Original Manuscript

Perfusion

Perfusion
2022, Vol. 0(0) 1–9

DOI: 10.1177/02676591221078694
journals.sagepub.com/home/prf
SAGE

"Pushing Geographic Boundaries: Interfacility transport and remote extracorporeal membrane oxygenation cannulation of patients during COVID-19 pandemic"

Christina Creel-Bulos,[1,2] Casey Miller,[3] Brian Hassani,[1] Heather Farthing,[2] Mark Caridi-Schieble,[1] Michael J Connor Jr,[4] Jeffrey Javidfar[3] and Mani Daneshmand[3]

Abstract

Amidst the pandemic, geographical boundaries presented challenges to those in need of higher levels of care from referral centers. Authors sought to evaluate potential predictors of treatment success; assess our transport and remote cannulation process; and identify transport associated complications.

Retrospective series of critically ill adults with COVID-19 transferred by our Extracorporeal Membrane Oxygenation (ECMO) team 24 March 2020 through 8 June 2021. Descriptive statistics and associated interquartile ranges (IQR) were used to summarize the data.

Sixty-three patients with COVID associated acute respiratory distress syndrome (ARDS) requiring ECMO support were admitted to our ECMO center. Mean age was 44 years old (SD 12; IQR 36–56). 59% (n = 37) of patients were male. Average body mass index was 39.7 (SD 11.3; IQR 31–48.5). Majority of patients (77.8%; n = 35) had severe ARDS. Predictors of treatment success were not observed.

Transport distances ranged from 2.2 to 236 miles (median 22.5 miles; IQR 8.3–79); round trip times from 18 to 476 min (median 83 min; IQR 44–194). No transport associated complications occurred. Median duration of ECMO support was 17 days (IQR 9.5–34.5). Length of stay in the Intensive Care Unit (median 36 days; IQR 17–49) and hospital (median 39 days; IQR 25–57) varied. Amongst those discharged, 60% survived.

Keywords

extracorporeal membrane oxygenation, COVID-19, acute respiratory distress syndrome, out of hospital, transport, cannulation

Introduction

Among those diagnosed with Coronavirus disease 2019 (COVID-19), the development of acute respiratory distress syndrome (ARDS) is associated with a significant increase in mortality.[1] Extracorporeal Membrane Oxygenation (ECMO) has been utilized in severe respiratory and cardiac failure. Due to the high incidence of ARDS in those affected by this disease, ECMO centers across the country began employing this therapy relatively early in the COVID-19 pandemic. ECMO, as a bridge to recovery or lung transplantation for COVID-19 related acute respiratory failure, has continued to expand after an international, multi-centered study demonstrated mortality outcomes comparable to those on ECMO in non-COVID related acute respiratory

[1]Division of Critical Care Medicine, Department of Anesthesiology, Emory Critical Care Center, Emory University School of Medicine, Atlanta, GA, USA
[2]Department of Emergency Medicine, Emory University School of Medicine, Atlanta, GA, USA
[3]Division of Cardiothoracic Surgery, Department of Surgery, Emory University School of Medicine, Atlanta, GA, USA
[4]Divisions of Pulmonary, Allergy, Critical Care, & Sleep Medicine, Division of Renal Medicine, Department of Medicine, Emory University School of Medicine, Atlanta, GA, USA

Corresponding author:
Christina Creel-Bulos, Department of Anesthesiology, Emory University Hospital, 1364 Clifton Road NE, Atlanta, GA 30322, USA.
Email: mcreelb@emory.edu

failure.[2,3] Although receiving care at a high volume ECMO center has been associated with improved mortality amongst this patient population, there are significant obstacles associated with providing this service to those residing far from such centers.[4,5] Amidst a pandemic, these challenges are compounded.

The feasibility and challenges of large volume, interfacility transport of adult patients on ECMO support has been reported as early as 2009 in association with the H1*N*1 pandemic.[6,7] A recent literature review examining transportation related mortality and morbidity found that rates were low when patients were transported by experienced ECMO center transport teams.[8] International reports of interhospital transport-of patients with COVID-19 on ECMO via various means of transport have been documented.[9–15] On evaluating the incidence of major inter-transport complications in patients on ECMO for COVID-19 and non-COVID-19 disease, no significant differences were found.[10]

Our urban, academic medical center serves as a busy ECMO referral center within the Southeastern United States with an average of 160 cannulations annually. In the battle against COVID-19, we were given the opportunity to expand our geographical boundaries and provide aid to those in need. We retrospectively report on 63 interfacility ECMO team transports, including: high risk patient characteristics, clinical outcomes, associated geographic and logistical challenges, and lessons learned.

Materials and methods

This is a retrospective case series of critically ill, adult patients (≥18 years of age) with laboratory-confirmed COVID-19 transported to our medical center by our ECMO transport team from 24 March 2020 through 8 June 2021. All diagnostic testing and therapeutic interventions-including decisions with respect to ECMO candidacy and cannulation technique-were performed at the discretion of the treating clinicians. At our institution, a multidisciplinary team consisting of members of Critical Care Medicine and Cardiothoracic Surgery is responsible for consultation, cannulation, and management of all patients on ECMO. Our research team retrospectively reviewed demographic, clinical, geographic, and diagnostic data obtained from each patient's transfer and admission.

Authors sought to describe characteristics of patients transported and evaluate for potential predictors of treatment success. Our team examined the following factors: age, gender, body mass index (BMI), ratio of arterial partial pressure to fractional inspired oxygen (P/F ratio); as well as duration of mechanical ventilation, ECMO support, and Intensive Care Unit (ICU) admission. We sought to review our transport and remote cannulation process. As well as to additionally identify transport associated challenges, complications and lessons learned.

Acute respiratory failure syndrome severity was categorized by P/F ratios prior to initiation of ECMO. Treatment success was defined as ECMO free survival to discharge from our facility. Interfacility transport was defined as: transfer from any medical facility outside of our ECMO center and included other hospitals in our hospital system without ECMO capabilities. We further divided transports into primary, secondary, and conventional transport. Primary transport was defined as cannulation and initiation of ECMO support that occurred at the referring facility by our ECMO team. Secondary transport involved patients who were placed on ECMO by the referring center and transported by our team to our facility for further medical management. Conventional transport describes patients who were transported to our facility from outside facilities without the utilization of ECMO support prior to transport. Our cohort was predominantly composed of primary cannulations-likely as a result of patients' disease severity. Secondary transports occurred infrequently.

Adverse outcomes were defined as accidental decannulation, circuit failure, hemorrhage, significant hemodynamic instability, cardiopulmonary arrest and transmission of COVID-19 to ECMO team members during transport of patients from outside medical facilities. Significant hemorrhage was further defined as requirement of transfusion of greater than two units of blood product. Hemodynamic instability referred to the initiation of a new inopressor agent or a greater than 30% increase in norepinephrine equivalents compared to dosage required on departure from the referring facility. Descriptive statistics including mean, standard deviation, ranges, median, percentages, and associated interquartile ranges (IQR) were used to summarize the data. All univariate statistical calculations were performed using Microsoft Excel and SPSS Data Analysis Software.

Extracorporeal membrane oxygenation transport team and pre-transport planning

At our institution, a multidisciplinary team consisting of members of Critical Care Medicine and Cardiothoracic Surgery is responsible for consultation, eligibility evaluation, cannulation, and management of all patients on ECMO. Transport team members include: paramedics, perfusionists, attending physician, critical care fellow, and an Advanced Practice Provider who serves as our ECMO program coordinator. During primary cannulations, all members of the team are present. In secondary cannulations a Critical Care Medicine fellow, perfusionist and two paramedics comprise the transport team.

Our center utilizes Maquet's Cardiohelp console exclusively for ECMO related transports due to its favorable size and easy mobility. Our team has a preferred cannulation strategy that includes usage of a right femoral (25 or 29 French) multi-stage venous drainage cannula and a (20 or 22 French) return cannula in the right internal jugular. This enables a "same side of the body" line configuration to simplify transport and daily management in the ICU. As a standard, patients remain on concomitant mechanical ventilatory support throughout transfer.

All patients were cared for under airborne isolation with personal protective equipment (PPE) that included: respirator or *N*-95 mask, goggles or face shield, bouffant or surgical cap, gloves, gowns, and hospital provided scrubs. Our medical centers Infection Control and Infectious Disease divisions in conjunction with representatives from the Center for Disease Control, provided online virtual and in person training on donning and doffing of PPE through healthcare system wide education.

Eligibility criteria review and pre-transfer communication was facilitated through our transfer center and managed by our ECMO program coordinator and multispecialty physicians (direct calls were made to the on-call providers cell phone 24/7). Once patients were accepted, the referring center received a letter with information about our center and detailing the cannulation and transport process. Additionally, a standard supplies list was sent ahead of time to ensure that additional supplies such as: an ultrasound machine with corresponding probes, extra surgical towels, saline etc. were available upon our arrival to expedite remote cannulations (Figure 1).

Our team carried supplies including, but not limited to: cannulae, circuit, and oxygenator, a specifically designed surgical tray and sterile attire in portable bags. During lengthy travel, the team would remain in regular communication with the transferring facility to receive clinical updates, provide travel arrival information and help ensure the patient, medical team, and patients surrogate were prepared for ECMO initiation and/or transport.

Remote site cannulation, transport, return, and admission process

In order to minimize unnecessary duration of time and frequency of times in patient rooms, teams were divided into groups. Applicable consent forms-including procedural and blood product consent-were obtained by the team physician while other members prepared equipment outside the room, including sterile surgical table layout. Once patient, staff and equipment were ready, those actively participating in cannulation and ECMO initiation entered the room with the pre-prepared sterile table. During cannulation and initiation, paramedics and staff from the transferring facility prepared a transport ventilator, intravenous infusion pumps, and medications outside of the patient's room. Once the patient was initiated on ECMO support, the second team consisting of medics entered the room to facilitate transfer of equipment and patient to EMS capable equipment and stretcher.

Airborne precautions and PPE remained throughout the duration of transfer. Anticipatory notice and clinically pertinent information were provided en route from transport to receiving team. Travel of our team through deemed ED "warm zone" and direct admission to COVID-19 specific ICU occurred on arrival. Care Endorsement occurred at bedside by ECMO transport team to the receiving team. Those not required to be present in patients' rooms received sign out information through utilization of e-ICU and in/out of room "walkie talkie" devices.

Results

Demographics, clinical characteristics, and diagnostic findings

During the study time period, 63 adult patients admitted to the ICU with COVID associated ARDS requiring ECMO support were admitted to our ECMO center. The mean age of those transferred was 44 years old (SD 12; IQR 36–56) (Table 1). 59% (n = 37) of patients were male, 52% (n = 33) were African American, and the average BMI of our cohort was 39.7 (SD 11.3; IQR 31–48.5). Medical history of hypertension and diabetes were commonly noted in 46 and 24 percent of patients, respectively (Table 1).

All but one patient (n = 62) required mechanical ventilation during their hospitalization. The majority of patients (77.8%; n = 35) had severe ARDS -defined as P/F ratio less than 100-on transfer. Median days of admission and mechanical ventilation days at the time of ECMO initiation were 8 days (IQR 5–12) and 4 days (IQR 2–6), respectively. The predominance of patients was cannulated with a venovenous strategy (96.8%; n = 61) and all were peripherally cannulated (Table 2).

Transport related data

Within this cohort, the majority of patients (92% n = 58) were transferred from facilities outside of our healthcare

EMORY MEDICINE | ECMO Center
Extracorporeal Membrane Oxygenation Center

Dear Staff,

Thank you for choosing Emory ECMO for your patient. We are very honored to be caring for them. So that we can most efficiently place your patient on support, we would like to ask that the following be ready on our arrival. We recognize that you may not have all these supplies, and we do carry a limited supply as backup, but it is very helpful to us to already have them at hand and just ask that you get as many as possible.

Supplies

- □ 1L bottle of sterile NS (as for sterile irrigation)
- □ 4x Sterile OR towels (multi-packs)
- □ 2x gauze packs, 4x4" (2 multi-packs)
- □ 2x Sterile drapes (like for central lines)
- □ 4x Chlorprep sticks (the medium or large ones)
- □ 2x Sterile gowns
- □ 2 Patient tables
- □ 2 empty garbage cans
- □ Hats and masks for anyone that will be in room
- □ Ultrasound machine, with both linear and cardiac probes (if available)
- □ 2x sterile probe covers

Medications

- □ Norepinephrine gtt on pump, in-line and ready to turn on if needed
- □ 10ml syringe filled from above norepi bag and labelled with concentration (we will direct bolusing during procedure)
- □ A bag of crystalloid (NS, LR or plasmalyte) in-line (not on a pump) in case rapid volume is needed
- □ 5000 units of heparin, drawn up and ready to give IV (we will direct when to give)
- □ Basic code drugs: 2 amps epi, 2 amps bicarb, 2 amp calcium chloride
- □ Please make sure that there are plenty of pressors left in the current bags and/or that there are extra bags already in the room.

Labs

- □ An ABG within last hour prior to arrival
- □ A type and cross for 2 units (does not necessarily need to be in room unless hemoglobin is less than 9.0)

Staff

- □ Respiratory therapist (on arrival and at end of procedure)
- □ Nurse required for entire procedure, will need to administer meds and manage hemodynamics
- □ Another nurse or aid available to help the room nurse obtain supplies, labs etc as needed during procedure
- □ We welcome anyone from the medical staff that would like to observe the procedure as long as they wear a hat and mask and there is adequate space in the room. We do not however allow recording.

Figure 1. Pre-transport remote cannulation letter.

system, with the primary method of transportation being ground via ambulance (98.3% n = 57). Amidst those transported, 87% (n = 55) were primary transports (Figure 2). Transport distances ranged from 2.2 to 236 miles (median 22.5 miles; IQR 8.3–79) and round-trip transport times—not including time for pre cannulation preparation, cannulation, initiation of ECMO support and preparing patients for transport—ranged from 18 to 476 min (median 83 min; IQR 44–194) (Figure 3). None of the referring medical centers had transplant or ECMO capabilities, with the exception of one hospital who had reached their capacity for patients on ECMO. Our standardized ECMO process, as described above in the methods section, was utilized with every transport of

EMORY MEDICINE | **ECMO Center**
Extracorporeal Membrane Oxygenation Center

Family

- We will need to obtain consent from the family upon arrival, so if it is possible to have them stay close, that would be ideal. If they are unavailable then we can obtain by phone as long as contact information is readily at hand.

Patient preparation

- As often as possible, we prefer to cannulate the R IJ. If there is a central line already in the R IJ, it would be preferable to have that moved to the left IJ or subclavian. We prefer not to have additional groin lines, but if one is already there it is not a problem. If the R IJ is occupied by a vascath but there is other central access elsewhere, then the vascath can simply be removed and we will place another once back to Emory.
- EKG leads should be moved such that they are on the patient's shoulders, back or sides and do not cross over the chest.

On arrival, we will talk with the family and set up for the procedure. The procedure itself takes about an hour, and then it usually takes another ½ hr to 45 min to prepare for transport. Because federal regulations do not allow us to bring medications for a patient that is not already in our hospital, we will also need to request medications for the trip back. Some of the amounts or specific medications (aside from current pressors) we may not need depending on the condition, so you don't have to have these ready before our arrival.

For trip back

- Drips: we will need at least 1 replacement bag for every drip that is currently hanging, especially vasopressors, paralytic and sedation. Our preference for sedation is midazolam and fentanyl, however we can also utilize propofol if the trip will be short.
- Code drugs: Depending on trip duration and stability of the patient, we are likely to request additional code drugs: 2 amps epi, 2 amps bicarb, 2 amp calcium chloride
- Blood: Also depending on the patient condition and duration of the trip, we may ask for blood

ETA FOR OUR TEAM TO ARRIVE AT YOUR FACILITY:

Your cannulation and transport team will consist of:

Cannulating attending:

Cannulation/transport fellow:

Perfusionist:

The accepting attending is:

Should you have any questions or concerns or patient updates, please call the Emory Transfer Center at (404) 686-8334 and ask for ECMO Coordinator (Primary Contact): Casey Miller, NP

Figure 1. Continued.

patients with active COVID-19 disease. When performing ECMO cannulations within our hospital, our team adhered to the same process and protocol to promote consistency and expedient reproducibility when clinically crucial.

As previously highlighted, transport related adverse outcomes were defined as accidental decannulation, circuit failure, hemorrhage, significant hemodynamic instability, cardiopulmonary arrest, and transmission of COVID-19 to transportation team members. To date, no adverse outcomes have been reported and none of our transportation team members have acquired illness related to their role on ECMO initiation or transport team. Despite continuing to further expand our geographical boundaries, this has remained true.

Table 1. Demographic characteristics and patient outcomes.

Characteristics	Patients (*N* = 63)	Odds ratio (95% CI)	*p*-value
Age, mean (SD)-yr	44 (12.3)	0.97 (0.64–1.47)	.89
Gender-no (%)		0.63 (0.22–1.84)	.40
Male	37 (58.7)		
Female	26 (41.3)		
BMI, mean (SD)	39.7 (11.3)	1.01 (0.68–1.51)	.95
Race-no (%)		0.83 (0.50–1.40)	.48
Asian	3 (4.8)		
American Indian	0 (0)		
Black	33 (52.4)		
Hispanic	7 (11.1)		
White	20 (31.7)		
Other	0 (0)		
Past medical history-no (%)		1.02 (0.63–1.68)	.92
Diabetes	15 (23.8)		
Coronary artery disease	3 (4.8)		
Obstructive lung disease	13 (20.6)		
Hypertension	29 (46.0)		
Chronic kidney disease	1 (1.6)		
Characteristics prior to ECMO initiation			
P/F ratio-no (%)		0.21 (0.02–1.73)	.15
Mild	1 (2.2)		
Moderate	9 (20)		
Severe	35 (77.8)		
Admission day-med (IQR)	8 (5–12)	0.91 (0.46–1.80)	.79
Mechanical ventilation day-med (IQR)	4 (2–6)	1.08 (0.83–1.41)	.58
Outcomes			
Duration of ECMO support (days)-med (IQR)	17 (9.5–34.5)	1.00 (0.78–1.26)	.97
Duration of mechanical ventilation (days)-med (IQR)	24 (14–34)	1.08 (0.83–1.41)	.58
ICU LOS (days)-med (IQR)	36 (17–49)	1.37 (1.07–1.75)	.012
Hospital LOS (days)-med (IQR)	39 (25–57)	1.42 (1.10–1.84)	.007
Mortality-no (%)	21 (40)		
Disposition-no (%)			
Home	10 (29.4)		
Rehabilitation facility	18 (52.9)		
Referral hospital	3 (8.8)		

ECMO: extracorporeal membrane oxygenation; ICU: Intensive care unit; IQR: interquartile ranges.

Additional outcomes

The median duration of ECMO support in this cohort was 17 days (IQR 9.5–34.5)). Duration of mechanical ventilator support was a median of 24 days (IQR 14–34). Length of stay in the ICU (median 36 days; IQR 17–49) and hospital (median 39 days; IQR 25–57) varied. Among those discharged from our facility thus far, 60% survived ($n = 31$). 29% ($n = 10$) were discharged to their homes, 53% ($n = 18$) were discharged to rehabilitation facilities and 9% ($n = 3$) were transferred back to the referral medical centers for continuation of care once they were determined to no longer have need for ECMO or transplantation. The majority of factors evaluated were not found to be statistically significant predictors of treatment success. Although ICU and hospital duration were noted to have *p*-values of significance, the associated odds ratios and small sample size make true clinical significance difficult to interpret.

Discussion

Our medical center's transport experience contributes to the growing body of literature outlining the limitations and opportunities presented by the COVID-19 pandemic. Not only has our center demonstrated that remote cannulation and ECMO transport can be both safe and feasible during a pandemic but we were able to do so

Table 2. Cannulation and transport characteristics and referring hospital and regional metrics. External transfer includes all those transferred from referring facility regardless of whether extracorporeal membrane oxygenation cannulation was performed remotely, prior to or after transfer.

Transport distance (miles)-median (IQR)	22.5 (8.5–79)
Transport time (minutes)-median (IQR)	83 (44–194)
COVID ICU hospital capacity no-median (IQR)	
Within our healthcare system	66 (IQR 66–86)
Outside of healthcare system	30 (IQR 18–48)
Average household income dollars-median (IQR)	
Within our healthcare system	92,000 (IQR 65,000–92,000)
Outside of healthcare system	47,000 (IQR 37,500–57,500)
ECMO type	
VV ECMO	61 (96.83)
VAV ECMO	2 (3.17)
Remote cannulation	
External transfer	58 (92.0)
Remote cannulation	55 (87.3)
Mode of transport	
Ground ambulance	57 (98.3)
Air	1 (1.72)

ECMO: extracorporeal membrane oxygenation; ICU: Intensive care unit; IQR: interquartile ranges.
*External Transfer includes all those transferred from referring facility regardless of whether ECMO cannulation was performed remotely, prior to or after transfer.

while ensuring the health of our transport team members. Our center was able to expand the geographic area in which we obtain referrals and provide services that would have previously been unavailable to numerous patients-many from regions with significant limitations in healthcare and economic resources. Additionally, we did so with a medically complex population with severe ARDS and exceptionally high BMI's. In light of disease variants and persistent burden to ECMO centers from COVID-19 related ARDS and its associated pulmonary sequelae, it is unclear how extensive a role ECMO will continue to play for this patient population. The management of patients with ARDS has dramatically transitioned over the past decades from a treatment to prevention based paradigm.[16] This has occurred not simply as a result of significant

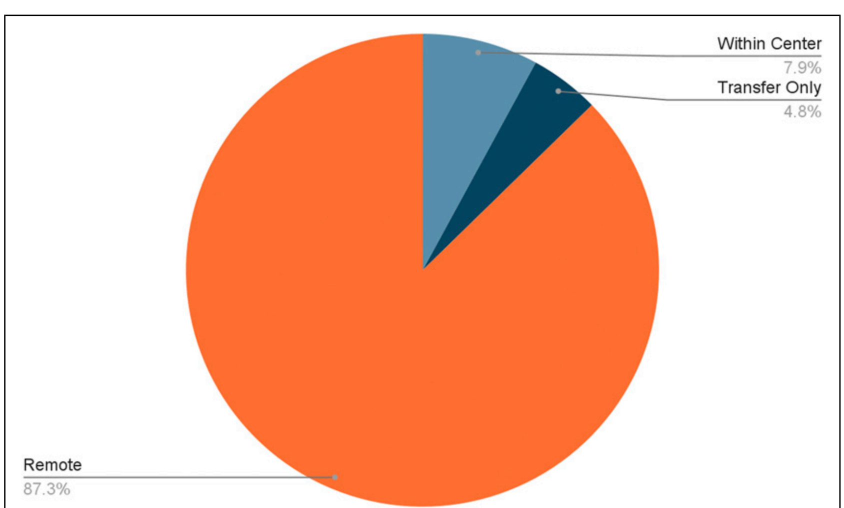

Figure 2. Analytic sample of cohort. Cohort based on location of cannulation.

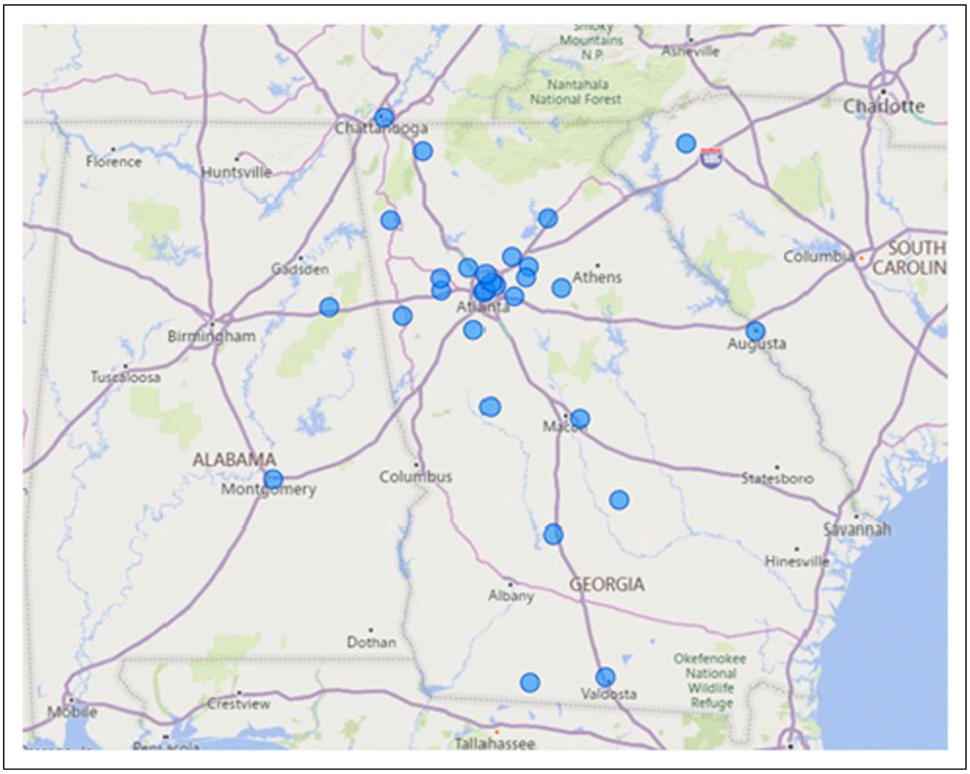

Figure 3. Geographical distribution of referring medical centers. Geographical distribution of cohort based on location of referring medical center relative to our medical center.

short and long term mortality rates, but also as a result of demonstrated long-term disease sequelae, complications, and reductions in health related quality of life.[17]

The longitudinal health implications and consequences of severe COVID-19 disease on patients—requiring prolonged mechanical ventilation and/or ECMO—are yet to be known. Even now-just a relatively short time from the commencement of this global pandemic-reports of persistently compromised pulmonary function in this patient population are being described.[18,19] The commonality of already reported reductions in walking distance, diminished physical activity, impaired pulmonary diffusion capacities, and persistence of fibrotic changes on imaging are of significant concern and have potentially dramatic long term implications for healthcare systems. A recently published, multicentered international cohort study reported a 53% 6 month all-cause mortality in patients who were treated with ECMO for COVID-19 related ARDS.[20] Although these patients represent a smaller percentage of the population, they are an important subset of highly morbid individuals that can potentially benefit from early and timely initiation of ECMO support.

Limitations due to our small sample size made it challenging to identify statistically significant predictors of treatment success. Further investigation is warranted and has the potential to influence clinical practice. Our cohort was evaluated in a retrospective manner and consisted of a sample from a single medical center. However, our institution is a regional ECMO center that services a state and surrounding region with a diverse population of over 15 million people. Additional limitations include the lack of long-term follow up beyond survival to hospital discharge and the inability to report on longitudinal complications due to the relatively recent nature of the Covid-19 pandemic.

There are potential implications with respect to expanding ECMO support in the future to those being treated at facilities far from large volume ECMO centers. The success of our recent expansion is largely due to the commitment of our leadership and team to provide a consistent, reproducible, and standard protocolized response to those needing ECMO initiation and/or transport to our center. This has not only facilitated expedient care delivery to those in extremis, but allowed us to provide this life saving therapy to many individuals who were previously too far from an ECMO referral center. Our ECMO center is committed to continuing to reduce disparities and expand access to ECMO within our region and promote its utilization nationally. We continue to focus on refining our transport process to ensure that we will continue to be able to provide these resources efficiently and expediently to those in need.

At present, it is unclear as to what post-pandemic healthcare will look like or what challenges may lie ahead as a result of this disease. Through our continued efforts, it is our hope that we will rise to meet the challenges ahead armed with the lessons learned during this pandemic.

Acknowledgements

This work was performed at Emory University Hospital in Atlanta Georgia and would not have been possible without the efforts and dedication of our critical care registered nurses, perfusionists, respiratory therapists, advanced practice providers, trainees and physicians.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Christina Creel-Bulos https://orcid.org/0000-0003-1984-4150

References

1. Tzotzos SJ, Fischer B, Fischer H, et al. Incidence of ARDS and outcomes in hospitalized patients with COVID-19: a global literature survey. *Crit Care* 2020; 24: 516. DOI: 10.1186/s13054-020-03240-7.
2. Barbaro RP, MacLaren G, Boonstra PS, et al. Extracorporeal membrane oxygenation support in COVID-19: an international cohort study of the extracorporeal life support organization registry. *Lancet* 2020; 396(10257): 1071–1078.
3. Magnusson JM, Silverborn M, Broome M, et al. Long term extracorporeal membrane oxygenation bridge to lung transplant after COVID-19. *Ann Thorac Surg* 2021; 113: e5–e8. DOI: 10.1016/j.athoracsur.2021.04.092.
4. Ranney DN, Bonadonna D, Yerokun BA, et al. Extracorporeal membrane oxygenation and interfacility transfer: a regional referral experience. *Ann Thorac Surg* 2017; 104(5): 1471–1478.
5. Barbaro RP, Odetola FO, Kidwell KM, et al. Association of hospital-level volume of extracorporeal membrane oxygenation cases and mortality. Analysis of the extracorporeal life support organization registry. *Am J Respir Crit Care Med* 2015; 191(8): 894–901.
6. Patroniti N, Zangrillo A, Pappalardo F, et al. The Italian ECMO network experience during the 2009 influenza A(H1N1) pandemic: preparation for severe respiratory emergency outbreaks. *Intensive Care Med* 2011; 37(9): 1447–1457.
7. Rawal G, Kumar R, Yadav S, et al. Air ambulance interhospital ECMO retrieval of H1N1 associated ARDS patient first of Its kind case reported in India. *Int J Life Sci Scienti Res* 2018; 4: 1649–1651. DOI: 10.21276/ijlssr.2018.4.2.5.
8. Puslecki M, Baumgart K, Ligowski M, et al. Patient safety during ECMO transportation: single center experience and literature review. *Emerg Med Int* 2021; 5: 1–16.
9. Daniela M, Felipe S, Van Nicolette SJ, et al. Mobile ECMO in COVID-19 patient: case report. *J Artif Organs* 2020; 24: 287–292. DOI: 10.1007/s10047-020-01209-5.
10. Riera J, Argudo E, Martínez-Martínez M, et al. Extracorporeal membrane oxygenation retrieval in coronavirus disease 2019: a case-series of 19 patients supported at a high-volume extracorporeal membrane oxygenation center. *Crit Care Explor* 2020; 2: e0228. DOI: 10.1097/cce.0000000000000228.
11. Imaeda T, Hattori N, Abe R, et al. Interhospital transportation of a COVID-19 patient undergoing venovenous extracorporeal membrane oxygenation by helicopter. *Am J Emerg Med* 2021; 43: 290e5–290e7.
12. Bascetta T, Bolton L, Kurtzman E, et al. Air medical transport of patients diagnosed with confirmed coronavirus disease 2019 infection undergoing extracorporeal membrane oxygenation: a case review and lessons learned. *Air Med J* 2021; 40(2): 130–134.
13. Almuqamam M, Mahmood HZ, Conway D, et al. A case of successful ECMO run in an immunocompromised pediatric patient with severe COVID-19. *Section Crit Care Program* 2021, abstract no. 414. DOI: 10.1542/peds.147.3_meetingabstract.414-a.
14. Sen A, Blakeman S, DeValeria PA, et al. Practical considerations for and outcomes of interfacility ECMO transfer of patients with COVID-19 during a pandemic: mayo clinic experience. *Mayo Clinic Proc Innov Qual Outcomes* 2021; 5: 525–531. DOI: 10.1016/j.mayocpiqo.2021.02.004.
15. Salas de Armas IA, Akkanti BH, Janowiak L, et al. Interhospital COVID ECMO air transportation. *Perfusion* 2021; 36(4): 358–364.
16. Yadav H, Thompson BT and Gajic O. Fifty years of research in ARDS. Is acute respiratory distress syndrome a preventable disease? *Am J Respir Crit Care Med* 2017; 195(6): 725–736.
17. Chiumello D, Coppola S, Froio S, et al. What's next after ARDS: long-term outcomes. *Respir Care* 2016; 61: 689–699. DOI: 10.4187/respcare.04644.
18. Huang C, Huang L, Wang Y, et al. 6-month consequences of COVID-19 in patients discharged from hospital: a cohort study. *The Lancet* 2021; 397: 220–232, DOI: 10.1016/s0140-6736(20)32656-8.
19. van Gassel RJJ, Bels JLM, Raafs A, et al. High prevalence of pulmonary sequelae at 3 months after hospital discharge in mechanically ventilated survivors of COVID-19. *Am J Respir Crit Care Med* 2021; 203(3): 371–374.
20. Biancari F, Mariscalco G, Dalén M, et al. Six-month survival after extracorporeal membrane oxygenation for severe COVID-19. *J Cardiothorac Vasc Anesth* 2021; 35: 1999–2006. DOI: 10.1053/j.jvca.2021.01.027.