TITLE: Maintaining Mobility in a Patient Who Is Pregnant and Has COVID-19 Requiring Extracorporeal Membrane Oxygenation: A Case Report

RUNNING HEAD: Maintaining Mobility During ECMO for COVID-19

TOC CATEGORY: COVID-19

ARTICLE TYPE: Case Report

AUTHOR BYLINE: Alex Mark, Jennifer P. Crumley, Kristina L. Rudolph, Kevin Doerschug, Anna Krupp

AUTHOR INFORMATION:

A. Mark, Department of Rehabilitation Therapies, University of Iowa, 200 Hawkins Dr, 0733 JPP**,** Iowa City, IA 52252 (USA). Address all correspondence to Dr Mark at: alex-mark@uiowa.edu.

J.P. Crumley, UI Heart and Vascular Center, University of Iowa.

K.L. Rudolph, UI Heart and Vascular Center, University of Iowa.

K. Doerschug, Department of Internal Medicine, University of Iowa.

A. Krupp, College of Nursing, University of Iowa.

KEYWORDS: Acute Care, Pregnancy, Early Mobilization, Ventilators, Lung

ACCEPTED: September 27, 2020

SUBMITTED: June 10, 2020

Abstract

Objective. Mobilization while receiving life support interventions, including mechanical ventilation and extracorporeal membrane oxygenation (ECMO), is a recommended intensive care unit (ICU) intervention to maintain physical function. The purpose of this case report is to describe a novel approach to implementing early mobility interventions for a patient who was pregnant and receiving ECMO while continuing necessary infectious disease precautions because of diagnosed coronavirus disease-19 (COVID-19).

Methods (Case Description). A 27-year old woman who was pregnant was admitted to the ICU with COVID-19 and rapidly developed acute respiratory failure requiring 9 days of ECMO support. After a physical therapist consultation, the patient was standing at the bedside by hospital day 5 and ambulating by hospital day 9.

Results. The patient safely participated in physical therapy during ICU admission and was discharged to home with outpatient physical therapy follow-up after 14 days of hospitalization.

Conclusion. Early mobility is feasible during ECMO with COVID-19, and active participation in physical therapy, including in-room ambulation, may facilitate discharge to home. Innovative strategies to facilitate routine activity in a patient who is critically ill with COVID-19 require an established and highly trained team with a focus on maintaining function.

Impact. Early mobility while intubated, on ECMO, and infected with COVID-19 is feasible while adhering to infectious disease precautions when it is performed by an experienced interdisciplinary team.

[H1]Background and Purpose

The coronavirus disease-2019 (COVID-19) pandemic has overwhelmed intensive care units (ICUs) around the world and disrupted normal processes for how some evidence-based interventions are delivered to adults who are critically ill with suspected or confirmed COVID-19. International guidelines report early mobility as safe and feasible in the ICU setting to reduce ICU-acquired weakness, reduce delirium, improve functional recovery, and reduce ICU and hospital lengths of stay.[1,2] Early mobility is a complex intervention, requiring thorough patient assessment and interdisciplinary teamwork to effectively implement the highest level of patient mobilization possible each day while maintaining patient and staff safety. A patient who is critically ill with highly contagious COVID-19 requires advanced assessment and an experienced team to maintain patient and staff safety when considering early mobility interventions.

COVID-19 mainly affects the respiratory system and can lead to acute respiratory distress syndrome (ARDS). ARDS is the result of an inflammatory response, causing diffuse alveolar damage and increased pulmonary vascular permeability, resulting in hypoxemia.[3] Most patients with ARDS from COVID-19 require mechanical ventilation, using low volume and low pressure to maintain oxygenation.[4] During mechanical ventilation, patients may require analgesics and sedatives to maintain comfort, and chemical paralysis may be added to maintain compliance with the ventilator.[3] If adequate oxygenation is not achieved with maximal ventilator settings, rescue therapy, such as extracorporeal membrane oxygenation (ECMO), may be initiated.[3] ECMO is an artificial lung and blood pump, continuously draining deoxygenated blood from a central vein, pumping it through a membrane oxygenator, removing carbon dioxide and returning oxygenated blood to the patient. Among hospitalized patients with COVID-19 to date, approximately 14% to 23% were treated in an ICU for ARDS and 1 international ECMO registry reported that more than 1000 patients with COVID-19 have received ECMO.[5–7]

ARDS is associated with high morbidity. Over one-third of ARDS survivors have post-ICU muscle weakness at hospital discharge and early mobility programs have been broadly implemented in ICUs to prevent muscle wasting and maintain functional status.[8,9] Early mobility clinical guidelines provide assessment criteria for determining patient safety to engage in out-of-bed activity, typically once hemodynamic, respiratory, and neurologic criteria are met.[10] For a routine ICU patient, a physical therapist, registered nurse, and/or respiratory therapist, at minimum work together to deliver early mobility interventions, with the goal of patient ambulation during the ICU admission. Early mobility is feasible among patients with ARDS requiring ECMO, with additional staffing (eg, ECMO specialist) and procedural (eg, location of ECMO cannulas, type of therapy) considerations prior to beginning out-of-bed activity.[11] Patients diagnosed COVID-19–related ARDS requiring ECMO require additional safety considerations prior to engagement in physical therapist interventions.

To minimize risk for exposure to COVID-19 while providing clinical care, the World Health Organization[12] and the American Physical Therapy Association[13] provide considerations for delivering interventions to patients with suspected or diagnosed COVID-19. For physical therapists, it is recommended that staffing plans are developed to consider increased staffing in the ICU and that alternate screening approaches are used to minimize both staff exposure and use of personal protective equipment. When there are clinical indications for active therapy interventions in the ICU, therapists with ICU skills should be involved in complex decision-making.[13] For patients requiring organ support, preventing tubing disconnections, a risk with out-of-bed activity, is of utmost importance. Ventilator tubing disconnections may cause alveolar decruitment and staff exposure to the virus.

The purpose of this case report is to describe the treatment of a patient who was pregnant, had COVID-19, and rapidly developed ARDS requiring ECMO. We outline the interdisciplinary assessment, treatment, and staffing strategies implemented to safely deliver early mobility interventions and successfully maintain physical function status until hospital discharge.

[H1]Case Description

The patient was a 27-year-old woman who was previously healthy, pregnant at 23 weeks 6 days, and presented to an outside hospital with worsening shortness of breath, cough, nausea, and vomiting. She tested positive for COVID-19 4 days prior to her presentation. She had a witnessed tonic-clonic seizure on arrival and was endotracheally intubated following the event. The patient was transferred to our facility via airlift. She was deeply sedated and given a cisatracurium infusion (chemical paralysis). The patient was subsequently diagnosed with ARDS and aspiration pneumonia. She continued to be hypoxic despite paralysis and required maximal ventilator support. The maternal fetal medicine service was consulted, and because of the severity of respiratory failure, agreed with emergent ECMO cannulation in lieu of a trial of prone positioning. The patient was therefore referred for venovenous ECMO consideration (VV ECMO). She was cannulated with a dual-lumen Avalon cannula (Getinge, Gothenburg, Sweden) placed in the right internal jugular vein. Cisatracurium infusion was discontinued following cannulation.

To account for increased oxygen requirements and to maintain adequate placental blood flow during pregnancy, the maternal fetal medicine service recommended specific monitoring parameters during ECMO therapy. The monitoring parameters included the following: maintenance of peripheral oxygen saturation at >95%; immediate treatment of blood pressures >160/110 mm Hg; maintenance of mean arterial pressure at >65 mm Hg; and signs and symptoms of preterm labor, such as increased pain, concern for contractions, bleeding, or leaking of fluid. Typically, a peripheral oxygen saturation of 75%–80% while a patient is receiving VV ECMO is tolerated.[14] Hemodynamic goals on VV ECMO followed the recommendations of fetal medicine. Otherwise, evidence-based ARDS management was used to optimize care of both fetus and mother, including conservative fluid management and daily sedative interruptions. We used ultra–lung protective ventilation strategies, including the maintenance of plateau pressures of ≤24 cm of H_2O and driving pressures of ≤14 cm of H_2O. The fetal medicine service monitored the fetus via daily ultrasound studies.

On day 2 of VV ECMO, weaning of sedation began, initially targeting a Riker Sedation-Agitation Scale score of 3 (the patient is sedated but awakens and is able to follow simple commands). This continued over days 3 and 4 of VV ECMO. Physical therapist–delivered interventions were held during this period, as out-of-bed mobility was not expected, in part because of issues in achieving effective lung protective ventilation. In light of the strain on hospital resources, including personal protective equipment, because of the COVID-19 pandemic, it was decided by the Department of Rehabilitation Services and ICU leadership that physical therapists would initiate direct treatment only for patients who were intubated if out-of-bed mobility was thought to be feasible. This was to conserve personal protective equipment, especially our supply of respirators, as mobilization during mechanical ventilation has the potential to be an aerosol-generating procedure.[13] The physical therapy service continued to follow the patient through the electronic medical record and daily face-to-face interaction with the ECMO team (Table).

The physical therapy service initiated direct intervention on day 5 of VV ECMO, as the patient was awake and calm on minimal sedation (Riker Sedation-Agitation Scale score of 4), mechanical ventilation parameters were stable, the ECMO flows were stable, the cannula was secure, and the patient was deemed to be ready for out-of-bed activity upon discussion by the multidisciplinary team. Physical therapy commenced with in-bed active-assisted range-of-motion exercises, in which the patient was deemed to have suitable extremity strength (at least 3/5 on the Medical Research Council Scale for Muscle Strength) to attempt sitting at the bedside. Nonessential intravenous infusions were paused, and a heparin lock flush was applied to minimize extraneous lines. The ECMO cannula and tubing were supported using an elastic headband with hook-and-loop closures that wrapped circumferentially around the head, with the bedside ECMO specialist providing additional manual support of the device. A respiratory therapist was present to exclusively manage the endotracheal airway catheter and ventilatory tubing. Securing these 2 devices allowed the bedside nurse and physical therapist to provide adequate assistance to the patient, wherein she was mobilized to sitting at the edge of the bed and eventually standing—although requiring considerable caregiver support to achieve weight bearing on this day. Vital signs were continuously monitored and remained within goal ranges (peripheral oxygen saturation of >95%, blood pressure of <160/110 mm Hg, mean arterial pressure of >65 mm Hg). Progression of mobility was limited by patient report of significant fatigue after standing.

Out-of-bed activity was held on day 6 because of concerns for preterm labor, as the patient was experiencing contractions on a tocodynamometer study. However, on days 7 and 8 of VV ECMO, the patient was again able to achieve standing at the bedside with improved duration of stance, strength of standing force, and performance of pregait exercises. Prior to the pursuit of out-of-bed activity, supine exercises were performed each day to ensure an adequate level of consciousness and appropriate responses in vital signs. On day 9 of ECMO and hospitalization, the patient began her final trial off VV ECMO support, in which the sweep gas blender was turned to zero—effectively placing her on mechanical ventilator support alone. Upon discussion with the multidisciplinary team in morning rounds, we elected to pursue a trial of ambulation prior to her expected decannulation from VV ECMO that afternoon. This was to further test her lungs and allow for a period of bed rest following cannula removal. The ECMO cannulas were secured, the sweep gas line was connected to a portable oxygen tank with a liters-per-minute flow meter (in case of the need for reinitiation of ECMO support), and medical air and oxygen tubing were disconnected from the wall sources and secured to the ECMO cart. Finally, the power cord was disconnected from the wall, placing the pump on battery power and making the ECMO circuit mobile. Extraneous intravenous lines were again discontinued. The hospital bed, ECMO circuit, and mechanical ventilator were rearranged to allow for approximately 3-m^2 (10 ft^2) of open room for ambulation (Figure). The patient was successful in ambulating this approximately 3-m (10-ft) space twice, through support of the primary physical therapist, registered nurse, ECMO specialist and an additional physical therapist to manage the remaining intravenous lines and continuous monitoring cords. Aside from an episode of transient hypotension following the walk (96/62 mm Hg; mean arterial pressure of 73 mm Hg), no adverse physiologic or equipment events occurred. The patient reported mild dyspnea with activity and lightheadedness during the episode of hypotension, which limited further progression of ambulation. The patient was safely returned to a supine position in bed, and decannulation from VV ECMO that afternoon was successful.

On day 10 the patient was successfully liberated from mechanical ventilation and placed on high-flow nasal cannula. She exhibited tachycardia and respiratory distress later that day, therefore physical therapist intervention was held. Over the proceeding days her supplemental oxygen requirements consistently improved. Ongoing interventions from the physical therapist included progression of ambulation distance, introduction of resistance band exercises, performance of single-stair repetitions, and increasing the frequency of her exercise sessions to twice per day (Table). She continued to report persistent lightheadedness and mild dyspnea during exercise and ambulation, despite her peripheral oxygen saturation and blood pressures remaining within goal ranges. These symptoms necessitated frequent rest periods during physical therapist sessions.

[H1]Outcomes

On day 14 of hospitalization the patient was discharged to home in her family's care, with the recommendation of full-time supervision and continuing rehabilitation through local outpatient physical therapy. The patient was ambulating for distances of up to approximately

18 m (60 ft) in her room using a walker with supervision. This was deemed suitable for her home environment. She was proficient in a home exercise program involving resistance bands. She was weaned to room air and did not exhibit hypoxemia on exertion, though she did endorse dyspnea with prolonged exertion. The primary care team, maternal fetal medicine service, and physical and occupational therapist teams supported home-based discharge.

[H1]Discussion

This case illustrates the unique approaches used to facilitate early mobility to maintain physical function in a patient who was pregnant and was diagnosed with COVID-19 requiring ECMO. Early mobility and exercise delivered by a physical therapist, including in-room ambulation, was feasible and likely facilitated discharge to home. The innovative strategies to enable routine activity in a patient who is critically ill with COVID-19 require an established and highly trained team with a focus on maintaining function.

This case report describes the efforts of experienced clinicians with an established early mobility program.[15] For ICUs planning to develop or maintain an early mobility program, there are multiple barriers to overcome. Twenty-eight distinct barriers to implementing early mobility have been identified and can be classified into patient, structural, ICU culture, and process related barriers.[16] Cultural barriers describe lack of staff buy-in, lack of knowledge about mobility, or not identifying early mobility as a priority, and strategies to overcome cultural barriers may include interdisciplinary training, sharing experiences, and champions that support practice change.[16] Generally, overcoming cultural barriers requires a significant time investment, but results in sustainable change.[17] Our ICU has been routinely ambulating patients requiring mechanical ventilation and during ECMO for several years, and has a strong culture of mobility. As a result, the team has considerable expertise and is more adaptable to unique and challenging situations.

The timing of mobility interventions was discussed during daily interdisciplinary rounds among the medical intensivist team, registered nurse, respiratory therapist, ECMO specialist, and physical therapist. Considering the balance of patient wakefulness with the maintenance of lung protective ventilation, our team aggressively weaned sedation starting on day 2 of admission, in order to enable early mobilization. The coordination of patient wakefulness with early mobility is a fundamental intervention as part of the ICU Liberation Clinical Practice Guideline, also known as "ABCDEF Bundle," which represents the current standard of care for ICU patients to reduce time on the ventilator and reduce iatrogenic complications, such as delirium and functional decline.[18] This standard of care is relevant to all ICU patients and needs multidisciplinary communication for success.

Cohort studies have identified that ambulation while awake on ECMO can be achieved by well-experienced ECMO teams.[19-21] This case presented a unique challenge, in that clinician interaction needed to be limited in order to preserve personal protective equipment and limit exposure to highly contagious COVID-19. The ECMO, nursing, and physical therapist teams met daily, identifying which exercise interventions could be performed during routine nursing cares and which activities required the presence of rehabilitation therapy, in order to preserve respirator supply. Prior to any mobilization attempt, provider roles were clearly identified to ensure safety and efficiency, in accordance with current best practice recommendations.[22] Although 5 to 7 staff members are typically required to mobilize a patient during ECMO, our case has demonstrated that out-of-bed mobility is feasible with a limited treatment team of 4 staff members, provided that team is highly experienced in performing early mobility interventions. Early mobility interventions are feasible during ECMO with COVID-19, and physical therapist-delivered treatments, including in-room ambulation, may facilitate discharge to home.

Author Contributions

Concept/idea/research design: A. Mark, K. Doerschug, A. Krupp
Writing: A. Mark, J.P. Crumley, K.L. Rudolph, K. Doerschug, A. Krupp
Project management: A. Mark
Providing participants: A. Mark
Providing facilities/equipment: A. Mark, K.L. Rudolph
Providing institutional liaisons: A. Mark
Consultation (including review of manuscript before submitting): A. Mark, J.P. Crumley, K.L. Rudolph, K. Doerschug, A. Krupp

Acknowledgments

The authors thank Kristina Rappaport, RN, MSN, ECMO specialist, Dan Dietzel, RN, BSN, ECMO specialist, and Danielle Burmeister, OTR/L, occupational therapist, for their clinical expertise.

Ethics Approval

This case report met the Health Insurance Portability and Accountability Act (HIPAA)/University of Iowa Hospitals & Clinics requirements for release of health information and public use of image. Patient consent was obtained.

Funding

There are no funders to report for this work.

Disclosures

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

References

1. National Institute for Health and Care Excellence (NICE). Rehabilitation after critical illness in adults. Published March 25, 2009. Accessed October 2, 2020. https://www.nice.org.uk/guidance/cg83/resources/rehabilitation-after-critical-illness-in-adults-pdf-975687209413
2. Gosselink R, Bott J, Johnson M, et al. Physiotherapy for adult patients with critical illness: recommendations of the European Respiratory Society and European Society of Intensive Care Medicine Task Force on Physiotherapy for Critically Ill Patients. *Intensive Care Med*. 2008;34:1188-1199.
3. Fan E, Brodie D, Slutsky AS. Acute respiratory distress syndrome advances in diagnosis and treatment. *JAMA*. 2018;319:698-710.
4. Marini JJ, Gattinoni L. Management of COVID-19 respiratory distress. *JAMA*. 2020;323:2329–2330.
5. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72314 cases from the Chinese Center for Disease Control and Prevention. *JAMA.* 2020;323:1239-1242.
6. Petrilli CM, Jones SA, Yang J, et al. Factors associated with hospital admission and critical illness among 5279 people with coronavirus disease 2019 in New York City: prospective cohort study. *BMJ*. 2020;369:m1966.
7. Extracorporeal Life Support Organization (ELSO). Reporting COVID-19 cases into the ELSO registry. Accessed October 2, 2020. https://www.elso.org/COVID19.aspx
8. DInglas VD, Aronson Friedman L, Colantuoni E, et al. Muscle weakness and 5-year survival in acute respiratory distress syndrome survivors. *Crit Care Med*. 2017;45:446-453.
9. Bakhru RN, Wiebe DJ, McWilliams DJ, Spuhler VJ, Schweickert WD. An environmental scan for early mobilization practices in U.S. ICUs. *Crit Care Med*. 2015;43:2360-2369.
10. Hodgson CL, Stiller K, Needham DM, et al. Expert consensus and recommendations on safety criteria for active mobilization of mechanically ventilated critically ill adults. *Crit Care*. 2014;18:658.
11. Munshi L, Kobayashi T, DeBacker J, et al. Intensive care physiotherapy during extracorporeal membrane oxygenation for acute respiratory distress syndrome. *Ann Am Thorac Soc*. 2017;14:246-253.
12. World Health Organization (WHO). Clinical management of severe acute respiratory infection when COVID-19 is suspected. Updated May 27, 2020. Accessed October 2, 2020. https://www.who.int/publications-detail/clinical-management-of-severe-acute-respiratory-infection-when-novel-coronavirus-(ncov)-infection-is-suspected
13. Thomas P, Baldwin C, Bissett B, et al. Physiotherapy management for COVID-19 in the acute hospital setting: clinical practice recommendations. *J Physiother.* 2020;66:73–82.
14. Extracorporeal Life Support Organization (ELSO*).* Guidelines for adult respiratory failure. Published August 2017. Accessed October 2, 2020. https://www.elso.org/Portals/0/ELSO%20Guidelines%20For%20Adult%20Respiratory%20Failure%201_4.pdf
15. Anfinson S, Greiner J. Early mobilization in the critically ill medical patient. Paper

presented at: 18th National Evidence-Based Practice Conference; April 28–29, 2011; Iowa City, IA.
16. Dubb R, Nydahl P, Hermes C, et al. Barriers and strategies for early mobilization of patients in intensive care units. *Ann Am Thorac Soc*. 2016;13:724-730.
17. Dinglas VD, Parker AM, Reddy DRS, et al. A quality improvement project sustainably decreased time to onset of active physical therapy intervention in patients with acute lung injury. *Ann Am Thorac Soc*. 2014;11:1230-1238.
18. Devlin JW, Skrobik Y, Gélinas C, et al. Clinical practice guidelines for the prevention and management of pain, agitation/sedation, delirium, immobility, and sleep disruption in adult patients in the ICU. *Crit Care Med*. 2018;46:e825-e873.
19. Garcia JP, Kon ZN, Evans C, et al. Ambulatory veno-venous extracorporeal membrane oxygenation: innovation and pitfalls. *J Thorac Cardiovasc Surg*. 2011;142:755-761.
20. Abrams D, Javidfar J, Farrand E, et al. Early mobilization of patients receiving extracorporeal membrane oxygenation: a retrospective cohort study. *Crit Care*. 2014;18:R38.
21. Wells CL, Forrester J, Vogel J, Rector R, Tabatabai A, Herr D. Safety and feasibility of early physical therapy for patients on extracorporeal membrane oxygenator: University of Maryland Medical Center experience. *Crit Care Med*. 2018;46:53-59.
22. Eden A, Purkiss C, Cork G, et al. In-patient physiotherapy for adults on veno-venous extracorporeal membrane oxygenation: United Kingdom ECMO Physiotherapy Network—a consensus agreement for best practice. *J Intensive Care Soc*. 2017;18:212-220.

Table. Major Medical Events, Safety Assessment, and Activity Interventions[a]

Hospital Day	Major Medical Events	Safety Assessment		Activity Intervention	Response to Progressive Mobility	Personnel Present in Room
		Respiratory	Neurologic and Sedative Infusions			
1	At admission: endotracheal intubation, VV ECMO cannulation	Mode = VC Fio_2 = 0.60 RR = 16 PEEP = 8	SAS = 2 Fentanyl, propofol	Bed rest		RN
2	Sedation weaning	Mode = VC Fio_2 = 0.40 RR = 16 PEEP = 10	SAS = 3 Fentanyl, propofol	PT consult PROM performed by RN		RN, ECMO specialist
3	Sedation weaning Adjustment in ECMO parameters	Mode = VC Fio_2 = 0.40 RR = 16 PEEP = 12	SAS = 3 Fentanyl, propofol	PROM performed by RN		RN, ECMO specialist
4	SAT Ventilator dyssynchrony	Mode = VC Fio_2 = 0.30 RR = 10 PEEP = 16	SAS = 3 or 4 Fentanyl, dexmedetomidine	PROM performed by RN, cardiac chair position in bed (head of bed 45°)	Stable vital signs in cardiac chair mode	RN, ECMO specialist
5	SAT	Mode = VC Fio_2 = 0.30 RR = 10 PEEP = 16	SAS = 3 or 4 Fentanyl, dexmedetomidine CAM-ICU positive for delirium	AROM exercises in supine position: ankle pumps, 10 reps; heel slides, 10 reps; short-arc quad exercises, 10 reps; shoulder flexion, 10 reps; elbow flexion and extension, 10 reps; all exercises performed bilaterally Sit-to-stand at bedside, 2 reps (60 s of rest between reps)	Patient's extremity strength improved with repetitions (MRC 1/5$\rightarrow$3/5) Spo_2 = 91%–100% Peak HR = 100 bpm BP = 113/60 (supine) and 115/80 (standing) Total treatment time = 55 min	PT, RN, ECMO specialist, RT
6	SAT Concern for preterm labor	Mode = VC Fio_2 = 0.30 RR = 10 PEEP = 16	SAS = 3 or 4 Fentanyl, dexmedetomidine	AROM exercises performed by RN in supine and cardiac chair positions	Out-of-bed activity held	RN, ECMO specialist
7	SAT Episode of hypertension	Mode = VC Fio_2 = 0.30 RR = 10 PEEP = 16	SAS = 3 or 4 Dexmedetomidine	AROM exercises performed by RN Sit-to-stand at bedside, 1 rep	Improved sit-to-stand strength and standing	RN, ECMO specialist, RT

					balance reported by RN	
8	First trial off ECMO	Mode = VC FiO_2 = 0.30 RR = 26 PEEP = 14	SAS = 4 Dexmedetomidine	Supine exercises: AROM heel slides, 10 reps; hip/knee extension with manual resistance by PT, 10 reps; ankle pumps with manual plantar flexion resistance by PT, 10 reps; all exercises performed bilaterally Standing at bedside, 3 reps (60 s of rest between reps), with marching for 30 s and side-stepping at bedside on final attempt	Extremity strength 4/5 bilaterally in lower extremities with supine exercise Best standing attempt = 60 s SpO_2 = 97%–100% Peak HR = 90 bpm BP = 118/65 (supine) and 75/49 (standing) Total treatment time = 39 min	PT, RN, ECMO specialist, RT, OT
9	ECMO decannulation	Mode = VC FiO_2 = 0.30 RR = 26 PEEP = 14	SAS = 4 Dexmedetomidine CAM-ICU **negative for delirium**	Supine exercises: AROM heel slides, 10 reps; hip/knee extension with manual resistance by PT, 10 reps; ankle pumps with manual plantar flexion resistance by PT, 10 reps; all exercises performed bilaterally Walking in room, ~3 m (10 ft), 2 reps (2 min of rest between reps)	Extremity strength 4/5 bilaterally in lower extremities with supine exercise SpO_2 = 92%–100% Peak HR = 87 bpm BP = 120/62 (supine) and 96/62 (after walking) Total treatment time = 45 min	PT (2), RN, ECMO specialist
10	Extubation to high-flow nasal cannula Respiratory distress in afternoon	40 L/min FiO_2 = 0.35	SAS = 4	Therapy by PT/OT held because of tachycardia, tachypnea, and respiratory distress after extubation		RN

11	Supplemental O_2 weaning	40 L/min FiO_2 = 0.30	SAS = 4	Morning physical therapy: Supine exercises: AROM heel slides, 10 reps; hip/knee extension with manual resistance by PT, 10 reps; ankle pumps with manual plantar flexion resistance by PT, 10 reps; all exercises performed bilaterally Walking ~6 m (20 ft) continuously (60 s of rest between supine exercise and walking) Afternoon physical therapy: Walking ~12 m (40 ft) continuously Occupational therapy: Upper extremity resistance band exercise; coping techniques for anxiety; breathing/relaxation exercises; ADL training	Extremity strength 4/5 bilaterally in lower extremities with supine exercise SpO_2 = 97%–100% Peak HR = 129 bpm BP = 126/68 (supine) and 134/60 (after walking) Total treatment time = 41 min	PT OT

12	Weaned off O_2	Room air	SAS = 4	Morning physical therapy: Walking ~6 m (20 ft) continuously Toileting tasks Resistance band exercises: seated knee extension, 10 reps; seated hip abduction, 10 reps; seated hip/knee extension against band, 10 reps; seated ankle pumps against band, 10 reps (30 s of rest between exercises) Afternoon physical therapy: Walking ~18 m (60 ft) continuously Single-stair training, 4 reps (60 s of rest between walking and stair training) Issued walker, written home exercise program of morning exercises to perform (10 reps, 3 times/d, independently), and resistance band for expected weekend discharge Occupational therapy: Upper extremity resistance band exercise review Discharge planning	SpO_2 = 97%–99% Peak HR = 116 bpm BP = 119/58 (after walking) Total treatment time = 39 min	PT OT
13		Room air	SAS = 4	Ambulation in room Independent resistance band exercise	SpO_2 = 97%–99%	RN
14	Discharged to home	Room air	SAS = 4	Ambulation in room Independent resistance band exercise	SpO_2 = 97%–99%	RN

[a]ADL = activities of daily living; AROM = active range of motion; BP = blood pressure; bpm = beats per minute; CAM-ICU = Confusion Assessment Method for the intensive care unit; ECMO = extracorporeal membrane oxygenation; FiO_2 = fraction of inspired oxygen; HR = heart rate; MRC = Medical Research Council Scale for Muscle Strength; OT = occupational therapist; PEEP = positive end expiratory pressure; PROM = passive range of motion; PT = physical therapist; rep = repetition; reps = repetitions; RN = registered nurse; RR = respiratory rate; RT = respiratory therapist; SAS = Riker Sedation-Agitation Scale score; SAT = spontaneous awakening trial; SpO_2 = peripheral oxygen saturation; VC = volume control; SAS = Riker Sedation Agitation Scale; VV ECMO = venovenous ECMO.

Figure.

Equipment and clinician setup for ambulation. The patient is preparing to walk, with a registered nurse supporting the endotracheal tube and advancing the ventilator on the left, an extracorporeal membrane oxygenation (ECMO) specialist securing the cannula and advancing the ECMO cart on the right, the primary physical therapist (PT) providing patient support and chair follow (not pictured), and an additional PT (not pictured) securing and advancing the intravenous and monitor lines in front.