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BRIEF REPORT

Practical Considerations for and Outcomes of Interfacility ECMO Transfer of Patients With COVID-19 During a Pandemic: Mayo Clinic Experience

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Abstract

Interfacility transport of a critically ill patient with acute respiratory distress syndrome (ARDS) may be necessary for a higher level of care or initiation of extracorporeal membrane oxygenation (ECMO). During the COVID-19 pandemic, ECMO has been used for patients with severe ARDS with successful results. Transporting a patient after ECMO cannulation by the receiving facility brings forth logistic challenges, including availability of adequate personal protective equipment for the transport team and hospital capacity management issues. We report our designated ECMO transport team's experience of 5 patients with COVID-19–associated severe ARDS after cannulation at the referring facility. Focusing on transport-associated logistics, creation of checklists, and collaboration with emergency medical services partners is necessary for safe and good outcomes for patients while maintaining team safety.

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Interfacility transport of a critically ill patient with acute respiratory distress syndrome (ARDS) due to COVID-19 may be necessary for a higher level of care or initiation of extracorporeal membrane oxygenation (ECMO). Bartlett et al[1] first described cannulation of the patient at the referring hospital and transport of the patient on ECMO. The concept of traveling to the referring hospital with a portable ECMO system, cannulating the patient at the referring hospital, and transporting the patient back to the receiving institution on ECMO was then further developed by Cornish et al.[2] It was not widely performed until the 2000s.[3] Since then, civilian and military institutions, including ours, have undertaken ECMO transport in various forms.[3,4] Adverse events have been reported in up to 27% of transports at experienced centers,[5] and patient selection, team training, and efficient use of limited resources have been described as important considerations.

Transportation of patients with COVID-19 presents a multitude of technical and workflow safety concerns for all members of both the sending and receiving facilities regarding effective and safe use of personal protective equipment (PPE) during interfacility transportation. Communication and preplanning have been described as key elements to minimize the risk of disease transmission.[6] Haphazard transport of infected patients, especially during complex ECMO transfers, can lead to nosocomial spread and endanger staff safety.[7] We report interhospital transport of 5 patients after initiation of venovenous ECMO by our ECMO transport team and subsequent transfer to our hospital for higher level of care with key considerations of PPE use for this transfer and transport-related issues.

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METHODS

A case series of 5 ECMO patients with COVID-19 who were transferred to our institution was included in this report by consecutive sampling from our institutional ECMO database.

ECMO Transport Team

Our ECMO transport team collaborates with private medical transportation companies (American Medical Response and Trinity Air Medical) that provide emergency medical services (EMS) as our transport partners. The ECMO team includes a cardiothoracic surgeon, an intensivist, a cardiovascular perfusionist, 2 intensive care unit (ICU) registered nurse ECMO specialists (RNESs), and an operating room (OR) registered nurse (RN)/scrub technician. Two vehicles are used for transport, 1 EMS ambulance and another chase vehicle. The team carries mobile extracorporeal life support components (Cardiohelp [Maquet] portable pump-oxygenator, cannulas) and transport equipment and portable monitor and ventilator courtesy of the EMS transport team. During the past 13 years, the team has performed 76 out-of-hospital cannulations for ECMO transport for venovenous support for acute hypoxic respiratory failure as well as for venoarterial support for cardiogenic shock. This experience prepared us well for the challenges of the COVID-19 pandemic.

Eligibility Criteria

Initial reports on use of ECMO for COVID-19 and prognosis were modest.[8] In addition, it is important to consider the challenge of initiating venovenous ECMO during a pandemic with resource implications. Our multidisciplinary ECMO team meets regularly and finalized the selection criteria for patients with COVID-19 on the basis of our institutional experience and Extracorporeal Life Support Organization (ELSO) guidelines.[9,10]

Capacity issues in the ICU were a concern with the local surge in patients with COVID-19. On the basis of the international consensus guidelines, our hospital was in contingency capacity through most of this pandemic.[11] In collaboration with hospital leadership, we limited the capacity of ECMO patients with COVID-19 ARDS to 5 in a 30-bed ICU. Staff availability was also a factor in transport-related decisions because of our designated ECMO transport team model (and not a dedicated team). Furthermore, other hospitals in the region participated in ECMO support of COVID-19 patients, and a statewide surge line was used to manage and to distribute the needs of community hospitals and regionalization of care. This was especially important from a resource and capacity standpoint such that regional hospitals worked in tandem to support all candidates meeting ECMO criteria.

Patient transports are requested by the referring provider. These requests are then triaged per standard ECMO triage protocol (a triage sheet is completed) by the house supervisor intake coordinator in the operations command center. The cardiothoracic surgeon and intensivist coordinate communication with the referring facility and decide on the candidacy for ECMO initiation and transfer.

Pretransport Planning and PPE

The modes of transmission of severe acute respiratory syndrome coronavirus 2 are primarily through the respiratory tract and mucous membranes by droplet and airborne exposure.[12] EMS vehicles for interhospital transfers have basic ventilation facilities. During episodes of patient transport outside of isolation, potential breaches of infection control can occur. Using recommendations from our infection prevention and control group, which are largely guided by the Centers for Disease Control and Prevention recommendations, the ECMO team made detailed plans before doing our first transfer for a patient with COVID-19. Maintaining staff safety and having adequate PPE along with a structured donning and doffing process were important parts of our preparation. Policies were implemented in partnership with American Medical Response, our EMS transport partners, to address PPE recommendations on the basis of transport risk.

A decision was made that all patients under consideration for interfacility transport were to be cared for with use of airborne isolation during the transport. Requirements of airborne isolation included a controlled air-purifying respirator, powered air-purifying respirator, or N95 mask with face shield,

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TABLE 1. Transport Recommendations[a]

	Transport team members[b]	Primary safety officer	Backup safety officer
Before transport	Bring provided transport PPE bag with gloves, gowns, CAPRs, trash bags, shoe covers ECMO transport equipment per protocol Pretransport huddle and huddle on arrival for donning checklist Surgical mask to be worn in transport around other transport team members Before entering sending facility, don shoe boot covers Don N95 or CAPR; surgical mask over N95, gown, bouffant/surgical cap, gloves		
During transport	Maintain airborne precautions at all times while in sending facility and on return ride to receiving facility Communication: The ability to communicate is decreased with the decrease in ability to see one another's faces. All personnel must pay added attention to communication, and at least 1 person should echo the orders or information given. RNES to call receiving facility ICU team leader and notify of 15-minute expected time of arrival	Notified of 25-minute expected time of arrival and proceed to ambulance bay Bring hand sanitizer and hospital-grade disinfectant wipes to the ambulance to be used while doffing PPE Bring all necessary PPE supplies (gowns, gloves, surgical masks) for the team to don before entering	
After transport	On arrival to receiving unit, transport team delays entry into the hospital until all instructions of primary safety officer have been followed to doff old PPE and to don new set of PPE	Ensures that entire transport team in the back of the ambulance exits through the back doors of the ambulance Provides doffing instructions to all transport team members, ensures proper technique: • Remove shoe boot covers • Remove your gown • Wash your hands • Replace your gloves • Remove your facemask and replace it with a clean one • Use a wipe to wipe down the front of your eye protection • Remove gloves • Wash hands Provides the following donning instructions, ensures proper technique: • Don new gown • Replace gloves	Once team has exited the back of the ambulance: • Receives equipment that is not in use from RNES • Uses hospital-grade disinfectant wipes to clean stretcher, ECMO console, ventilator, IV pumps, and any other DME that accompanies the patient

[a]CAPR, controlled air-purifying respirator; DME, durable medical equipment; ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit; IV, intravenous; PPE, personal protective equipment; RNES, registered nurse ECMO specialist.
[b]The transport team members are to bring their own N95 masks and eye protection. A CAPR is obtained from ICU stock if the N95 fails to fit.

gloves, and gown. The transport team additionally donned shoe covers, bouffant cap/OR hat, and hospital-provided scrubs. A tabletop exercise was done to focus on PPE donning/doffing checklist criteria, role clarification, patient-centered care, teamwork, collaborative leadership, and interprofessional communication. All transport team members completed online educational modules.

Transport equipment included portable golf bags carrying cannulas of various sizes, oxygenator cart, surgical equipment cart, intravenous (IV) pumps, and medication backpacks consisting of life support medications, IV infusion drugs (sedatives, vasopressors, inotropes, antiarrhythmics, electrolytes), and PPE. Oxygen tanks, transport ventilator, and advanced cardiac life support drugs are also provided by the EMS team. We do not bring our own blood cooler but receive blood from the sending facility, which has it typed and crossmatched, if needed.

A predeparture huddle and time-out was organized along with the EMS crew (1 RN and 1 emergency medical technician) so that everyone was familiar with the donning and doffing criteria/checklist. Each transport team member brings with them their own N95 mask and face shield. Roles and responsibilities were clarified along with coordination and communication issues. On arrival at the sending facility, another huddle was done, and 1 RNES ensured that the team donned the PPE that was brought with the transport team appropriately.

In-Procedure Safety Measures

Our in-procedure safety measures consisted of limiting the number of people in the ICU room and full airborne PPE use. The in-room team consisted of the surgeon, the intensivist (assisting with cannulation or managing the critically ill patient), 1 perfusionist, 1 ICU RN and 1 respiratory therapist from the requesting team, and 1 OR nurse/scrub technician. Our RNES is on standby outside the room ready to assist as necessary. Whereas our standard of care in the ICU is a negative pressure room or pod, this was not always feasible in the referring hospitals. After cannulation was completed, the RNES and EMS transport team (RN and emergency medical technician) entered the room as the cannulation team stepped out to move the patient to a transport gurney while maintaining full precautions. The perfusionist stayed in the room to assist with the process.

Return Transport and Decontamination

Factors including limited ambulance space, EMS policy, and necessity for continued patient care are taken into consideration for the return to the ECMO facility. The team that rides with the patient in the ambulance included the intensivist, 2 RNESs, and the perfusionist. En route, the team maintained airborne precautions at all times. The surgeon and OR scrub technician/RN doff PPE and return "clean" in the chase vehicle.

On arrival at the receiving facility, 2 safety officers (ICU RNs) familiar with proper donning and doffing procedures are sent from the ICU. The safety officers bring all necessary PPE supplies (gowns, gloves, surgical masks, alcohol-based hand sanitizer) for the team to don before entering the receiving hospital. The primary safety officer is responsible for the arriving ECMO team in the ambulance to follow proper doffing procedures (Table 1). The backup safety officer is then responsible for receiving the equipment from the RNES before the team's exiting the ambulance and transporting it back to the ICU for decontamination. The backup safety officer is also responsible for wiping down the stretcher, ECMO circuit, ventilator, monitor, IV pumps, and any other equipment. Once the transport team has donned new PPE and the equipment has undergone initial decontamination, they proceed through a pre-established route for transporting patients with COVID-19 within the hospital.

RESULTS

Patients' outcomes and demographic characteristics are provided in Tables 2 and 3. Most patients were young and female (4 [80%]) and had a high median body mass index of 31.9 kg/m^2 (interquartile range [IQR], 25.5-36.9 kg/m^2). The median time to intubation for these patients was 4.3 hours (IQR, 1.6-13 hours), and median time from admission to hospital to ECMO cannulation was 3.77 days. Transport-related metrics are provided in Table 4. Median distance covered was 19.7 miles (IQR, 17.75-24.6 miles).

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Referral to cannulation time median was 315 minutes (IQR, 249-816 minutes). Of the 5 patients, 2 had diabetes, 1 had asthma, and 1 had rheumatoid arthritis. Most patients had high ventilator requirements with refractory hypoxemia. Four patients (80%) had been placed prone, and 1 patient could not be placed prone because of unstable airway/cricothyroidotomy. All 5 patients survived ECMO decannulation. The median duration of ECMO run was 30 days (range, 12-88 days).

TABLE 2. Demographic Characteristics and Patient Outcomes[a,b]

Demographic characteristics	(N=5)
Age (y)	39 (31.5-48.5)
Female	4 (80)
Body mass index (kg/m^2)	31.9 (25.5-36.9)
Past medical history	
Smoker	0
Asthma/COPD	1 (20)
Diabetes mellitus	2 (40)
Coronary artery disease	0
Hypertension	0
Malignant disease	0
Transplant	0
Chronic kidney disease	0
Rheumatoid arthritis	1 (20)
Diagnostics and therapeutics	
Confirmed COVID+ before ECMO transfer	5
Time from admission to intubation (h)	4.3 (1.6-13)
Time from admission to ECMO cannulation (h)	90.5 (43.15-246)
Prone before ECMO	4 (80)
Paralyzed before ECMO	5 (100)
Inhaled pulmonary vasodilator before ECMO	2 (40)
COVID-related therapies during hospital stay	
Hydroxychloroquine	2 (40)
Tocilizumab	2 (40)
Plasma therapy	3 (60)
Remdesivir	4 (80)
Steroids	5 (100)
Complications	
AKI requiring CRRT	2 (40)
Airway hemorrhage	1 (20)
Sepsis/septic shock	2 (40)
Cannula bleeding	2 (40)
Stroke	0
Circuit exchanges	0 (0-0.75)

[a]AKI, acute kidney injury; COPD, chronic obstructive pulmonary disease; CRRT, continuous renal replacement therapy; ECMO, extracorporeal membrane oxygenation.
[b]Categorical variables are presented as number (percentage). Continuous variables are presented as median (interquartile range).

DISCUSSION

For patients with COVID-19 severe ARDS, ECMO has been successful with survival rates similar to prepandemic ARDS outcomes.[13] However, hospital and ICU capacity determines the ability to offer this resource-intense therapy, especially if the patient is in a contingency or crisis state. Whereas a transport team for safe cannulation and retrieval of patients from referring centers is feasible, the logistics are immense, and adequate PPE supplies must be available. At the time of this report, the ELSO Registry has 21 patients transported to outside facilities while on ECMO, of which 16 cases occurred in North America.[14]

Good collaboration with transport partners for interfacility transfer is vital. Our prior experience of a designated team for ECMO transport enabled us to cannulate unstable patients and to support them on ECMO, patients who would have a worse outcome otherwise. Creation of a checklist, tabletop exercises, and huddles ensured that all necessary steps of donning and doffing PPE and transport logistics were followed, reducing staff exposure and adverse outcomes. Role clarity, situational awareness, and backup behaviors were encouraged, especially when it came to ensuring PPE compliance. Thus far, no transport team members have suffered from an exposure.

Although risks do exist for transport teams, meticulous preparation, experience of ECMO transports, and strict adherence to checklists and protocols ensure team safety. This can be difficult to initiate or to maintain during a contingency or crisis pandemic surge. Few centers offer aeromedical transport for ECMO patients, and the risk of exposure can be high because of a small pool of qualified staff. However, successful air transports of ECMO patients with COVID-19 have been described by other teams by streamlining of their processes during this COVID-19 pandemic.[15] Whereas COVID-19 numbers may plateau soon as the vaccination efforts go up, it is unclear, with new variants, whether we will ever be able to go back to

TABLE 3. Cannulation Strategy and Flow Characteristics of ECMO Patients

	Circuit details				
	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
ECMO modality	V-V	V-V	V-V	V-V	V-V
Cannulas					
Drainage/outflow cannula (size F)	L FV (25)	L FV (25)	L FV (25)	L FV (25)	L FV (25)
Return/inflow cannula (size F)	R FV (21)	R FV (21)	R FV (23)	R FV (23)	R FV (23)
Location patient cannulated	Referral ICU	Referral ICU	Referral ICU	Referral ICU	Referral ICU
P:F ratio at time of cannulation	73	72	107	51	72
Hemodynamics and flow characteristics for first 7 d of run					
Maximum values					
Plateau pressure (cm H_2O)	28	29	30	29	35
Flow (L/min)	4.08	5.59	4.05	3.35	5.46
Sweep (L/min)	3.5	3.5	2.5	3.5	6
Sweep gas (%)	100	100	100	100	100
Median (IQR)					
Plateau pressure (cm H_2O)	21 (20-22)	26 (25-27)	27 (24-28)	26 (25-26)	31 (30-32)
Flow (L/min)	3.87 (3.53-3.95)	4.12 (4.07-5.41)	3.34 (3.27-3.50)	3.24 (3.22-3.27)	4.23 (4.02-5.12)
Sweep (L/min)	3 (2-3)	5.5 (4-5.5)	1.5 (1.5-1.6)	3 (3-3)	2.5 (2-3.6)
Sweep gas (%)	100 (70-100)	100 (100-100)	80 (70-90)	100 (90-100)	100 (100-100)

ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit; IQR, interquartile range; L FV, left femoral vein; P:F ratio, partial pressure of oxygen/fraction of oxygen ratio; R FV, right femoral vein; V-V, venovenous.

the prepandemic world in the near future. Precautions and protection of transport staff with PPE may well become the new standard of care for mobile ECMO teams.

Overall, our patients' outcomes have been satisfactory. All of them were successfully decannulated. Two of them have been discharged, and the other 2 are recovering in the hospital.

TABLE 4. Transport Metrics

Transport distance (miles)	19.7 (17.75-24.6)
Referral to cannulation time (min)	315 (249-816)
Total time on transport (min)	220 (189-243)
Total time from referral to return (min)	406 (358-949)

Values are reported as median (interquartile range).

One patient died several days after decannulation of neutropenic septic shock due to suspected disseminated coccidiomycosis with recurrence of ARDS. Our outcomes are reflective of careful and uniform candidate selection. The ECMO runs were variable, and the prolonged run of 88 days in 1 patient indicates that it is difficult to predict lung recovery, especially in young patients with minimal comorbidities. Prolonged ECMO runs can lead to capacity management issues, staff burnout, and fatigue, especially during a contingency state in a pandemic.

CONCLUSION

The ELSO guidelines recommend that programs with an established mobile ECMO program and with sufficient resources to maintain it should continue to offer this highly specialized therapy to surrounding hospitals. We report successful mobile ECMO cannulation for COVID-19–associated severe ARDS by

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an experienced transport team for 5 patients while adhering to checklists and maintaining staff safety, with no known exposure. Although it is heavily resource intensive, maintaining strict PPE protocols is necessary to ensure successful patient and staff outcomes.

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Abbreviations and Acronyms: **ARDS** = acute respiratory distress syndrome; **ECMO** = extracorporeal membrane oxygenation; **ELSO** = Extracorporeal Life Support Organization; **EMS** = emergency medical services; **ICU** = intensive care unit; **OR** = operating room; **PPE** = personal protective equipment; **RN** = registered nurse; **RNES** = registered nurse ECMO specialist

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