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Mobile Extracorporeal Membrane Oxygenation for Covid-19 Does Not Pose Extra Risk to Transport Team

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Previous experience has shown that transporting patients on extracorporeal membrane oxygenation (ECMO) is a safe and effective mode of transferring critically ill patients requiring maximum mechanical ventilator support to a quaternary care center. The coronavirus disease 2019 (COVID-19) pandemic posed new challenges. This is a multicenter, retrospective study of 113 patients with confirmed severe acute respiratory syndrome coronavirus 2, cannulated at an outside hospital and transported on ECMO to an ECMO center. This was performed by a multidisciplinary mobile ECMO team consisting of physicians for cannulation, critical care nurses, and an ECMO specialist or perfusionist, along with a driver or pilot. Teams practised strict airborne contact precautions with eyewear while caring for the patient and were in standard Personal Protective Equipment. The primary mode of transportation was ground. Ten patients were transported by air. The average distance traveled was 40 miles (SD ±56). The average duration of transport was 133 minutes (SD ±92). When stratified by mode of transport, the average distance traveled for ground transports was 36 miles (SD ±52) and duration was 136 minutes (SD ±93). For air, the average distance traveled was 66 miles (SD ±82) and duration was 104 minutes (SD ±70). There were no instances of transport-related adverse events including pump failures, cannulation complications at outside hospital, or accidental decannulations or dislodgements in transit. There were no instances of the transport team members contracting COVID-19 infection within 21 days after transport. By adhering to best practices and ACE precautions, patients with COVID-19 can be safely cannulated at an outside hospital and transported to a quaternary care center without increased risk to the transport team. ***ASAIO Journal*** **2022; 68;163–168**

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Extracorporeal membrane oxygenation (ECMO) can be lifesaving in patients with severe cardiac and respiratory failure refractory to conventional treatments.[1] However, it requires extensive resources and expertise that often exist only at specialized regional ECMO centers, making the transport of patients on ECMO to these centers of vital importance.[2] Until recently, there has been a variable amount of success with transporting patients on ECMO. In a study by Foley *et al.*,[3] there was a 17% complication rate during transport, including electrical failure, circuit tubing leakage, circuit rupture, membrane lung thrombosis, and membrane lung leakage. Since its publication, significant improvements have been made in ECMO technology, education and training, as well as the logistics of critical care transport that have allowed for greater ease of transport while experiencing less adverse events in transit. More recent studies reflecting modern practices and technologies have found similar survival rates for patients transported on ECMO; however, complication rates were decreased.[4–8]

Although the use of ECMO in acute respiratory distress syndrome (ARDS) has been widely established, the role of ECMO in patients with COVID-19 caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection is an ongoing area of exploration. Initial studies have shown the incidence of ARDS varies from 14.8% to 42%, and carries with it a mortality rate of 74–88%.[9–11] The World Health Organization and the Extracorporeal Life Support Organization (ELSO) recommend that ECMO be considered in patients with COVID-19 who have refractory hypoxemia.[12,13] Recent studies also suggest that ECMO could play a role in the treatment of COVID-19 patients.[14–16] Although early studies do suggest promise, the long-term benefit of ECMO in patients with COVID-19 remains unclear due to a lack of data and short follow-up times.[17,18] In terms of interhospital transfer, it should be further noted that patients who meet indications for ECMO are often too hypoxic and hypercarbic to be managed by conventional treatments that would allow for safe non-ECMO transfer.[3,19]

Given the role that ECMO can play in patients with COVID-19 and the proven benefits of transporting ECMO patients to regional ECMO centers, the logical progression is the transporting of patients with COVID-19 on ECMO. This presents both an opportunity and a distinct challenge. Specifically, the question is whether transportation can be done safely for both the patient and the team members involved in cannulation in an ICU setting and patient transport. To that end, we conducted a multi-institutional review of the experiences of five quaternary care centers responsible for the cannulation, transport and care of patients with COVID-19 from an outside hospital to an ECMO center.

Methods

Data Collection

This is an Institutional Review Board approved, prospectively collected retrospective analysis of clinical data collected from a cohort of patients enrolled in the COVID-19 Critical Care Consortium from five quaternary care hospitals. Waivers of informed consent were granted for all patients, since the study was observational, data recorded in the central repository were deidentified, and there was minimal risk to participants. All patients are individuals 18 years of age or older with a positive COVID-19 diagnosis who required ICU admission and ECMO support. Patient data were studied from time of ICU admission until hospital discharge. Data were prospectively collected at each site, stripped of identifying information, and then sent to central COVID-19 Critical Care Consortium database. These data were collected on a server through REDCap software hosted at Oxford University. Data were extracted for all five sites from the central database.

ECMO Cannulation and Transport:

Each patient was evaluated and found to meet institution specific criteria for venovenous or venoarterial ECMO before cannulation. Broadly speaking, this was for refractory hypoxic or hypercarbic respiratory failure as well as in certain instances profound vasodilatory and cardiogenic shock. Each site used their standard remote cannulation teams and protocols. In general, the cannulation teams consisted of one or two physicians for cannulation and patient management, one to two critical care transport nurses, and an ECMO specialist or perfusionist in addition to the transport personnel specific to the mode of transportation.

The teams adhered to strict airborne contact precautions with eyewear (ACE) and personal protective equipment (PPE) protocols that included face shield or goggles, N95 or higher respirator or facemask, nonsterile gloves, and an isolation gown. Cannulators donned standard sterile equipment in addition to ACE and PPE at the time of procedure. Special care was taken to not break ACE and PPE protocol from the time the team came into contact with the patient until they returned to their respective ECMO center. Extra care was taken to avoid disruption of the closed ventilator circuit after the patient was placed on the transport ventilator. As part of the transport equipment, extra components for ACE PPE were brought on the transport vehicle. If there was a concern for a breach of the PPE, it was appropriately doffed and a replacement was donned. As the transport vehicles (ambulances, planes, and helicopters) were previously used to transport ECMO patients with infectious causes of ARDS before COVID-19, no additional changes were made to the vehicles. The flight crew wore PPE, but the vehicles were too small to accommodate social distancing even with the minimum number of ECMO team members. All the surfaces in the vehicles and all the reusable transport ECMO gear were cleaned thoroughly after each use. Per protocol, family members were not transported along the patient. If an ECMO center allowed visitors to their COVID-19 ICUs, then they family members arrived at the hospital on their own.

As per protocol, each ECMO team brought preferred cannulation equipment and ECMO circuits. Particular attention was focused on not disrupting the airway circuit until the patient was ready to be placed on the portable ventilator. Before disconnecting from the ventilator, the endotracheal tube was clamped and the ventilator was turned off momentarily to mitigate against aerosolization of SARS-CoV-2. The patient was then transported to the ECMO center per institution standard protocols. Modes of transportation included ground transportation, helicopter, and fixed wing aircraft depending on distance and logistical needs of the transport teams. Decisions for different cannulation strategies (venovenous *versus* venoarterial ECMO) was made by cannulation team in conjunction with the respective ECMO referral center.

Outcomes

The primary endpoint studied was incidence of proven COVID-19 infection among members of the transport team within 21 days of the transport. Transport team members were retrospectively surveilled about sign or symptoms of COVID-19 at 3 weeks after each transport. There were also questioned about any instances of positive COVID-19 tests or the need for isolation due to an unprotected exposure. Due to limited COVID-19 testing supplies during the study period, routine testing of asymptomatic transport start was not done. However, if an unprotected exposure occurred, or if team members developed signs or symptoms they were tested. Per ECMO center protocol, if a team member had a positive COVID-19 test they were isolated at home. Team members agreed to the collection.

Demographic data were collected such as patient age and patient sex. Transport specific endpoints such as mode of transport (air *versus* ground), time spent out of the hospital (minutes), and distance traveled between hospitals (miles) was collected. Extracorporeal membrane oxygenation-specific endpoints such as duration of ECMO, mode of ECMO support, and physiologic parameters before and after ECMO cannulation were collected. Finally, in-hospital outcomes data such as survival to decannulation and survival to discharge were collected. Special care was taken to collect any instance of transport or ECMO-related complications such as pump failures, cannulation complications at outside hospital, or decannulations in transit.

Statistical Analysis

Continuous variables were summarized using the mean and SD. Categorical variables were reported using counts and percentages. Statistical analysis was conducted using Excel version 16.45 (Microsoft Corporation, Redmond, WA) and SAS version 9.4 (SAS Institute Inc., Cary, NC).

Results

The sample size for this prospectively assembled and retrospectively collected study was 113 patients. All patients were over the age of 18 with confirmed positive COVID-19 by polymerase chain reaction at time of cannulation for ECMO. These data include consecutive patients that were cannulated at an outside hospital and transported while on venovenous (VV) or venoarterial (VA) ECMO support to one of the five quaternary care centers from April 2020 to March 2021. The average age of patients was 46 (SD ±10), with 62% (N = 71) of patients being males. The average distance traveled was 40 miles (SD ±56) from ambulance bay to ambulance bay. The average duration of transport from ambulance bay to ambulance was 134 minutes (SD ±92). Ninety-one percent (N = 103) patients were transported by ground and 9% (N = 10) were transported by air. When distance and duration of transport was stratified according to ground *versus* air transport, the average distance traveled for ground was 36 miles (SD ±53) compared with 66 miles (SD ±82) for air transport. The average duration of ground transport was 136 minutes (SD ±94) compared with 104 minutes (SD ±70) for air transport. The majority of patients (95%, N = 107) received VV ECMO. Although the remaining patients (5%, N = 6) received VA ECMO (Table 1).

The average duration of ECMO was 22 (SD ±18) days. At the time of analysis, zero patients remained on ECMO, but 22 were still admitted to the hospital after having been decannulated from ECMO. Fifty four percent (N = 61) of patients were alive 48 hours after decannulation from ECMO, and 44% (N = 55) survived to hospital discharge (Table 2).

Of the 113 patient transports in the study, there were zero transport-related adverse events including pump failures, cannulation complications, or decannulations in transit. There were zero instances of transport team members contracting COVID-19 21 days after transport.

Table 1. Study Sample Demographics and Transport Characteristics

	Average (SD) or Number of Patients*		
Variable	Air and Ground Transport (N = 113)	Ground Transport (N = 103)	Air Transport (N = 10)
Age, years	46 (±10)	45 (±11)	54 (±8)
18–39	25 (25%)	25 (27%)	0 (0%)
40–59	66 (65%)	60 (65%)	6 (67%)
60+	10 (10%)	7 (8%)	3 (33%)
Sex			
Male	69 (61%)	59 (57%)	10 (100%)
Female	44 (30%)	44 (43%)	0 (0%)
Distance traveled, miles	40 (±56)	36 (±53)	66 (±82)
0–19	57 (50%)	52 (50%)	5 (50%)
20–39	31 (28%)	29 (28%)	2 (20%)
40+	25 (22%)	22 (22%)	3 (30%)
Duration of travel, minutes	134 (±92)	136 (±94)	104 (±70)
60–89	52 (46%)	45 (44%)	7 (66%)
90–119	32 (28%)	31 (30%)	1 (10%)
120+	29 (26%)	27 (26%)	2 (20%)
Mode of transport			
Ground	103 (91%)		
Fixed wing aircraft	2 (2%)		
Helicopter	8 (7%)		
ECMO type			
Venovenous	107 (95%)	97 (94%)	10 (100%)
Venoarterial	6 (5%)	6 (6%)	0 (0%)

*Data are summarized as average (±SD) or frequency (percentage). ECMO, extracorporeal membrane oxygenation.

Discussion

Recent studies exploring the transportation of individuals while on ECMO have established interhospital transport on ECMO is safe.[20–24] However, the transport of patients with COVID-19 poses an additional theoretical risk including the transmission of SARS-CoV-2 to the members of the transport team. SARS-CoV-2 is most commonly transmitted through close contact with infected individuals *via* respiratory droplets, airborne transmission, and to a lesser extent contact with contaminated surfaces.[25,26] Studies exploring the transmission of SARS-CoV-2 in the healthcare setting have shown that current recommended ACE and PPE appears to be effective in preventing virus transmission.[27]

During transport, the ECMO team is at increased risk of exposure to SARS-CoV-2. This can be due to the close proximity of transport team members to the COVID-19 patient, the amount of time spent with patient, and the absence of negative pressure air flow in the transport vehicle.[25,26] Though the distances that transport team members traveled with the patient were small at times, there was additional time spent with team members in close proximity to the patient during the loading and unloading phases of transport for all methods of transportation.[28] This variable was greatest for fixed wing aircraft in particular. When transporting a patient *via* fixed wing aircraft there are additional steps of loading the patient onto the aircraft from the ambulance at the airport and unloading the patient from the ambulance once they have arrived at the ECMO center. This is also true for helicopter transport if the referring hospital does not have a helipad on site.[29] Other studies have shown safety for interhospital air transport of COVID-19 patients on ECMO.[29]

The process from beginning to end including all patient loading and unloading typically took more than 5 hours, and increased beyond that as the distance between hospitals increased. This period includes the time traveling together to the outside hospital, assessing the patient at the referring hospital ICU, ECMO cannulation, postprocedure optimization, and preparing the patient for safe and secure transport back to the ECMO center.

This study from five quaternary care hospitals part of the COVID-19 Critical Care Consortium (https://www.covid-critical.com) provides data on 113 individuals with COVID-19 transported on ECMO support. Although transport team members for each site drew from a small cache of all volunteer individuals. Each patient transport represents a distinct opportunity for transmission of SARS-CoV-2 to a transport team member and, therefore, should be considered a separate potential exposure. At minimum five individuals per team involved in 113 patient transports represents more than 565 SARS-CoV-2 individual transport member exposures. In this group of more than 565 individual transport member exposures, there were

Table 2. Study Sample Outcomes

Variable	Average (SD) or No. Patients* (N = 113)
Duration of ECMO, days	22 (±18)
0–29	85 (75%)
30–59	24 (21%)
60–90	4 (4%)
Remained on ECMO	0 (0%)
Decannulated and remained in-hospital	22 (19%)
Survival 48 hours after decannulation	61 (54%)
Survival to hospital discharge	55 (44%)

*Data are summarized as average (±SD) or frequency (percentage). ECMO, extracorporeal membrane oxygenation.

zero instances of transport team members contracting COVID-19 twenty-one days after transport.

These findings suggest that COVID-19 does not pose an increased risk to the transport team as long as the transport team adheres to strict infection prevention and control practice and ACE precautions.[30] This is in accordance with recent literature showing that healthcare providers in critical care units are not contracting COVID-19 at a higher rate than the general population.[31]

Additionally, this study reinforces the finding that it is safe for experienced teams to transport patients while on ECMO.[28] There were zero instances of transport-related adverse events. In patients with COVID-19 supported on ECMO who were transported, the survival to decannulation and survival to discharge were 54% (N = 61) and 44% (N = 55), respectively. This value is comparable to recent studies of patients with COVID-19 supported on ECMO who were not transported.[15,32] This suggests that transportation does not pose an increased risk to the patient.

Our study has several limitations. First, data for this study were analyzed in a retrospective fashion and it was not a randomized control study. Due to the pervasive nature of the COVID-19 pandemic, there was not a sizeable group of non-COVID-related ECMO transports in this period to serve as a control. Therefore, one should take care to not draw broad definitive conclusions beyond the safety of transporting COVID-19 patients on ECMO. Second, due to the relatively recent nature of COVID-19, there is a lack of longitudinal follow-up data regarding long-term patient survival. Although we can comment on in-hospital outcomes for patients, we cannot comment on long-term outcomes for all patients. The third limitation was the lack of routine COVID-19 testing for asymptomatic team members after transports. This was due to limited COVID-19 testing supplies at the ECMO care centers. However, due to strict adherence to ACE PPE, no team members had an unprotected exposure to COVID-19.

As COVID-19 poses the greatest risk to the elderly, it should be acknowledged that most ECMO transport team members were in the 30s, 40s, and early 50s and, therefore, not in the highest risk category for adverse events. However, they were representative members of the local population and carried comorbidities such as obesity and hypertension. Nonetheless, there is a likelihood that they could have become asymptomatic carriers from a workplace exposure that were never tested. Nonetheless, it appears that simply being a member of a COVID-19 ECMO transport team does not carry with it an undue risk to workplace health and safety.

Another limitation is the relatively small sample size for a study of critically ill patients. However, this study was not powered to look for specific survival benefits regarding the use of ECMO in patients with COVID-19. Rather, it focused on the safety related to patient transport on ECMO and the safety of transport team. And in this facet, more than 565 prolonged patient interactions by team members without contraction of COVID-19 is compelling. Finally, the group of centers involved in the study were self-selected on the basis of having resources and preparedness to transport patients on ECMO during the COVID-19 pandemic. A potential criticism of this study could be that an average distance of 40 miles might be only applicable to metropolitan areas. However, 22% of transports were more than 45 miles, and 9 patients were transported >100 miles making this study applicable to transports from a more rural area to a regional ECMO center. The longest transport was >300 miles and safely took place by ground transportation (Figure 1). This can allow an ECMO center to not only provide a large catchment area for bridge to recovery, but also be a bridge to lung transplantation. It should be noted that during extralong transports the teams provisioned with extra medications, IV fluid, and oxygen.

One strength of the group of centers involved in the study is that they represent a wide variety of geographic locations and hospital resources both within the United States and internationally. This suggests that transporting COVID-19 patients while on ECMO can be safely achieved by a skilled team in many different environments without increased risk to the ECMO team.

Conclusion

This study is a review of 113 patients with COVID-19 refractory to maximal mechanical ventilation and pharmacological support who were cannulated at an outside hospital and then subsequently transferred to one of the five ECMO centers.

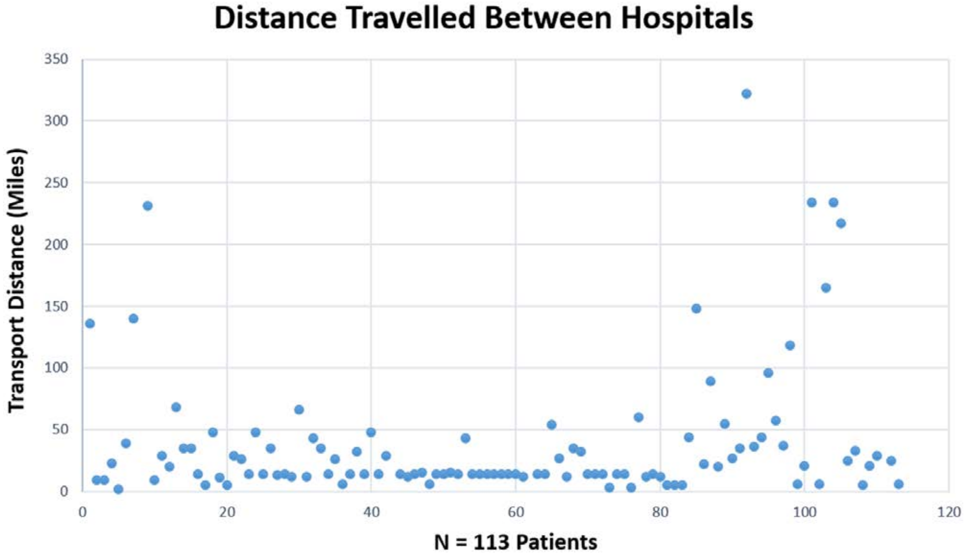

Figure 1. Remote cannulation and interhospital transfer of 113 patients with ARDS secondary to COVID-19 by ground and air. ARDS, acute respiratory distress syndrome. full color online

One hundred and thirteen patients were transported, which represented over 565 individual transport member exposures. There were zero instances of transport-related transmission of SARS-CoV-2 within 21 days following transport. There were also zero instances of ECMO-related complications during the transports.

This study suggests that experienced teams using established transport protocols augmented by ACE precautions can safely cannulate and transport a critically ill COVID-19 patient. Further study regarding the intermediate and long-term safety and efficacy of ECMO for the treatment and management of SARS-CoV-2 would be recommended.

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