Extracorporeal Life Support Organization 2024 Guideline for Early Rehabilitation or Mobilization of Adult Patients on Extracorporeal Membrane Oxygenation

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Disclaimer:This Extracorporeal Life Support Organization guideline describes early rehabilitation or mobilization of patients on extracorporeal membrane oxygenation (ECMO). The guideline describes useful and safe practices put together by an international interprofessional team with extensive experience in the field of ECMO and ECMO rehabilitation or mobilization. The guideline is not intended to define the delivery of care or substitute sound clinical judgment. The guideline is subject to regular revision as new scientific evidence becomes available. *ASAIO Journal* 2025; XX:XX–XX

Key Words: early rehabilitation, mobilization, extracorporeal membrane oxygenation

Purpose

This guideline describes early rehabilitation or mobilization of adult patients supported with extracorporeal membrane oxygenation (ECMO). The intent is to provide the interprofessional team caring for patients receiving ECMO with best practices for early rehabilitation or mobilization based on current evidence and extensive clinical experience.

Background

Early rehabilitation or mobilization of critically ill patients is recommended by several professional societies.[1–7] This may be due to the perceived benefits of early rehabilitation or mobilization such as reduced intensive care unit (ICU)-acquired weakness (ICU-AW), enhanced cognitive and functional recovery, and improved muscle strength.[8,9] Patients on ECMO represent the sickest cohort of critically ill patients, often having near-total dependence on the ECMO circuit for survival. Literature regarding early rehabilitation or mobilization of patients with ECMO is largely retrospective and observational and, to some extent, extrapolated from general ICU literature.

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Submitted for consideration November 2024; accepted for publication in revised from November 2024.

Disclosure: C.H. received research support from the NHMRC in Australia. She sits on the Executive and Scientific Committee of the International ECMO Network (ECMONet). She is leading an NHMRC-funded trial of early rehabilitation of patients during ECMO (NCT05003609). K.R. is the Extracorporeal Life Support Organization (ELSO) Chair of the Publications Committee. D.B. receives research support from and consults for LivaNova. He has been on the medical advisory boards for Xenios, Medtronic, Inspira, and Cellenkos. He is the President-elect of the ELSO and the Chair of the Executive Committee of the International ECMO Network (ECMONet) and he writes for UpToDate. K.S. received research support from the Metro North Hospital and Health Service. He is a member of the Scientific Committee of the International ECMO Network and Chair of the ELSO Guidelines & Protocol Committee. B.Z. is the ELSO Chair of Education. The other authors have no conflicts of interest to report.

C.H. and B.Z. are joint senior authors of this article.

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).

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DOI: 10.1097/MAT.0000000000002375

A recent scoping review of early rehabilitation or mobilization on ECMO, including a large cohort study, reported minor rates of complications.[10,11] Although studies have demonstrated that early rehabilitation or mobilization during ECMO is possible in high-volume centers, for most patients on ECMO, rehabilitation or mobilization remains largely an in-bed activity. A recent international cohort study reported only 22% of patients on veno-venous (VV) ECMO achieved some level of physical mobilization. Factors independently associated with receiving early rehabilitation or mobilization included cannulation for prelung transplantation, avoidance of mechanical ventilation, being at a high-volume ECMO center, and cannulation with a dual-lumen cannula.[12] Increased rehabilitation or mobilization for patients on ECMO as a bridge to lung transplantation (BTT) is a consistent finding in the literature, suggesting that some patients may be better suited than others.[12] Maintenance of functional and rehabilitative status for the patient awaiting lung transplantation is a prerequisite to surgical intervention and ambulation has been reported as an independent predictor of successful BTT.[13] Indeed, lack of rehabilitation or mobilization for this population is considered a strong relative contraindication and may preclude transplantation altogether.[14]

A recent randomized controlled study of mechanically ventilated patients found no difference in the number of days alive and out of the hospital or in adverse event rate for the early mobilization group when compared to usual care.[15] Patients on ECMO represent a unique patient population and balancing risks *versus* benefits of early rehabilitation or mobilization in this group can be challenging. Ensuring the safety of early rehabilitation or mobilization requires individualized patient assessment before each activity and is dependent upon the collaborative efforts of an interprofessional team of experienced practitioners to mitigate potentially deleterious events.[16,17]

To determine best practice regarding early rehabilitation or mobilization in this group, we performed a literature search of the MEDLINE, SCOPUS, and EMBASE databases using appropriate keywords pertaining to "ECMO," "rehabilitation," "exercise therapy," "ambulation," and "muscle strength" from January 2009 through August 2024 and summarize the data for the recommendations (Table 1). We provide a framework outlining team structure, premobility assessment, challenges, and training needs for maximizing the safety of early rehabilitation or mobilization of patients during ECMO. The guidelines have been constructed with key stakeholders involved, including relevant professional groups and the target population, including an ECMO survivor.

Guideline

Early Rehabilitation or Mobilization for Patients Receiving Extracorporeal Membrane Oxygenation

1. Interprofessional team discussions regarding early rehabilitation or mobilization can commence before or upon cannulation and are initiated once the patient is deemed medically stable and at an appropriate sedation/comfort level.
2. Early rehabilitation or mobilization may include an array of activities, both passive and active, from bed-level tasks to upright sitting, potentially progressing to transfer out of the bed and ambulation.

Barriers to Early Rehabilitation or Mobilization

Although early rehabilitation or mobilization in carefully selected patients during ECMO support appears safe and feasible when performed at centers experienced in both ECMO and rehabilitation or mobilization of patients in ICU, barriers and challenges exist.[19,20] These potential barriers fall into several domains and are listed in Table 2. Each facility should seek to identify and mitigate such barriers to the extent possible to implement successful early rehabilitation or mobilization of patients with ECMO.

Interprofessional Team for Early Rehabilitation or Mobilization

1. Members of the interprofessional team may include the physical therapist or rehabilitation expert, airway specialist/respiratory therapist, registered nurse, medical provider, and ECMO specialist with each member providing input specific to their specialty.
2. The suggested roles and responsibilities of the interprofessional team are summarized in Table 4.
3. Each member of the team should have adequate training and competency with ECMO relevant to their specialty.[21] Facility-based policies and procedures regarding the rehabilitation or mobilization of patients during ECMO should be developed and implemented.

Patient Rehabilitation or Mobilization

1. Patient assessment
   a) Once a patient is cannulated for ECMO, the interprofessional team may perform a thorough review of the patient's clinical status to identify any potential barriers to early rehabilitation or mobilization.
   b) Patient assessment should be conducted before each rehabilitation or mobilization session and include a review of:
      (1) ECMO circuit: the team should review the ECMO cannulation strategy, cannula(e) position(s), and circuit settings including blood flow rate, blender fraction of delivered oxygen (FdO_2), sweep gas flow (SGF) rate, and circuit function. Assessment of cannulation site integrity and distal perfusion is detailed later in the Prerehabilitation or mobilization assessment.
      (2) Medical history: relevant patient history should be reviewed to identify conditions that could impact early rehabilitation or mobilization. Determination of preadmission frailty, disability, exercise tolerance, and use of assistive devices (including audiovisual aids) should be identified as this equipment may be necessary for the progression of rehabilitation or mobilization.
      (3) Relevant imaging: imaging should be reviewed to assess cannula and device positioning, with special attention given to the tip of the cannula, to ensure no forward or backward movement, kinking, or perforation has occurred, as these may affect the patient's ability to participate in rehabilitation or mobilization.

Table 1. Summary of Evidence Regarding Rehabilitation or Mobilization of Patients on ECMO

No.	Study	Sample Size	Inclusion Criteria	Cannulation Strategy	Physiotherapy Type	Number of Sessions
1	Garcia 2011	10 10 PT	Severe respiratory failure despite maximal conventional therapy with predicted mortality of >90%	IJ DLC	Ambulatory ECMO	NR
2	Fuehner 2012	60 26 PT, 34 (some without ECMO)	All patients receiving awake VV ECMO between August 2008 and March 2011 as BTT	VA FF/FS VV FJ/Avalon	NR	NR
3	Abrams *et al.*[18]	100 35 PT, 65 control	ECMO for refractory respiratory or cardiac failure in ICU	23 VV with DLC VA *via* JS 8 Femoral cannulation	Turning in bed (including active-assisted ROM of extremities) Sitting in bed with head of bed elevated Sitting on edge of bed with feet on floor Sitting in a chair Standing Marching in place Ambulation	7.2 ± 6.5
4	Lang *et al.*[19]	16 5 PT, 11 control	BOS 3, absence of other organ dysfunction, age < 60 years, no immunosuppression, able to eat and communicate	NR for some patients 1 VA (FF) 3 VV 1 VV (FJ) to VA (FF) 1 VV (FJ) to iLA DLC (J) 6 iLA	Awake ECMO without MV, patients fully mobilized	NR
5	Sommer 2015	23 23 PT, 0 control	Severe cardiac failure receiving VA ECMO	VA FF 23	Awake ECMO without MV	NR
6	Boiling 2016	18 18 PT	VV ECMO cases between January 1, 2011 and November 1, 2013	Right IJ DLC	Nurse-led ambulation Nurses assessed medical stability and alertness, and then led multidisciplinary team. Two nurses assisted the patient, with additional nurses, nursing care technicians, and physical therapy staff as needed Median distance 61 m per session	NR
7	Hermens 2017	14 14 PT, 0 control	Refractory hypoxemic or hypercapnic respiratory failure despite noninvasive ventilation	14 VV: 5 FJ, 6 FF, 3 Avalon	Active physical therapy Sputum mobilization and airway clearance Leg press or squatting from sitting Bed-to-chair mobilization Stationary marching Treadmill ambulation	Performed daily 6 (IQR: 2–10)
8	Hilty 2017	34 6 PT, 14 control	All patients between October 1, 2009 and March 31, 2013 treated with ECCO2R	NR	"Awake" ECMO without MV	NR
9	Munshi 2017	61 50 PT, 11 control	All adult patients who underwent VV ECMO for severe ARDS	DLC PT: 26, No PT: 6 FJ PT: 23, No PT: 4 Unspecified PT: 1 No PT: 1	Passive ROM Active ROM Sitting Standing	NR
10	Hoetzenecker 2018	71 26 PT, 45 control	All patients who received VV ECMO as BTT between January 2006 and September 2016	Isolated hypercapnia: pumpless FF AV Novalung or dual-lumen VV ECMO In severe hypoxemia, DLC VV ECMO	Fully ambulatory/treadmill: 14 Bed exercises: 6 Stand/steps: 4 Dangling feet: 2	NR

(Continued)

Table 1. Continued

No.	Study	Sample Size	Inclusion Criteria	Cannulation Strategy	Physiotherapy Type	Number of Sessions
11	Benazzo 2019	120 33 PT, 87 control	Patients who received ECMO between January 1998 and December 2017 as BTT	VV: 10 Single-site 31 double-site 9 iLA 17 iLA-ActiVVe 36 VA 1 V-AV	Active physiotherapy in bed Sat up once or twice daily Ambulation for some	Once or twice daily
12	Bonizzoli 2019	101 101 PT	All patients with refractory ARDS on VV ECMO	19 FF 82 DLC	1. No mobilization or passive range of motion of extremities 2. Turning in bed (including active-assisted ROM of extremities) 3. Sitting in bed with the head of the bed elevated 4. Sitting on the edge of the bed with feet on the floor 5. Out-of-bed sitting in a chair 6. Standing out of bed 7. Marching in place 8. Ambulating 35 “0” Passive ROM, dependent bed mobility 66 “1” Exercises in bed	NR
13	Inci 2019	26 6 PT, 20 control	All patients undergoing ECMO or iLA as BTT from January 2007 to October 2013	10 VV ECMO (FJ) 12 Avalon cannula 4 VA (FF, JF, AF) iLA (FF)	“Awake” ECMO without mechanical ventilation	NR
14	Pasrija 2019	15 15 PT, 0 control	Patients ambulated on VA ECMO	15 VA FF	Aggressive stepwise PT with the goal of ambulation 1. Out of bed 2. Into a chair 3. Marching in place 4. Walking	NR
15	Tipograf *et al.*[13]	121 82 PT, 39 control	Patients on ECMO as BTT, with intact neurologic status, absence of bacteremia or organ failure, and potential to participate in pretransplant physical therapy	63 VV 52 VA 3 V-AV 2 RA-LA 1 PA-LA	Ambulation between 55 and 525 feet	4.5 Sessions

(Continued)

Table 1. Continued

No.	Study	Sample Size	Inclusion Criteria	Cannulation Strategy	Physiotherapy Type	Number of Sessions
16	Wells 2019	254 167 PT, 87 control	Patients receiving ECMO and PT	VA: 1 femoral cannula 40 bifemoral 24 central 4 (bifemoral + 1 cannula) VV: 67 one femoral 18 bifemoral 4 central 4 (bifemoral + 1cannula) 5 dual lumen	Therapeutic exercises (ROM, stretching/ strengthening, muscle endurance, breathing exercises): 268 sessions across 28 patients Bed mobility (rolling, supine to sit transfer training, bridging activities), 170 sessions in 55 patients Edge of bed activities (sitting balance, posture, prestanding activities, breathing, and coughing): 100 sessions in 28 patients Sit-to-stand transfer activities (sit-to-stand transfers and functional strengthening using sit-to-stand from the bed or chair): 106 sessions in 35 patients Stand pivot transfers (PT completing pivot or taking small steps from bed or chair with the purpose of transferring to another surface): 39 sessions in 14 patients Standing activities (balance and tolerance, strengthening, perambulation activity such as weight shifting, marching, and stepping in place): 98 sessions in 23 patients. Ambulation (gait training, gait speed, and ambulation tolerance): 37 sessions in 5 patients	See prior column
17	Yanagida 2019	15 11 PT, 4 control	Irreversible lung disease with respiratory failure and DLC VV ECMO cannula	15 VV R IJ Avalon	Aggressive PT to be ambulatory	NR
18	Deng 2020	40 12 PT, 28 control	Patients undergoing VA ECMO	40 VA FF	Awake ECMO without MV Mobilization (active/passive) In-bed positioning (sitting, upright) Ambulation (sitting in bed, standing, sitting on the chair, and then ambulation)	NR
19	The ECMO-PT Study Investigators & International ECMO Network[17]	20 10 PT, 10 control	Functionally independent before admission and received ECMO for at least 24 hours	All femoral	PT: IMS: 2.67 (0–5.3) No PT: 1.5 (1–4.7) 7/56 Sessions IMS > 3 for PT, 0/68 control	PT: 133 (82–220) minutes No PT: 27.5 (20.4–43) minutes
20	Abrams *et al.*[10]	511 177 PT, 334 control	Patients on VV or VA ECMO who received PT	Not reported	Ambulation based on ICU Mobility Scale	8 (2–21)
21	Hayes *et al.*[11]	15 7 PT, 8 control	Anticipated ECMO duration of > 24 hours	FF in 13 patients	Mobility based on ICU Mobility Scale	7 days, up to 1 hour per day >20 minutes for passive PT >30 minutes for active PT

(Continued)

Table 1. Continued

No.	Study	Sample Size	Inclusion Criteria	Cannulation Strategy	Physiotherapy Type	Number of Sessions
22	Patrick 2021	9 9 PT	Patients receiving ECMO blood flows of 3–5 L/minute with a RAAS score of −1 to 0, able to follow commands, not on more than 2 vasopressors, and stable hemoglobin level	VV: 2 IJ, 2 femoral VA: 1 IJ, 1 femoral, 3 IJ/femoral	Carried out by two ECMO nurses, physiotherapist, occupational therapist, pulmonary therapist, and perfusionist	NR
23	Bohman 2022	44 44 PT	Initially, patients on VV ECMO for ARDS. Later, matching of each patient on VV ECMO for COVID ARDS to a patient without COVID ARDS	FJ in 19 non-COVID, 20 COVID IJ DLC in 1 non-COVID, 20 COVID FF in 2 non-COVID, 2 COVID	Passive PT with ROM exercises Active PT Activity assessed by simple ordinal score 0–3, where 0 = none, 1 = passive PT, 2 = active PT, 3 = ambulation	Median ECMO days with PT level ≥ 2 COVID: 0.225 (0–0.58) Non-COVID: 0.075 (0–0.31)
24	Cerier 2022	67 67 PT	Patients on VV ECMO for ARDS excluding death before hospital discharge	FJ or IJ DLC	Daily PT based on exercise tolerance Verticalization Dangling at the edge of the bed Activities of daily living Standing Ambulating Aerobic training Stair negotiation	NR
25	Hayanga 2022	128 128 PT	Patients older than 18 years diagnosed with COVID-19 or non-COVID ARDS who required VV ECMO	R IJ in 22 Other in 106	Physical therapists working in conjunction with ECMO specialist, perfusionists, and nurses to ambulate patient using walking aid and following the patient around the unit with an armchair with wheels permitting intermittent rest stops	NR
26	Mayer 2022	315 218 PT, 97 control	Patients on any configuration ECMO for at least 72 hours	IJ: 119 (92 PT, 26 control) Femoral: 115 (80 PT, 45 control) Aorta: 45 (27 PT, 18 control) Subclavian artery: 20 (15 PT, 7 control) Atrium: 5 (4 PT, 1 control)	Mobilization of patients with the following goals Sitting on the edge of the bed Participating in standing Walking for > 1.5 m Walking for > 45 m	NR
27	Ponholzer 2022	88 35 Awake BTT, 53 sedated BTT	Patients on ECMO as BTT and received lung transplant	VV DLC: 19 (14 awake, 5 sedated) VV 41 (8 awake, 33 sedated) VA: 15 (5 awake, 10 sedated) iLA: 3 (1 awake, 2 sedated) iLA active: 10 (7 awake, 3 sedated)	Standing upright Active physiotherapy while sitting in bed	Median BTT duration Awake: 6 (1–80) days Sedated: 7 (<1–60) days

(Continued)

Table 1. Continued

No.	Study	Sample Size	Inclusion Criteria	Cannulation Strategy	Physiotherapy Type	Number of Sessions
28	Cerier 2023	67 Total 37 Delayed PT 30 Early PT	Patients on VV ECMO for severe ARDS	FJ *vs.* Protek Duo	Progressive PT/OT from verticalization to dangling at the edge of bed, activities of daily living, standing, ambulating, aerobic training, and stair negotiation	NR
29	DiVito 2023	104 Total 104 PT	Patients on VV ECMO for severe COVID-19 ARDS	55 Femoral cannulation DLC later in the study	3 Phase program Phase 1: patient is intubated and sedated Phase 2: patient is alert and following commands Phase 3: patient I decannulated	At least two to three times a week
30	Rottmann 2023	343 Total ICU mobilization scale ≥ 2: 62 ICU Mobilization Scale < 2: 281	Patients on VV ECMO	Not reported	ICU Mobility Scale from 0 to 4 0: No mobilization other than the prone position 1: mobilization in bed 2: mobilization to sit on the edge of the bed 3: mobilization to chair 4: mobilization to stand	NR
31	Liu 2024	45 Total 22 Control 23 Early PT	Patients on VV ECMO ≥ 48 hours	FJ	Evidence-based rehabilitation measures based on the ICU Mobility Scale scores and Richmond agitation-sedation grading	NR

ARDS, acute respiratory distress syndrome; AV, arteriovenous; BOS, bronchiolitis obliterans syndrome; BTT, bridge to transplant; COVID, coronavirus disease; CTVICU, cardiothoracic and vascular intensive care unit; DLC, dual-lumen cannula; ECCO2R, extracorporeal carbon dioxide removal; ECMO, extracorporeal membrane oxygenation; FF, femoral vein–femoral artery; FJ, femoral vein–internal jugular vein; FS, femoral vein–subclavian artery; JS, internal jugular vein–subclavian artery; ICU, intensive care unit; IJ, internal jugular vein; iLA, interventional lung assist; IQR, interquartile range; J, jugular vein; LA, left atrium; MV, mechanical ventilation; NR, not reported; OT, occupational therapy; PA, pulmonary artery; PT, physiotherapy; RA, right atrium; ROM, range of motion; VA, veno-arterial; V-AV, veno-arteriovenous; VV, veno-venous.

(4) Hemodynamics and other vital measures: the patient's hemodynamic status should be reviewed and acceptable ranges during rehabilitation or mobilization defined. These variables may include arterial blood pressure, heart rate, respiratory rate, arterial oxygen saturation, venous oxygen saturation, central venous pressure, pulmonary artery pressure, arterial blood gas values, and anticoagulation levels.

(5) Medications: relevant medications should be reviewed with the goal of adjusting vasoactive, sedative, and analgesic medications to maximize participation in rehabilitation or mobilization, while maintaining patient safety and pain control.

2. Team brief
   a) Once the patient is deemed to be an appropriate candidate for early rehabilitation or mobilization, the interprofessional team should be empowered to raise concerns, if any, and evaluate the appropriateness of the planned intervention.
   b) Once concerns are addressed, the team member designated to lead the rehabilitation or mobilization session should schedule a time when all necessary team members and required equipment are available to assist with mobilization.
3. Prerehabilitation or mobilization assessment
   a) Immediately before commencing activity, a rehabilitation or mobilization checklist (Table 3) should be reviewed to ascertain cannula site integrity and limb perfusion, patient's neurocognitive integrity, and baseline hemodynamic stability and circuit function.

(1) In the case of groin cannulation, positional integrity of the cannula with movement may be evaluated before commencing the rehabilitation or mobilization session. This can be assessed by positioning the patient in the supine position and manually flexing the hip of the cannulated limb to 90° while assessing the cannula position, ECMO blood flow stability, and distal limb perfusion. Extra caution should be taken with patients with obesity as the cannula tip may only be superficially within the vessel. Marking the skin in relation to the cannula may be helpful in assessing movement.

(2) In the case of neck cannulation, care should be taken to secure the cannula while moving to upright or out-of-bed positioning. This can be accomplished with a headband or strap worn around the head or by designating a member of the team to be responsible for securing and monitoring the cannula.

(3) It is paramount that before rehabilitation or mobilization, a cannulating medical provider is aware of mobility efforts and is available as needed in the rare event that cannula malpositioning or accidental decannulation occurs.

(4) Screening cognitive integrity as part of a general neurocognitive examination is an essential component of a prerehabilitation or mobilization assessment.[22] Cognitive impairment is multifaceted, requiring a multimodal screening approach. There is limited evidence, however, regarding the assessment of cognitive integrity of patients on ECMO.[22]

Table 2. Barriers to Early Rehabilitation or Mobilization

Domain	Barriers
Patient physical and psychological	Sedation and pain management
	Delirium, agitation, anxiety, or inability to follow direction
Safety	Physiologic/hemodynamic/medical stability
	Line security and management
	Monitoring and risk management
Clinician and team	Team communication
	Culture for rehabilitation or mobilization
	Expertise and staff training
	Role clarity and accountability
	Leadership and expectation setting
Motivation and beliefs	Clinicians/staff
	Patients and family
Environmental and structural	Access to services and equipment
	Hospital administration
	Financial constraints
	Protocol development
	Implementation *via* a quality improvement framework

Validated tools to consider include the Richmond Agitation-Sedation Scale (RASS),[23] Glasgow Coma Scale (GCS),[24] and alertness and orientation (A&O) questions for assessing alertness and consciousness; the confusion assessment method for the ICU (CAM-ICU) for delirium[25]; and the mini-mental state examination (MMSE) for evaluating orientation, recall, attention, language, and praxis.[26]

(5) Patients unable to follow commands due to cognitive impairment or sedation may be unable to participate in higher-level rehabilitation or mobilization activities described in stage 3 or 4 (Figure 1). Such a case should not preclude patients receiving rehabilitation or mobilization. Verticalization therapy using tilt tables or standing beds with support straps may be useful in the management of neurocognitive impairment[27,28] and may facilitate pulmonary recovery for patients with respiratory failure.

b) A thorough circuit check must be performed and may include evaluating the blood and SGF rates, circuit pressures, membrane lung function, and integrity of tubing, sutures, and anchors. This baseline assessment may be recorded at rest and during rehabilitation or mobilization to ensure stable circuit function or changes within the anticipated range.

c) In anticipation of increased cardiorespiratory demand during rehabilitation or mobilization, the team should discuss the need for augmenting ECMO or ventilatory support, if indicated.

d) The plan for rehabilitation or mobilization should be communicated to the patient and family/caregivers. When reasonable, verbal informed consent should be obtained.

4. During rehabilitation or mobilization

a) A member of the team (typically the physical therapist or rehabilitation expert) should be designated as the mobility team leader. This leader should assign roles and delegate tasks to other team members, communicate the rehabilitation or mobilization plan to the patient, and initiate a time-out.

b) A staged rehabilitation or mobilization protocol with recommended activities and equipment for each stage, as well as a guideline for determining tolerance of activity, is provided in Figure 1.

c) Cannula stability should be assessed regularly, including during the rehabilitation or mobilization session as well as after each position change.

d) If ambulating, consider following behind the patient with a chair equipped with a sling (see Figure 1, Supplemental Digital Content, http://links.lww.com/ASAIO/B401). This will allow for rest breaks during ambulation, while offering a method for safe return to bed in the case of patient intolerance.

e) For patients with distal perfusion catheters (DPCs), consider monitoring blood flow rates through the DPC and performing vascular checks while sitting out-of-bed, as there may be a risk for kinking of the DPC with prolonged sitting. The use of a wire-reinforced DPC may help mitigate this risk.

f) Patient tolerance and physiologic response should also be regularly assessed with titration of ECMO blood flow and SGF rates as needed (Figure 1).

g) Patients should be progressed to the highest level of functional mobility that can be safely tolerated. A recent trial of early mobilization in critically ill patients not receiving ECMO indicated that very early mobilization at higher doses than usual may be associated with adverse events (arrhythmias, desaturation, and altered blood pressure).[10] As such, a balance must be struck between the right "dose" of rehabilitation or mobilization and patient tolerance or risk. The level and duration of exercise need to be carefully discussed among the interprofessional team. If at any point the patient no longer tolerates the activity, or if there is an adverse event, rehabilitation or mobilization should be paused and the activity should not be recommenced until the team has discussed and agreed on a modified plan for rehabilitation or mobilization (*ie*, stepping down to a lower level) or to stop all efforts until the next session.

Table 3. Suggested ECMO Rehabilitation or Mobilization Checklist

Pre-Rehabilitation or Mobilization Chart Review
- ◻ Past medical history/history of present illness
- ◻ Imaging
- ◻ Hemodynamics
- ◻ Medications
  - ◻ Anticoagulation Status
- ◻ Additional medical/organ support devices required

Patient Assessment
- ◻ Patient/caregiver verbal informed consent
- ◻ Physical Exam
  - ◻ Cardiovascular assessment (Pulses, capillary refill, signs of venous, or arterial disease, etc.)
  - ◻ Pulmonary assessment (Auscultation, mechanics and work of breathing, percussion, fremitus, etc.)
  - ◻ Neurocognitive assessment (Cognitive, motor, and sensory screen, reflexes, coordination, proprioception, etc.)
  - ◻ Integumentary assessment (Palpation, color, temperature, edema, skin integrity/wound assessment, etc.)
  - ◻ Pain assessment

Interprofessional Team Brief
- ◻ Physical Therapist/Rehabilitation expert
- ◻ Medical provider
- ◻ ECMO specialist
- ◻ Nursing staff
- ◻ Respiratory therapist
- ◻ Discuss plan for mobilization
- ◻ Identify the team leader and provide delineated roles
- ◻ Obtain all necessary equipment (Including any audiovisual aids as needed)

ECMO Circuit Assessment and Preparedness
- ◻ 4 clamps
- ◻ Cannulation site and insertion depth
- ◻ Cannula securement (anchors/sutures)
- ◻ Invasive line assessment, ETT/tracheostomy secured
- ◻ ECMO circuit check
- ◻ ECMO console parameters: RPMs and flow, pre/postoxygenator pressures, FdO_2, SGF/, SvO_2, Battery status
- ◻ Code cart, portable ventilator, transport bag checked and are immediately accessible

Rehabilitation or Mobilization (Figure 1)
- ◻ Notify medical team prior to mobilization
- ◻ Ensure cannulating provider is available
- ◻ Confirm staff roles/responsibilities
- ◻ Obtain necessary mobility equipment
- ◻ Complete time-out with involved team members
- ◻ Assess cannula regularly throughout session
- ◻ Assess patient's physiologic response/tolerance
- ◻ Titrate ECMO blood flow, SGF/ to support activity
- ◻ Progress through stages of mobility

  Stage achieved_____

  Barriers to progression:

  Plan to mitigate barriers:

Post-Rehabilitation or Mobilization Patient
- ◻ Cannulation site unchanged, cannulas secure (anchors/sutures).
- ◻ Reassess patient (see physical exam above).
- ◻ Communicate plan for ongoing rehabilitation or mobilization during admission.

Circuit
- ◻ Pump plugged into wall power.
- ◻ Gas lines connected to wall.
- ◻ O_2 line to membrane lung reconnected to gas blender/flowmeter.
- ◻ Blood flow rate, SGF and blender FdO_2 at correct settings.
- ◻ Water lines (heater-cooler device) reconnected and set to desired temperature.
- ◻ O_2 tank full.

ECMO, extracorporeal membrane oxygenation; ETT: endotracheal tube; FdO_2, fraction of delivered oxygen; RPM, revolutions per minute; SGF, sweep gas flow.

5. Postrehabilitation or mobilization assessment
   a) After the appropriate activity, completion of the checklist discussed in the prerehabilitation or mobilization assessment is advised. Of note, gas lines should be reattached to the blender and wall and ECMO blood flow and SGF rates returned to prerehabilitation or mobilization settings, if safe to do so. Additionally, documentation of patient performance and physiologic tolerance ensures safe and accurate hand-off.
   b) If the patient tolerates sitting upright edge of bed and has progressed to passive or active out-of-bed transfers, evaluation of prolonged time out of bed should be assessed. A dependent lift sling (see Figure 1, Supplemental Digital Content, http://links.lww.com/ASAIO/B401) may be positioned in the chair before active transfer out-of-bed to assist with return in case the patient is intolerant of sitting or becomes unable to actively transfer back to the bed.

Table 4. Suggested Professional Roles and Responsibilities for Rehabilitation or Mobilization

Interprofessional Team Member	Roles and Responsibilities
Physical therapist/rehabilitation expert	1. Review medical notes, laboratory/imaging, pharmacological support, and ECMO cannulation strategy and circuit settings 2. Consent patient to rehabilitation or mobilization session explaining goals and intended outcomes 3. Plan and lead the rehabilitation or mobilization process, including obtaining necessary assist devices/equipment and organizing support personnel to be present during the session 4. Follow up with interprofessional team and patient postrehabilitation or mobilization to discuss tolerance to activity and modifications to plan of care to improve tolerance for the next session
Medical provider	1. Ensure the patient is appropriate for the planned session 2. Ensure availability of emergency medications, equipment, and personnel 3. Review ECMO settings and circuit with ECMO specialist 4. Optimize cardiorespiratory support
ECMO specialist	1. Inspect ECMO circuit 2. Document cannula insertion depth 3. Ensure cannula securement 4. Document circuit settings and pressures 5. Obtain portable oxygen in sufficient quantity (if moving out-of-the ICU) 6. Ensure the battery capacity of the device (if moving out of the ICU) 7. Ensure 4 clamps are immediately available
Registered nurse	1. Ensure comfortable and cooperative patient 2. Review and monitor vital signs 3. Check infusions and lines/tubing
Respiratory therapist	1. Check portable ventilator settings/circuit 2. Prepare suction (oral, subglottic, endotracheal) 3. Ensure tracheostomy or, endotracheal tube securement 4. Ensure adequate oxygen supply and connections

ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit.

6. Complications during rehabilitation or mobilization
   a) Reported complications during rehabilitation or mobilization of patients on ECMO are generally uncommon—although these studies were conducted primarily at centers with experience in ECMO and in ICU rehabilitation—and can be categorized into major and minor. Patient safety remains the top priority and hence all efforts should be made to anticipate and prevent these complications before each rehabilitation or mobilization session.
      (1) Major complications are events that require emergent response and could result in serious harm or death to the patient. These may include accidental decannulation, cannula fracture, significant cannula migration, severe bleeding from the insertion site, cannula kinking with alteration of ECMO blood flow rate and cardiorespiratory instability, ECMO component malfunction, significant arrhythmias, accidental extubation, severe or sustained hypoxemia, stroke, fall, or cardiac arrest.
      (2) Minor complications are events that do not require emergent response and do not place the patient at immediate risk for injury or death. These may resolve with discontinuation of rehabilitation or mobilization. They include minor cannula migration (not requiring repositioning), minor bleeding at insertion sites that ceases spontaneously or with manual pressure, interruptions in ECMO blood flow without cardiorespiratory instability or desaturation, arrhythmias, hypotension, or patient symptoms such as agitation, restlessness, shortness of breath, headache, or pain.
7. Other ECMO configurations
   a) As is the case for traditional cannulation techniques, an interprofessional approach is vital to ensure the safe progression of mobility for patients with central and hybrid cannulation configurations. These may include central left or right ventricular assist device (VAD), central VA ECMO (aortic, subclavian, or axillary artery return) as well as veno-venoarterial (V-VA), veno-arteriovenous (V-AV), or venoveno-arterial (VV-A) configurations.
   b) Single-site, dual-lumen catheters (DLCs) are also widely used and may increase ease of mobilization when groin and dual-site cannulation strategies are barriers in certain institutions. It should be noted that single-site DLC may be associated with an increased risk of cannula migration and malposition.[29]
   c) Regardless of the cannulation strategy, a prerehabilitation or mobilization discussion with the interprofessional team should outline a suitable strategy (see D.2.)
8. Additional mechanical circulatory support (MCS) devices:
   a) When patients are supported with temporary circulatory devices (*eg*, intra-aortic balloon pump or percutaneous VAD) in conjunction with ECMO, adjustments to the early rehabilitation or mobilization plan need to be considered. Early rehabilitating or mobilizing patients with multiple forms of MCS is perceived as high risk and there is limited research supporting safety and feasibility. There have been reports of the use of a tilt table/standing bed to achieve standing and ambulation in patients with femoral intra-aortic balloon pumps.[30]

Staged Rehabilitation or Mobilization Protocol for Patients on ECMO

Stage	Patient Description	Activity	Equipment	Progress	Regress	Examples
0 PASSIVE Bed level Activity/ Passive Sitting or Standing	• Patient not fully awake, unable to follow commands consistently • Patient unable to lift UE/LE against gravity and unable to assist with movement in bed	• Bed level AAROM/PROM • Rolling • Limb positioning • Extremity edema control • Long sitting • Dependent transfer to seated surface (overhead lift/lateral slide) • Passive Standing on tilt bed/table	• Cardiac Chair • Airway clearing device • Positioning slings • Mechanical lifts • Standing Bed/Tilt Table	PROGRESS TO STAGE 1 IF: •Patient Tolerates Stage 0 Activity (Bed mobility and Passive Sitting/Standing) •Demonstrates initiation of motor tasks •Follows safety commands	REASSESS STAGE 0 IN 24 HOURS IF: • Patient does NOT tolerate Stage 0 Patient intolerant of any stimulation	
1 ACTIVE Sitting	•Patient awakens to voice or physical stimulation. •Follows basic motor and safety commands inconsistently.	• Sitting edge of bed/Dangling • Supine or Sitting UE/LE exercise • Sitting balance activities • Mechanics of breathing • Postural Re-education • Dependent transfer to seated surface (overhead lift/lateral slide)	• Cardiac Chair • Thera-band/Free Weights • Incentive spirometer • Airway clearing devices • Stationary bike • Leg Press Table • Positioning slings • Mechanical lifts	PROGRESS TO STAGE 2 IF: •Patient Tolerates Stage 1 Activity (Active Sitting) •Able to sit unsupported >10 seconds	REASSESS STAGE 1 IN 24 HOURS/ REGRESS TO STAGE 0 IF: •Patient does NOT tolerate Stage 1 Actvity	
2 ACTIVE Static Standing	•Patient awakens to voice or physical stimulation. •Follows basic motor and safety commands.	• Functional sit to stand transfer • Standing (static) balance activities • Squat/Stand-Pivot Transfer to Bedside Chair • Mechanics of breathing • Postural Re-education	• Tilt Table/Standing bed • Bedside Chair • Thera-band/Free Weights • Incentive spirometer • Airway clearing devices • Standing Assist Devices	PROGRESS TO STAGE 3 IF: •Patient Tolerates Stage 2 Activity (Static Standing) •Able to stand with/without assist device >10 sec.	REASSESS STAGE 2 IN 24 HOURS/ REGRESS TO STAGE 1 IF: •Patient does NOT tolerate Stage 2 Actvity	
3 ACTIVE Dynamic Standing	• Patient awake and alert • Follows all motor and safety commands consistently.	• Transfer training • Pre-gait activities • Standing (dynamic) balance activities- Weight shift/marching • Standing UE/LE exercise at EOB or using tilt table/Standing bed • Transfer from bed to chair • Mechanics of breathing • Postural Re-education • Standing Assist Devices	• Tilt Table/Standing bed • Bedside Chair • Thera-band/Free Weights • Incentive spirometer • Airway clearing devices • Standing Assist Devices	PROGRESS TO STAGE 4 IF: •Patient Tolerates Stage 3 Activity (DynamicStanding) •Able to complete pre-gait activities with/without assist device >30 seconds	REASSESS STAGE 3 IN 24 HOURS/ REGRESS TO STAGE 2 IF: •Patient does NOT tolerate Stage 3 Actvity	
4 ACTIVE Ambulation	• Same as above	• Gait training • Standing (dynamic)Balance activities • Standing UE/LE Exercises • Standing on tilt table/standing bed with progression to gait training	• Tilt Table/Standing bed • Bedside Chair • Thera-band/Free Weights • Standing Assist Devices	INCREASE TIME/DISTANCE OF AMBULATION AND DECREASE ASSIST IF: •Patient Tolerates Stage 4 Activity (Gait)	REASSESS STAGE 4 IN 24 HOURS/ REGRESS TO STAGE 3 IF: •Patient does NOT tolerate Stage 4 Actvity	

Activity Tolerance Assessment

Objective	Subjective

• Assessment of hemodynamic parameters should be performed prior to, throughout, and following mobility. These values may include, but are not limited to HR/rhythm, BP, SpO2, RR, ScvO2/SvO2, Flow throught circuit, CVP, PA pressures.
  • Any significant changes to basleine hemodynamic values should be dsicussed with the medical team, and mobility terminated if necessary to ensure patient safety
• Additionally, rehabilitation may be terminated with any of the following:
  • ECMO Circuit Alarms
  • Anchors/sutures for cannulas no longer intact
  • Insertion site no longer intact
  • Bleeding, hematoma
  • Evidence of Kinking/migration
	• Rehabilitation may be terminated if patients reports any of the following:
	  • Dizziness/Pre-Syncope
	  • Nausea
	  • Active chest pain
	  • Dyspnea >7/10
	  • Insertion Site Pain >7/10
	  • Change to level of alertness

Figure 1. Suggested staged early rehabilitation or mobilization protocol for patients on ECMO. ECMO, extracorporeal membrane oxygenation.

b) If the additional temporary MCS device is placed in the upper extremity, early rehabilitation or mobilization may be conducted as described in the guideline.

9. Stop protocol for rehabilitation or mobilization:
   a) A stop protocol should be established before rehabilitation or mobilization attempts in the event of circuit malfunction, clinical instability, or patient intolerance to movement. A stop protocol order may be activated by any member of the team. Each facility should clearly define the roles of the team during the stop protocol. It is recommended to have team members who can return the patient to a safe position, troubleshoot ECMO alarms and resume ECMO circuit function, and support the patient as needed. A cannulating physician should be available to assist with repositioning or replacement of ECMO cannulas as indicated.
      (1) For patient intolerance, consider returning the patient to the prior stage in the protocol or stopping and returning the patient to the supine position for reevaluation.

Staff Training and Clinical Governance

1. Education and training for early rehabilitation or mobilization
   a) Centers that engage in early rehabilitation or mobilization of patients on ECMO should have a well-defined program for staff training.
      (1) Staff training should include role-specific simulation training and education for rehabilitation or mobilization as well as for stop protocols and emergency responses.
      (2) Education regarding early rehabilitation or mobilization technique and safety should be provided in part by the physical therapist responsible for routinely providing rehabilitation or mobilization for patients on ECMO.
2. Clinical governance and risk management
   a) ECMO providers should ensure adherence with local and national standards for early rehabilitation or mobilization of patients with ECMO, if and where they exist. These may include the use of auditing, incident reporting, and feedback from patients, relatives, and caregivers regarding their experience.
   b) We suggest the following key performance indicators (KPIs)
      (1) Outcome measures
         (a) Proportion of successful early rehabilitation or mobilization sessions to a total number of eligible patients/sessions.
         (b) Highest rehabilitation or mobilization level achieved during ECMO support. We recommend using the ICU Mobility Scale (IMS).[18,31]
         (c) Discharge disposition and functional outcomes. We recommend using the independent activities of daily living (IADL) and modified Rankin Scale.[32]
         (d) Complications (as defined above).
      (2) Process measures
         (a) Compliance with mobility checklist.
         (b) Time from cannulation to mobility assessment.
         (c) Equipment failure/malfunction.

Summary

This guideline describes the safe application of early rehabilitation or mobilization of adult patients on ECMO. Despite a lack of strong evidence, early rehabilitation or mobilization is encouraged when patient condition allows and when adequate resources and a well-trained interprofessional team are available. Complications, whereas uncommon, can lead to patient harm and efforts should be made to both anticipate and address them. To this end, we propose the use of a mobility checklist, emergency stop protocol, and staff empowerment. Extracorporeal membrane oxygenation centers are encouraged to provide appropriate training and implement risk management strategies to ensure safe and effective rehabilitation or mobilization.

Acknowledgments

The authors acknowledge Dr. Ryan Ruiyang Ling, Dr. Christopher Jer Wei Low, and Dr. Megan Ruien Ling from the Yong Loo Lin School of Medicine, Singapore for their help with Table 1. The authors also acknowledge Mr. Muhamed Aleef, Senior PT, Hamad Medical Corporation, Doha, Qatar for his help with media.

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