DOI: https://doi.org/10.5114/ait.2024.139526

Utilisation and outcomes of a mobile (ambulance and air transport) venovenous extracorporeal membrane oxygenation (VV-ECMO) program in Poland during the COVID-19 pandemic – a retrospective, two-centres, case-series study

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Abstract

Background: Many patients required mechanical ventilation support due to severe COVID-19 pneumonia. A significant proportion of mechanically ventilated patients also required venovenous extracorporeal membrane oxygenation (VV-ECMO) due to refractory hypoxemia. A high demand for VV-ECMO support during the pandemic was challenging due to many factors, including limited resources and lack of established transfer protocols. This study aims to present the organisation and outcomes of a mobile VV-ECMO program in two high-volume centres in Poland during the COVID-19 pandemic.

Methods: This retrospective, two-centre case series study, which lasted 36 months, was conducted between March 10, 2020, and January 31, 2023. The data of all patients transferred using venovenous extracorporeal membrane oxygenation (VV-ECMO) were analysed, including five women in the perinatal period with severe respiratory failure attributed to the COVID-19 virus. The analysis encompassed baseline patient demographics, Sequential Organ Failure Assessment (SOFA) scores, admission laboratory parameters, ECMO therapy, duration of mechanical ventilation, and patient survival to ICU discharge.

Results: We assessed 86 patients who met the ELSO inclusion criteria and were transported during VV-ECMO support. Mortality in the analysed group was high (80.3%). Despite high mortality, VV-ECMO appeared to be a safe procedure in COVID-19 patients with severe ARDS. No complications were noted in more than half of the analysed procedures. Despite the above, many severe complications were observed, including stroke or cerebral haemorrhage (9.8%) and limb or gut ischemia (1.6%). The most common problems co-existing with VV-ECMO treatment were bleeding complications (34.4%).

Conclusions: The ICU mortality rate among patients requiring VV-ECMO for COVID-19 in high-volume ECMO centres was high but not associated with the type of transportation.

Keywords: COVID-19, VV-ECMO, transport, ARDS, complications, mortality.

Anaesthesiol Intensive Ther 2024; 56, 2: 141–145

Received: 29.02.2024, **accepted:** 04.04.2024

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Most SARS-CoV-2 infections resulting in COVID-19 are asymptomatic or mild. Nevertheless, some patients develop severe acute respiratory distress syndrome (ARDS). Incidence of COVID-19 pneumonia ranges widely [1, 2]. Respiratory failure in COVID-19 pneumonia is often treated with prone positioning, oxygen supplementation with high flow nasal cannula (HFNO), non-invasive, and mechanical ventilation. However, during the pandemic, the massive increase in patients with respiratory failure resulted in poor availability of intensive care unit (ICU) beds. Thus, a significant number of patients were treated in small primary hospitals with inadequate experience in treating patients with severe ARDS. The World Health Organisation and The Surviving Sepsis Campaign guidelines on the management of patients with ARDS due to COVID-19 recommend venovenous extracorporeal membrane oxygenation (VV-ECMO) for mechanically ventilated patients with refractory hypoxemia [3, 4]. Early onset of VV-ECMO

may mitigate the adverse effects of conventional mechanical ventilation and result in improved outcomes.

Nevertheless, mortality in COVID-19 patients on VV-ECMO support was higher than during the previous flu pandemic. This was partially explained by initiating the procedure in low-volume centres without sufficient clinical expertise [5]. The Extracorporeal Life Support Organisation (ELSO) guideline clearly states that centres should provide VV-ECMO support for a minimum of six patients per year, as high-volume ECMO centres have reduced morbidity when compared with low-volume ECMO centres [6]. Due to a limited number of high-volume centres in Poland, a mobile VV-ECMO program was launched at the beginning of the COVID-19 pandemic. In most cases, the outreach teams initiated VV-ECMO support in the referring hospital with subsequent transport to the ECMO centre by either ambulance or helicopter. Transport is preferably performed following stabilisation on ECMO. However, the possible influence of the mode of transportation on the outcomes in patients with ECMO remains elusive.

This study aims to assess the safety and outcomes of the ECMO transports performed by mobile teams of two ECMO centres in Poland during the COVID-19 pandemic.

METHODS

We retrospectively analysed databases of two academic ECMO centres in Poland: University Clinical Hospital No. 1 in Lublin and University Hospital in Opole. The study covered 36 months between March 2020 and January 2023. Data were collected on all consecutive patients transferred on VV-ECMO assist for ARDS due to COVID-19. SARS-CoV-2 infection was confirmed in all patients by PCR tests. Data collection included baseline demographics, previous medical history, distance and time of transportation on ECMO, SOFA score at admission, laboratory results, performed procedures, complications, use of blood products, duration of both ECMO therapy and ICU stay, time of mechanical ventilation, as well as survival rate until the ICU discharge.

Two independent analyses were conducted, one based on transportation type (air vs. road) and the second on overall outcome (survivors vs. non-survivors). The air transport group included patients transported to ECMO centres via civil or army air ambulances, and the road group included patients transported via specialised ambulances. Pregnant women as a specific subgroup were analysed. Patients were considered non-survivors if they died during ECMO therapy or ICU stay. Patients who stayed alive until discharge from the hospital were considered survivors.

For primary ECMO transports, where the patient was cannulated at the referring hospital by the mobile ECMO team, a team consisted of an ECMO physician (anaesthesiologist and transport team leader), an anaesthesiology resident, and a trained paramedic. The decision to send a mobile ECMO team and start therapy in a referring hospital was up to a doctor on duty at the ECMO centre. The qualification followed the current recommendations of ELSO [7]. Other factors such as age, weight, comorbidity, weather conditions, and distance from the respective centre were considered when choosing a means of transport.

We obtained consent from the ethics committee of the Medical University of Lublin KE- 0254/37/2018. Additionally, measures have been implemented to safeguard the confidentiality of individual patient data, ensuring that they cannot be identified in the study results.

Statistical analysis

We analysed continuous variables with the *t*-test or the Mann-Whitney *U* test and categorical parameters with the χ^2 or Fisher's exact tests. The distribution of the data through the Shapiro-Wilk test was checked. We used mean and standard deviations (SD) for normally distributed parameters, medians, interquartile ranges (IQR) for non-normally distributed parameters, and numbers and percentages to present categorical data. All measurements were performed using Statistica 13.3 software (Stat Soft. Inc., Tulsa, OK, United States).

RESULTS

Eighty-six patients met the inclusion criteria according to ELSO guidelines and underwent primary transport while on VV-ECMO support. There were 30 air transports and 56 ground transports (Table 1). Patient characteristics, admission diagnosis, SOFA scores, selected laboratory parameters, ECMO and mechanical ventilation time are presented in Table 2. The distribution of the referring facility (patients' primary hospital) is presented in Table 3. The mean age of all patients was 46 years (SD ± 8.9), and 62 (72.1%) of patients were male. Mean BMI was 33.9 (SD ± 7.5), admission SOFA score was 8.2 (SD ± 2.6), PaO_2 70.5 mmHg (SD ± 34.2), pCO_2 54.1 mmHg (SD ± 19.4), lactates 2.1 mmol L^{-1} (SD ± 1.4). The average ICU stay was 17.7 days (SD ± 12.2), and the average ECMO duration was 12.9 days (SD ± 9). The overall mortality was 80.3%.

No complications occurred during transport. In-hospital complications included bleeding complications (36%), stroke or cerebral haemorrhage (11.6%), and limb or gut ischemia (2.3%). No in-hospital complications were noted in almost half of the procedures. No statistically significant differences were

TABLE 1. Characteristics of patients in terms of mode of transport

Factor	Air transport ($n = 30$)	Road transport ($n = 56$)	*P*-value
Age (years)	45.9 (SD ± 8.8)	46.6 (SD ± 9.0)	0.74
BMI, kg m^{-2}	33.7 (SD ± 7.2)	34.0 (SD ± 7.7)	0.69
SOFA	8.1 (SD ± 2.3)	8.4 (SD ± 2.7)	0.33
pO_2 at admission (mmHg)	83.0 (SD ± 47.5)	63.8 (SD ± 22.2)	0.02*
pCO_2 at admission (mmHg)	54.0 (SD ± 20.7)	54.1 (SD ± 18.9)	0.98
Lactates at admission (mmol L^{-1})	2.2 (SD ± 1.0)	2.0 (SD ± 1.5)	0.40
Distance (km)	194.4 (SD ± 99.5)	141.6 (SD ± 61.9)	0.003*
Transport time (minutes)	120 (110–140)	110 (65–135)	0.07
ECMO duration (days)	11.3 (SD ± 8.3)	13.7 (SD ± 9.4)	0.23
ICU stay (days)	16.9 (SD ± 11.5)	18.0 (SD ± 12.6)	0.61

found when comparing comorbidities in patients transported by air and ground. Patients did not differ based on the occurrence of hypertension 43% vs. 32% ($P = 0.3$), obesity 50% vs. 51% ($P = 0.87$), diabetes 23% vs. 21% ($P = 0.84$), other diseases 26% vs. 28% ($P = 0.85$), or pregnancy and postpartum 10% vs. 5% ($P = 0.42$). Both groups had a similar mortality rate of 83% vs. 78% ($P = 0.59$), thromboembolic complications incidence rate of 40% vs. 55% ($P = 0.17$) and need for continuous renal replacement therapy of 30% vs. 19% ($P = 0.56$). Prone positioning before ECMO was implemented in 30% vs. 44% ($P = 0.3$) patients, and tracheostomy was performed in 66% vs. 60% ($P = 0.59$) patients. The median amount of pRBC used during ICU stay was 5.5 (3.5–8.5) in the air transport group and 6 (2–11) in the road transport group ($P = 0.75$). Median FFP transfused was 0 (0–4) and 0 (0–2.5) ($P = 0.55$), and PCC 0 (0–0) and 0 (0–1) ($P = 0.55$), respectively.

Patients in survivors and non-survivors groups did not differ based on the occurrence of hypertension 29% vs. 37% ($P = 0.52$), obesity 35% vs. 26% ($P = 0.14$), diabetes 17% vs. 23% ($P = 0.39$), other diseases 35% vs. 26% ($P = 0.45$), or pregnancy and postpartum 17% vs. 4% ($P = 0.054$) (Table 4). The thromboembolic complications occurred more often in the non-survivors group than in survivors (29% vs. 55%), but it did not meet statistical significance ($P = 0.058$). Patients in the survivors' group were more likely to undergo prone positioning before ECMO without reaching a statistical significance of 58% vs. 36% ($P = 0.08$). The median amount of pRBC used during ICU stay was 4.0 (2.0–8.5) in the survivors' group and 6 (3–11) in the non-survivors group ($P = 0.24$). The median FFP transfused was 0 (0–4) and 0.5 (0–3.5) ($P = 0.03$), and PCC 0 (0–0) and 0 (0–1) ($P = 0.39$), respectively.

TABLE 2. Patient characteristics and outcome

Factor	
Median age (years)	46
Male sex, *n* (%)	62 (72.1)
Mean BMI (kg m^{-2})	33.9
Comorbidities, *n* (%)	
Obesity	51 (59.3)
Hypertension	31 (36)
Diabetes	21 (24.4)
Peripartum	5 (5.8)
Past neurological disorders	1 (1.1)
Asthma, COPD	3 (3.4)
Mean SOFA score at ECMO implementation	8.2
ECMO complications, *n* (%)	
Bleeding	31 (36)
Stroke/cerebral ischemia	10 (11.6)
Required ECMO recannulation	1 (1.4)
Hyperbilirubinemia	4 (4.1)
Limb or gut ischemia	2 (2.3)
Acute pancreatitis	1 (1.1)
None	40 (46)
Tracheostomy, *n* (%)	54 (62)
Blood products use, *n* (%)	74 (86)
COVID 19 survival to ICU discharge, *n* (%)	17 (19.7)

TABLE 3. Distribution of referring facility (patients' primary hospital)

Referring facility	
Primary hospital, *n* (%)	60 (69.7)
Secondary hospital, *n* (%)	21 (24.4)
Tertiary hospital, *n* (%)	1 (1.1)
University hospital, *n* (%)	3 (3.4)

DISCUSSION

Despite the high overall mortality, our study indicates that primary transport with V-V ECMO assistance can be considered a safe intervention in patients with COVID-19 pneumonia. No complications were noted during transport, and the profile

TABLE 4. Characteristics of patients in terms of survival

Factor	Survivors ($n = 17$)	Non-Survivors ($n = 69$)	*P*-value
Age (years)	45.7 (SD ± 10.3)	46.5 (SD ± 8.6)	0.76
BMI (kg m^{-2})	32.3 (SD ± 8.4)	34.3 (SD ± 7.2)	0.34
SOFA	7.8 (SD ± 2.3)	8.4 (SD ± 2.6)	0.41
pO_2 at admission	66.5 (SD ± 19.0)	71.6 (SD ± 37.2)	0.61
pCO_2 at admission	46.5 (SD ± 11.6)	56.0 (SD ± 20.5)	0.08
Lactates at admission	1.8 (SD ± 0.7)	2.1 (SD ± 1.5)	0.32
Distance (km)	148.2 (SD ± 68.5)	162.9 (SD ± 83.5)	0.50
ECMO duration (days)	11.9 (SD ± 8.1)	13.1 (SD ± 9.3)	0.62
ICU stay (days)	27.8 (SD ± 14.9)	15.2 (SD ± 10.1)	0.0007

of in-hospital complications indicates no relationship between the modes of transport. Almost half of the VV-ECMO procedures were completed without complications, underscoring its safety profile in this patient population.

Because regional hospitals have limited access to VV-ECMO therapy, a mobile ECMO team was crucial in COVID-19 refractory hypoxemia. High-volume ECMO centres in Lublin and Opole are experienced with both ARDS treatment and transportation of VV-ECMO patients [8].

Transports on ECMO are highly complex, requiring additional organisational, logistical, and clinical efforts. Mobile VV-ECMO retrieval system has been created as part of regional or national ECMO networks to provide access to the technique for patients hospitalised in primary care hospitals and for whom transport without ECMO to the network ECMO centre would be hazardous. Implementation of internal protocols is crucial to maintain patient safety [9]. During the pandemic, a limited number of mobile ECMO teams were launched, and due to high demand and increased transportation distance, road transport and aerial transportation had to be implemented. Our study assessed the impact of different transportations on patients' ICU treatment periods and outcomes. Distance for transportation by flight was significantly longer than for road transport, as it was one of the deciding factors for choosing the type of transportation for each case. The only difference between those two groups was admission PaO_2, which was significantly higher in patients transported by flight. However, better initial oxygenation at the admission to our centre did not affect the patients' mortality or complication rates. Aerial transport was not associated with an increased complication rate, and no major event was noted. Thus, aerial transportation should be considered safe and feasible [10].

According to the current knowledge, VV-ECMO implementation should not be considered ultimate therapy [11]. The guidelines emphasise that VV-ECMO should be applied in strictly defined cases [7]. Even despite a long time of mechanical ventilation, VV-ECMO may be a life-saving procedure, including for COVID-19 patients [12]. In our ECMO centres, patient selection for VV-ECMO was based on current ELSO guidelines. All patients in our study fulfilled standard inclusion criteria. The mean days of mechanical ventilation before ECMO in the entire analysed group was 2.83, which is shorter than in the national data [13, 14].

Compared to patients treated with VV-ECMO because of AH1N1 ARDS, mortality in the entire analysed group was higher [15]. Rare but serious complications like stroke or cerebral haemorrhage were recognised complications (6 patients; 9.8%). This number exceeds usual cerebrovascular events during extracorporeal circulation therapies [16, 17].

This situation may be attributed to the significant influx of patients who, before admission to our centre, required treatment not in the ICU but in temporary wards established during the COVID-19 pandemic. Within these temporary facilities, widespread staff shortages, medications, and equipment often meant that not all therapeutic options could be fully explored. This included using neuromuscular blocking agents, comprehensive sedation, prone positioning, and lung-protective ventilation. While some temporary ICUs were established as comprehensive intensive care centres, others provided primarily oxygen therapy and essential mechanical ventilation. Additionally, many healthcare professionals needed more experience in ventilating patients with ARDS due to COVID-19. These challenges were not unique to our setting but reflected a global problem that healthcare workers worldwide had to confront [18, 19].

In our study, peripartum women were the subpopulation with 50% mortality compared to 82.5% mortality of other patients. Although the difference did not reach statistical significance, it remains in compliance with the data from the literature [20, 21]. The peripartum period might be a positive prognostic factor in VV-ECMO and should be further evaluated.

CONCLUSIONS

Aerial and road transport are viable options for VV-ECMO patients. The distance from the referring centre might be a significant factor in deciding on the type of transportation. The causes of mortality during the COVID-19 pandemic are multifactorial, but given the results of our study, they don't seem to be related to either transport or mode of transportation. The peripartum physiological changes and their impact on survival in COVID-19 should be further examined.

LIMITATIONS

Due to limited data availability, our study focuses specifically on short-term complications of VV-ECMO. A small sample size and retrospective design may increase the risk of selection and observational bias. No uniform monitoring protocol was implemented during transport, so mild patient-related or equipment-related complications could be missed.

ACKNOWLEDGEMENTS

1. Assistance with the article: none.
2. Financial support and sponsorship: none.
3. Conflicts of interest: none.
4. Presentation: none.

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