ORIGINAL ARTICLE

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Survival of Patients Transferred from a Distant Hospital on ECMO Support

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Abstract

Objective: Extracorporeal membrane oxygenation (ECMO) may be used in patients with severe respiratory and/or cardiac pathologies. Transferring a patient on ECMO support to advanced hospital may become life-saving for whom. We evaluated the effects of very long distance transportation with ECMO.

Methods: This study includes 10 patients who were transferred from a distant hospital to an advanced care hospital while on veno-venous (VV) or veno-arterial ECMO between 2017 and 2019. A transfer distance of at least 1000 km was the required inclusion criterion for the study. The primary outcome was all cause mortality in the hospital and in 1-year. The secondary outcomes were the duration of ECMO run and mechanical ventilation, durations of intensive care unit and hospital stay.

Results: The mean distance of transport was 1878.2±440.7. One adverse event occurred because inappropriate electrical connection of the plane so backup ECMO device was switched on. Overall hospital mortality of the patients was 40% and 1-year survival was 50%.

Conclusion: Interfacility transfer on ECMO support between too far centers is safe and may be a life-saving procedure for the patient. The survival rates of VV ECMO seems to be better.

Keywords: Extracorporeal membrane oxygenation, patient transfer, lung diseases, heart diseases

INTRODUCTION

Extracorporeal membrane oxygenation (ECMO) may be used in patients with severe respiratory and/or cardiac pathologies. Although it's possible to start ECMO treatment in many hospitals, it is best to follow these patients in centers specifically experienced in ECMO where more advanced treatment options such as heart or lung transplantation are also available. Therefore, the transfer of a patient with an ECMO device from a hospital where maintenance of ECMO support is impossible may be a life-saving decision for that patient. The patient transfer with ECMO device has been used for about 3 decades. International centers have reported increasingly more experience on the transport of patients with ECMO between hospitals (1-3). In this article, we evaluated the effects of very long distance (>1000 km) ECMO transfer on patients' outcomes.

METHODS

This retrospective study included 10 patients who were transferred from a distant hospital to the intensive care unit (ICU) of ECMO specialized hospital with the support of veno-venous (VV) or veno-arterial (VA) ECMO between 2017 and 2019. Inclusion criteria of the study were the suitability of the patients for ECMO indications according to Extracorporeal Life Support Organization guidelines (4) and the distance of air transport with

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ECMO support regardless of the main pathology. The transfer distance must be at least 1000 km for inclusion in the study. Patient characteristics such as the main pathology and indication for ECMO support, concomitant diseases, duration of ICU and hospital stay after ECMO running were recorded. Data related to ECMO, such as technical features of cannulation, the duration of ECMO run, transport distance, complications during transfer and patient outcomes, were retrospectively collected from medical reports. The primary outcome was all cause mortality in the hospital and in 1-year. The secondary outcomes were the duration of ECMO run and mechanical ventilation, durations of ICU and hospital stay. The study protocol was approved by University of Health Sciences Turkey, Prof. Dr. Cemil Tascioglu City Hospital Institutional Ethical Committee (date: 30.06.2020, number: 48670771-514.10). Information concerning the study was provided to and the signed consent received from all patients volunteering to participate, or from relatives if patients were unable to express consent.

ECMO Support and Transport Procedure

All of the ECMO interfacility transport had been carried out in accordance with the primary transport situation of the ECMO transfer guideline (5). That is the transport team required to perform cannulation for ECMO support at the referring facility and than transport the patient to an ECMO center. Demographic features including body surface area (BSA) and detailed medical status of the patient were analyzed before the ECMO and transport. The appropriate size for the ECMO cannula and oxygenator was determined according to the BSA of the patient. We preferred a rotaflow pump head with console (Maquet; Getinge Group, Rastatt, Germany), a Maquet Quadrox PLS membrane oxygenator (Maquet; Getinge Group, Rastatt, Germany) and an HLS© cannula (Maquet; Getinge Group, Rastatt, Germany). All ECMO cannulations were performed percutaneously under the ultrasonography (USG) guidance by our team. VV ECMO was usually maintained by femoral and jugular veins and VA ECMO was performed via femoral vessels. All patients were followed up for at least 4 h after the onset of ECMO support to ensure hemodynamic stability. The eritrocyte and thrombocyte levels of the patient were optimized with appropriate blood product replacement before and immediately after the start of ECMO. The last clinical and laboratory findings especially hemoglobin and platelet levels, were interviewed with the patient's doctor before starting the journey.

Patients were on invasive monitoring all the time during transport and suitable kits for the blood gases and activated clotting time (ACT) measurements were available. The blood gas analyzed and ACT level was measured at regular intervals. Heparin was applied according to the patients' weight to ensure that ACT values were in the range of 160-200 seconds. The development of hypothermia was avoided. A portable USG device was kept and used to verify the correct position of cannulas when necessary.

Transfer of all patients from the ICU bed to the ambulance, ambulance to aircraft, aircraft to ambulance and finally to advanced care hospital was provided with a vacuum patient stretcher. ECMO device was placed on the foot side of the stretcher and circuits were kept in view for safety. The suitability of the aircraft door passage for the patient, ECMO device and circuits on the vacuum stretcher was checked. As soon as the patient arrived at the ICU of the advanced care hospital, the patient's hemodynamic status, cannulation sites and ECMO parameters (flow, pressure and RPM) were checked.

The back up equipment was also necessary to be prepared and ready due to the very long transport distance. These backup ECMO circuits and equipment included size-specific spare cannulas, tubing connectors, spare medical oxygen gas tank, oxygenator and another ECMO device. Additionally, the backup battery and electrical connections of all transfer vehicles were planned and their converters were supplied. Possible weather were checked and consultated with the pilot and precautions were planned.

Statistical Analysis

IBM SPSS statistics software for Windows, version 25 (SPSS, Inc, Chicago, IL) was used for statistical analyses. Descriptive statistics on patient demographics and clinical measures were summarized by mean and standard deviation or median and interquartile range for continuous variables. Categorical variables were summarized by percentage. The Kaplan-Meier method was used to analyze survival rates.

RESULTS

A total of 10 patients with ECMO support were transferred from a distant hospital to an advanced care hospital between 2017 and 2019. Mean age of the patients was 48±17.9 years (ranged, 18-67). Six of the patients were male, the others were female. The mean body mass index was 27.5±3.9. Concomitant diseases included essential hypertension, diabetes mellitus and coronary artery disease in 4, 3, and 1 patients, respectively. The patients' demographic information is shown in Table 1.

The ECMO cannulation of all patients was performed by our ECMO team, which consisted of a cardiovascular surgeon, a

Table 1. Demographics and ECMO characteristics of patients	
Variable	**No (%) or mean ± SD**
Age	48±17.9
Sex	
Female	4 (40%)
Male	6 (60%)
BMI	27.5±3.9
Concomitant disease	
Hypertension	4 (40%)
Diabetes mellitus	3 (30%)
Coronary aretry disease	1 (10%)
Reason for support	
Cardiac	3 (30%)
Respiratory	7 (70%)
ECMO mode	
VV ECMO	7 (70%)
VA ECMO	3 (30%)
BMI: Body mass index, ECMO: Extracorporeal membrane oxygenation, VV: Veno-venous, VA: Veno-arterial, SD: Standard deviation	

perfusionist and a nurse. The most frequent diagnosis in our transport ECMO group was acute respiratory distress syndrome (ARDS) that occurred because of primary causes in 6 patients and secondary cause in 1 patient. VV ECMO performed to 7 (70%) patients with ARDS before transfer. According to blood gas count and mechanical ventilatory measurements before ECMO support and pretransfer for those patients were PaO_2/FiO_2 <100 on FiO_2 >90%, Murray score between 3 and 4, APSS score 8 (the age, PaO_2/FiO_2 ratio, and plateau pressure) and CO_2 retention (higher than 70 mmHg despite Pplat >30 cm H_2O) on mechanical ventilation despite optimal medication for at least 6 h (6,7). VV ECMO was maintained by femoral and jugular veins in all except in one patient who had superior vena cava syndrome and thus underwent ECMO by bilateral femoral veins. VA ECMO was performed in 3 (30%) patients with refractory cardiogenic shock syndrome or acute cardiac failure caused by dilated cardiomyopathy, myocarditis and acute coronary syndrome. A common femoral artery and vein were used to maintain the VA ECMO circuit. A distal perfusion cannula was placed to protect the children from limb ischemia. The detailed diagnosis of patients with VA or VV ECMO support is shown in Table 2.

The mean and median distance of transport were 1878.2±440.7 (range, 1100-2231) and 2161 km, respectively All patients were transferred with aircraft by airway. All patients arrived safely at the advanced care hospital after transfer. Blood gas changes in patients during pre and on-ECMO, transfer and on-arrival to ECMO center hospital are summarized in Table 3. Evaluation of

Table 2. Indications of ECMO	
Diagnosis	**No (%)**
ARDS	
Viral pneumonia	5 (50%)
Inhalation burning	1 (10%)
Histiocytosis X	1 (10%)
Cardiogenic shock	
Cardiomiopathy (dilated)	1 (10%)
Myocarditis	1 (10%)
Coronary artery disease	1 (10%)
ARDS: Acute respiratory disstress syndrome, ECMO: Extracorporeal membrane oxygenation	

Table 3. Blood gas measurements (pre, on-ECMO, transfer, ECMO center)	
Blood gas changes (pre, on-ECMO, transfer, ECMO center)	**Mean ± SD**
Pre-ECMO PaO_2/FIO_2 ratio	55.6±7.8
Pre-ECMO PaO_2 (mmHg)	53.0±6.1
Pre-ECMO pH	7.27±0.12
Pre-ECMO PCO_2 (mmHg)	73.3±6.0
On-ECMO pH	7.41±0.02
On-ECMO PaO_2 (mmHg)	120.9±18.1
On-ECMO PCO_2 (mmHg)	40.2±1.6
Transfer ECMO PH	7.41±0.02
Transfer ECMO PaO_2 (mmHg)	130.4±13.0
Transfer ECMO PCO_2 (mmHg)	40.6±1.9
On-arrival pH	7.41±0.02
On-arrival PaO_2 (mmHg)	133.0±11.0
On-arrival PCO_2 (mmHg)	40.6±1.4
ECMO: Extracorporeal membrane oxygenation, SD: Standard deviation	

the ECMO run time, ICU and hospital stay is calculated after the transfer of the patient to an advanced care hospital. In the VA ECMO group, the mean duration of the ECMO was 12±5 days (range, 7-17) and the mean duration of the ICU and hospital stay were 18.3±12.0 (range, 7-31) and 23.6±20.8 days (range, 7-47) respectively. In this VA ECMO group, two patients died during the following days in the ICU. One of these died of disseminated intravascular coagulation on the 17th day and the other patient died of cardiopulmonary insufficiency on the 10th day. Only one patient survived in the VA ECMO group. The patient was 48 years old female with a familial type of dilated cardiomyopathy. She was weaned from ECMO support on the 12th day and a left ventricular assist device implantation was performed as a bridge to the heart transplantation. The patient was discharged from the hospital and was on the transplant list. She died of septic

shock originating from LVAD 255th days after her discharge. In the VV ECMO group, the mean duration of the ECMO was 26.4±23.4 days (range, 3-72) and the mean duration of the ICU and hospital stay were 34.8±29.2 (range, 8-90) and 56.2±57.4 days (range, 17-176) respectively. Two patients died from irreversible lung insufficiency in the VV ECMO group. The data are summarized in Table 4.

We encountered only one problem during transfers. In one patient, we had to switch to a backup ECMO device due to the lack of proper electrical connection on the plane. Overall hospital mortality of the patients was 40% and 1-year survival was 50%. The Kaplan-Meier estimate of overall survival were 60% and 50% at hospital discharge and 1-year survival, respectively (Figure 1).

DISCUSSION

The management of acute and chronic cardiac and pulmonary diseases has improved in parallel with the advancement of medical technologies. Even irreversible cardiac or pulmonary diseases may be treated with transplantation of the heart, lung, or both of them in centers specialized in these subjects (8). However, reversible but life threatening cardiac and pulmonary pathologies may heal if enough time to respond main treatment can be provided with adjunct and salvage ECMO support. In the literature, there are several articles supporting ECMO usage for ARDS or cardiogenic shock syndrome. In a study during pandemic H1N1 influenza in 2009, lower mortality rates were observed in centers where severe ARDS related to influenza was treated with ECMO support (9,10). However, complex management of patients on ECMO support, especially in prolonged cases or advanced treatment options such as transplantation, are not available in all hospitals. CESAR multicenter trial recommends the transfer of adult patients with severe ARDS or reversible pulmonary failure to an advanced care hospital with ICU specialized in ECMO because this strategy significantly improves survival without disability (11). Interhospital transfer of the patients on ECMO support by airway or ground transport is the solution to that problem and it has been performed for at least 2-3 decades (12). Thus, an ECMO transfer team is necessary to perform a safe and proper interfacility transport (13).

The transfer of the patients on ECMO support has already been reported in the literature (12,14-16). In these articles, all transfer distances of the journey with ECMO had been analyzed, but in this study, we exclusively evaluated patients who were transferred for at least 1000 km of distance. Our ECMO transport strategy is to cannulate and provide emergency ECMO support at the primary facility and then to transfer the patient to the advanced care hospital. This approach is similar to other studies in the literature (17).

In our study, hospital and 1-year overall mortality of transported ECMO patients was 40% and 50%, respectively. Mortality rates of the non-transferred patients with severe ARDS supported by ECMO treatment vary between 23 and 43% in some studies (9,18). Coppola et al. (19) reported the survival of patients transferred to ECMO from other centers as 65%. Additionally, Bonadonna et al. (20) declared that the mortality rate of transported VA ECMO patients was 51.9% whereas the hospital mortality rate (66.6%) of VA ECMO patients was higher. The hospital mortality rate of our patients was approximately similar to that of other studies although the survival rates of VA ECMO patients were not satisfying. However, 1-year survival rate was 71.4% in the VV ECMO patients.

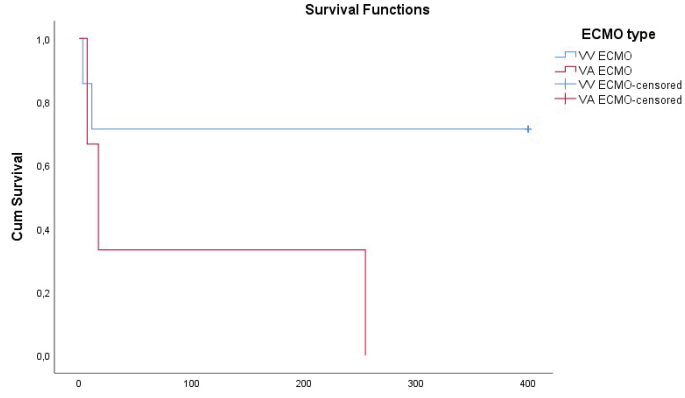

Figure 1. One-year survival of patients (Kaplan-Meier)
ECMO: Extracorporeal membrane oxygenation

Table 4. Patient outcomes

Variable	VA ECMO (mean ± SD)	VV ECMO (mean ± SD)	Overall (mean ± SD)
ECMO run time	12±5	26.4±23.4	22.1±20.5
ICU stay	18.3±12.0	34.8±29.2	29.9±25.8
Hospital stay	23.6±20.8	56.2±57.4	46.5±50.4
Distance of length	2231±0	1727±449.9	1878.2±440.7
Hospital mortality	66.6%	28.5%	40%
One year mortality	100%	28.5%	50%

ECMO: Extracorporeal membrane oxygenation, VV: Veno-venous, VA: Veno-arterial, ICU: Intensive care unit, SD: Standard deviation

CONCLUSION

In conclusion, the transportation on ECMO support from a distant hospital is safe and may be a life-saving procedure for the patient. There should be a plan to solve every medical and techniqual adverse event that may occur during the journey. Survival rates of VV ECMO seem to be better. Large, randomized trials must analyze the effect of long distance transfer on patient survival.

Ethics

Ethics Committee Approval: The study protocol was approved by University of Health Sciences Turkey, Prof. Dr. Cemil Tascioglu City Hospital Institutional Ethical Committee (date: 30.06.2020, number: 48670771-514.10).

Informed Consent: Information concerning the study was provided to and the signed consent received from all patients volunteering to participate, or from relatives if patients were unable to express consent.

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Authorship Contributions

Surgical and Medical Practices: S.K., T.D., K.D., A.K., Concept: N.K., İ.S., Design: S.K., N.K., İ.S., Data Collection or Processing: S.K., C.Y., T.D., K.D., Analysis or Interpretation: S.K., A.K., Literature Search: S.K., C.Y., Writing: S.K., N.K.

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