient, crew, and equipment. Alarms can be hard to hear.
7. In-flight communication system should allow communication with flight crew and pilot.
8. Ensure all equipment is approved for aircraft use by the appropriate governing body.
9. Consider the appropriate position of infants/neonates to reduce intracranial pressure during take-off and landing, if possible.

e. Considerations for transport of patients with transmittable diseases:[14–15].

1. Follow local and international recommendations.
2. Must adhere to infection control guidelines and use of personal protective equipment.
3. Avoid aerosol-generating procedures where possible.
4. Use of high efficiency particulate absorbing filters can be added to the expiratory limb of the ventilator.
5. Vehicle decontamination is required before returning to in-service status.
6. Essential diagnostic and therapeutic interventions warrant careful planning and coordination to protect other patients, medical personnel, and the public.

f. Post-transport considerations:

1. Formal endorsement and handoff to receiving team should occur.
2. Patient transferred to the hospital bed.
3. Equipment should be cleaned and restocked for immediate use.
4. Team debriefing should occur for each case; high-volume transport centers may create more narrow debrief criteria.

Figure 3. (A, B, and C). An example of air ambulance. Note the special mechanism for lifting patient and difficult access.

5. Regular educational sessions incorporating significant events and critical incident stress debriefing should occur.

Section V: Clinical Governance and Risk Management

Providers should establish governance to ensure local and national standards for the Transport and Retrieval of ECMO-supported patients are maintained. Governance should include the use of audit, incident reporting, and feedback from patients and relatives regarding their experience.

a. Quality improvement process should be standard.
    1. Use predetermined KPIs as quality metrics (*e.g.*, cardiac arrest, air embolism, bleeding).
    2. Track process metrics (*e.g.*, compliance with checklists, timelines, and equipment failure/malfunction).
    3. Review any critical incident comprehensively, noting opportunities for improvement, if any, with actionable items. Reviews should include:
        i. Accidents or incidents affecting transport team,
        ii. Blood product utilization or waste during transfer, and
        iii. Educational opportunities for inappropriate or preventable referrals.
    4. Critical incident stress debriefing is available for crews.
b. Training and competency development includes:[16–20]
    1. Formal training in transport medicine and mobile ECMO for all team members.
        i. Course should include formal education specific to transport of ECMO patients (both primary and secondary); and
        ii. If able, simulation should be incorporated into the course for team training.
    2. High and low fidelity simulation should be utilized for facilitation and maintenance of technical and practical competency.
    3. Regularly scheduled clinical validation process is recommended.
c. Licensure and indemnity should be determined before mobilization of the ECMO transport team.
    1. Emergency credentialing is recommended for primary ECMO transport.
        i. Local, regional, and national governance should consider the need for emergency privileging to allow universal access to ECMO therapy.
        ii. Each system should develop a standard workflow to obtain emergency privileging for the primary ECMO team.
        iii. The team leader is responsible for ensuring credentialing is in place for the mobile ECMO team at the requesting hospital.
        iv. When interacting with staff at a requesting hospital, the ECMO team should utilize the expertise at the referring hospital to best understand how to obtain emergency privileges.
    2. Safety and well-being of the ECMO transport and retrieval team is top priority. Organizations should ensure appropriate indemnity and insurance to the mobile ECMO team.
        i. A priori discussions with the administration, risk management, and, as required, insurance coverage to ensure appropriate coverage for the mobile ECMO team.
    3. For teams that are flying, appropriate considerations should be taken for the implications of air travel for insurance, *etc*.
d. Finance:
    1. Close collaboration is necessary regarding documentation, coding, and billing teams to ensure adequate and comprehensive documentation from the medical and fiscal perspectives.
    2. Review of mobile cases by a multidisciplinary team to ensure appropriate coding and documentation is recommended for optimization of billing practices.
    3. While fiduciary responsibilities are important, they should not influence the candidacy of a patient for ECMO therapy.

Summary

Primary and secondary transport of patients on ECMO support is both challenging and rewarding and should be undertaken by a specialized and well-trained multidisciplinary team of experienced ECMO practitioners. The team should be self-sufficient and readily available. Mobile ECMO can be undertaken by regional or high-volume centers as this is associated with improved patient outcomes and cost reduction.[2,3] Checklists, regular practice including high fidelity simulation, and effective coordination of team roles are key elements of providing safe and efficient ECMO transport.

Acknowledgement

The authors would like to acknowledge the following people for their contributions and support in the completion of this guideline: Christine Stead, MHS (ELSO CEO), Peter Rycus, MPH (ELSO Executive Director), Elaine Cooley MSN, BSN, RRT (ELSO Clinical Program Manager), the ELSO Board of Directors as well as members of the Transport Work Group – Pranay Oza, MD, Bishoy Zakhary, MD, Lakshmi Raman, MD, Bradley Kuch, MHA, RRT-NPS, Ozzie Jahadi, CCP, Camilla Lambert Rodrigues, CCP, Bernadette Elliott, RN, Ethan Kurtzman, MBA, RRT-NPS.

References

1. Guidelines for ECMO Transport Extracorporeal Life Support Organization (ELSO), Ann Arbor MI. Available at: https://www.elso.org/Portals/0/Files/ELSO%20GUIDELINES%20FOR%20ECMO%20TRANSPORT May2015.pdf Accessed August, 2019.
2. Abrams D, Garan AR, Abdelbary A, *et al*; International ECMO Network (ECMONet) and The Extracorporeal Life Support Organization (ELSO): Position paper for the organization of ECMO programs for cardiac failure in adults. *Intensive Care Med* 44: 717–729, 2018.

3. Combes A, Brodie D, Bartlett R, *et al*; International ECMO Network (ECMONet): Position paper for the organization of extracorporeal membrane oxygenation programs for acute respiratory failure in adult patients. *Am J Respir Crit Care Med* 190: 488–496, 2014.
4. Peek GJ, Mugford M, Tiruvoipati R, *et al*; CESAR trial collaboration: Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): a multicentre randomised controlled trial. *Lancet* 374: 1351–1363, 2009.
5. Broman LM, Holzgraefe B, Palmér K, Frenckner B: The Stockholm experience: interhospital transports on extracorporeal membrane oxygenation. *Crit Care* 19: 278, 2015.
6. Bryner B, Cooley E, Copenhaver W, *et al*: Two decades' experience with interfacility transport on extracorporeal membrane oxygenation. *Ann Thorac Surg* 98: 1363–1370, 2014.
7. Biscotti M, Agerstrand C, Abrams D, *et al*: One hundred transports on extracorporeal support to an extracorporeal membrane oxygenation center. *Ann Thorac Surg* 100: 34–9; discussion 39, 2015.
8. Clement KC, Fiser RT, Fiser WP, *et al*: Single-institution experience with interhospital extracorporeal membrane oxygenation transport: a descriptive study. *Pediatr Crit Care Med* 11: 509–513, 2010.
9. Broman LM, Frenckner B: Transportation of critically ill patients on extracorporeal membrane oxygenation. *Front Pediatr* 4: 63, 2016.
10. Fletcher-Sandersjöö A, Frenckner B, Broman M: A single-center experience of 900 interhospital transports on extracorporeal membrane oxygenation. *Ann Thorac Surg* 107: 119–127, 2019.
11. Ehrentraut SF, Schroll B, Lenkeit S, *et al*. Interprofessional two-man team approach for interhospital transport of ARDS-patients under extracorporeal membrane oxygenation: a 10 years retrospective observational cohort study. *BMC Anesthesiol* 19:19, 2019.
12. Sherren PB, Shepherd SJ, Glover GW, *et al*. Capabilities of a mobile extracorporeal membrane oxygenation service for severe respiratory failure delivered by intensive care specialists. *Anaesthesia* 70:707–714, 2015.
13. Broman LM, Dirnberger DR, Malfertheiner MV, *et al*: International survey on extracorporeal membrane oxygenation transport. *ASAIO J* 66: 214–225, 2020.
14. Shekar K, Badulak J, Peek G, *et al*; ELSO Guideline Working Group: Extracorporeal life support organization coronavirus disease 2019 interim guidelines: a Consensus Document from an International Group of Interdisciplinary Extracorporeal Membrane Oxygenation Providers. *ASAIO J* 66: 707–721, 2020.
15. Ramanathan K, Antognini D, Combes A, *et al*: Planning and provision of ECMO services for severe ARDS during the COVID-19 pandemic and other outbreaks of emerging infectious diseases. *Lancet Respir Med* 8: 518–526, 2020.
16. ELSO Guidelines for Training and Continuing Education of ECMO Specialists Extracorporeal Life Support Organization (ELSO), Ann Arbor MI. Available online at: https://www.elso.org/Portals/0/IGD/Archive/FileManager/97000963d6cusersshyerdocumentselsoguidelinesfortrainingandcontinuingeducationofecmospecialists.pdf. Accessed June, 2019.
17. Zakhary BM, Kam LM, Kaufman BS, Felner KJ: The utility of high-fidelity simulation for training critical care fellows in the management of extracorporeal membrane oxygenation emergencies: a Randomized Controlled Trial. *Crit Care Med* 45: 1367–1373, 2017.
18. Fehr JJ, Shepard M, McBride ME, *et al*: Simulation-based assessment of ECMO clinical specialists. *Simul Healthc* 11: 194–199, 2016.
19. Alinier G, Hassan IF, Alsalemi A, *et al*: Addressing the challenges of ECMO simulation. *Perfusion* 33: 568–576, 2018.
20. Labib A, Alinier G: Transport and Retrieval on Extracorporeal Membrane Oxygenation (ECMO): setup and activities of an immersive transport and retrieval on ECMO Workshop. *J Cardiothorac Vasc Anesth* 35: 1603–1610, 2021.