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Clinical Research

Outcomes of Extracorporeal Membrane Oxygenation in COVID-19: A Single-Center Study

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Background: Coronavirus disease 2019 (COVID-19) can lead to acute respiratory failure, which frequently necessitates invasive mechanical ventilation and extracorporeal membrane oxygenation (ECMO). However, the limited availability of ECMO resources poses challenges to patient selection and associated decision-making. Consequently, this retrospective single-center study was undertaken to evaluate the characteristics and clinical outcomes of patients with COVID-19 receiving ECMO.
Methods: Between March 2020 and July 2022, 65 patients with COVID-19 were treated with ECMO and were subsequently reviewed. Patient demographics, laboratory data, and clinical outcomes were examined, and statistical analyses were performed to identify risk factors associated with mortality.
Results: Of the patients studied, 15 (23.1%) survived and were discharged from the hospital, while 50 (76.9%) died during their hospitalization. The survival group had a significantly lower median age, at 52 years (interquartile range [IQR], 47.5–61.5 years), compared to 64 years (IQR, 60.0–68.0 years) among mortality group (p=0.016). However, no significant differences were observed in other underlying conditions or in factors related to intervention timing. Multivariable analysis revealed that the requirement of a change in ECMO mode (odds ratio [OR], 366.77; 95% confidence interval [CI], 1.92–69911.92; p=0.0275) and the initiation of continuous renal replacement therapy (CRRT) (OR, 139.15; 95% CI, 1.95–9,910.14; p=0.0233) were independent predictors of mortality.
Conclusion: Changes in ECMO mode and the initiation of CRRT during management were associated with mortality in patients with COVID-19 who were supported by ECMO. Patients exhibiting these factors require careful monitoring due to the potential for adverse outcomes.

Keywords: COVID-19, Extracorporeal membrane oxygenation, Acute respiratory distress syndrome

Introduction

In March 2020, coronavirus disease 2019 (COVID-19) was declared a global pandemic by the World Health Organization [1]. Extensive research has since revealed that COVID-19 may lead to a range of complications, with respiratory issues being the most common and severe [2]. Acute respiratory failure resulting from COVID-19 infection frequently necessitates the use of invasive mechanical ventilation, and extracorporeal membrane oxygenation (ECMO) has emerged as a potentially life-saving intervention [3-7].

ECMO serves as an effective means of temporary respiratory and/or circulatory support. However, during the COVID-19 pandemic, the limited availability of ECMO resources has challenged healthcare professionals. This scarcity has necessitated difficult decisions regarding patient selection [3,4,8-10]. Thus, it is crucial to identify the factors associated with patient outcomes and mortality in this context.

Existing research has primarily been focused on patients with COVID-19 who are supported by veno-venous ECMO

[3-5,8,9,11,12]. However, some patients with COVID-19 infection not only have impaired lung function but also require circulatory support, due to conditions such as right ventricular (RV) failure and septic shock. This necessitates veno-arterial or veno-arterio-venous ECMO. The objective of this study was to examine the characteristics, risk factors, and outcomes of COVID-19 patients who received ECMO. The findings may provide comprehensive clinical insights for the management of this patient group.

Methods

Patient information

This retrospective study was approved by the Institutional Review Board of Hallym University Sacred Heart Hospital (IRB no., 2023-06-014-001). The requirement for informed consent was waived due to the retrospective nature of the research. The study incorporated patients who required ECMO support for COVID-19 between March 2020 and July 2022. The exclusion criteria included patients under 19 years of age, those with an ECMO support duration of less than 24 hours, and those who needed ECMO support for surgical intervention. One patient who required surgical intervention was excluded, yielding a final analysis cohort of 65 patients.

Patient characteristics and clinical outcomes were retrospectively reviewed through the analysis of electronic medical records. Arterial blood gas analysis was performed prior to ECMO cannulation, and additional laboratory data were collected immediately after ECMO initiation.

Extracorporeal membrane oxygenation management protocol

The use of ECMO was guided by the Extracorporeal Life Support Organization guidelines, which stipulate that ECMO is indicated if: (1) the ratio of the partial pressure of arterial oxygen to the inspired fraction of oxygen is less than 100, and/or (2) the pH is less than 7.25 with a partial pressure of arterial carbon dioxide greater than or equal to 60 mm Hg, despite the application of optimal conventional management [6]. Initially, ECMO was implemented in the veno-venous mode. However, if the patient required an intravenous norepinephrine dosage exceeding 0.5 μg/kg/min, or if bedside echocardiography revealed an ejection fraction of less than 20%, veno-arterial or veno-arterio-venous ECMO was initiated.

The cannulae for ECMO were inserted at the bedside under ultrasound guidance, with routine postprocedural chest and abdominal X-rays conducted. Fluoroscopic guidance was not available due to quarantine requirements. The management of COVID-19 aligned with the guidelines set by the Korea Disease Control and Prevention Agency and the Korean Society of Infectious Diseases. Adjustments to mechanical ventilation were made to protect the lungs. Once patients completed their quarantine period and were transferred to the general intensive care unit, efforts were made to achieve awake ECMO, utilizing high-flow support or nasal prongs for oxygen supply.

Changes to the ECMO mode were considered based on the findings of follow-up echocardiography. In instances in which lung transplantation was considered for patients undergoing a change in ECMO mode, an oxygenated RV assist device (Oxy-RVAD) was preferred over veno-arterial-venous ECMO.

Statistical analysis

Continuous variables were presented as either means±standard deviations or as medians with corresponding interquartile ranges (IQRs), as appropriate. Either the Student t-test or the Mann-Whitney U test was used to compare continuous variables between groups. Categorical variables were expressed as percentages (%) and assessed using the chi-square test or Fisher exact test for comparison. A p-value of less than 0.05 was considered to indicate statistical significance.

To identify the risk factors associated with mortality, multivariable logistic regression analysis was performed. This analysis incorporated variables that demonstrated a p-value of less than 0.05 in the univariate analysis. Patient survival was assessed using Kaplan-Meier survival analysis in conjunction with a Cox proportional hazards model. All statistical analyses were performed using R statistical software ver. 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Of all examined patients with COVID-19 who received ECMO support, 15 (23.1%) were discharged from the hospital as survivors, while 50 (76.9%) died during their hospital stay. The primary cause of death was sepsis for 46 patients, while 2 patients died from cerebrovascular accidents, 1 from gastrointestinal bleeding, and 1 from pulmonary hemorrhage. Successful weaning from ECMO was achieved for 33.8% (22/65) of patients, including 7 who later died.

The median duration of follow-up was 405 days (IQR, 341.0–613.5 days), with no reported instances of mortality after discharge during the follow-up period. Demographic data were compared between the survival and mortality groups. A significant difference in median age was observed between these groups, with the survival group being substantially younger (52.0 years [IQR, 47.5–61.5 years] versus 64.0 years [IQR, 60.0–68.0 years], p=0.016). However, no significant differences were found in other underlying conditions or in factors related to intervention timing. Detailed data are presented in Table 1. Although pre-ECMO initiation conditions—including sepsis-related organ failure assessment score, simplified acute physiologic score, and blood gas analysis—displayed no significant differences, patients in the survival group had lower respiratory ECMO survival prediction (RESP) scores (p=0.014) than those in the mortality group. However, the RESP score lost statistical significance in the univariate logistic regression analysis (score of 1, p=0.6569; score of 2, p=0.9166, score of 3, p=0.9943; score of 4, p=0.8192) and was consequently excluded from the multivariable analysis. In the initial laboratory tests conducted after ECMO initiation, the survival group had a higher platelet count ($257.0\times10^3/\mu L$ [IQR, $208.0\times10^3/\mu L$–$312.5\times10^3/\mu L$] versus $159.0\times10^3/\mu L$ [IQR, $134.0\times10^3/\mu L$–$189.0\times10^3/\mu L$]) and cholesterol level (127.0 mg/dL [IQR, 85.5–159.0 mg/dL] versus 87.0 mg/dL [IQR, 73.0–104.0 mg/dL]) than the mortality group. No significant differences were observed in the other results. All laboratory test results are summarized in Table 2.

Table 3 details data on the initial mode of ECMO, its duration, any changes in mode, concomitant management of CRRT, and complications such as pneumothorax, bleeding, and limb ischemia. Bleeding complications were defined as a drop in hemoglobin of 1 g/dL, the need for transfusion of more than 1 pack of red blood cells, or the requirement for surgical repair due to bleeding at the intervention site. These complications could occur in the nasopharyngeal, gastrointestinal, and urinary tracts. Intracranial bleeding was also considered a bleeding event, regardless of its severity. Initially, veno-venous ECMO was initiated in 12 (80.0%) of the 15 patients in the survival group and 42 (84.0%) of the 50 patients in the mortality group. The re-

Table 1. Demographics of patients with COVID-19 managed with ECMO

Characteristic	Survival (n=15)	Mortality (n=50)	p-value
Age (yr)	52.0 (47.5–61.5)	64.0 (60.0–68.0)	0.016
Male	8 (53.3)	30 (60.0)	0.872
Body mass index (kg/m^2)	26.2 (23.4–29.2)	24.4 (22.9–26.5)	0.269
Body surface area (m^2)	1.7 (1.6–1.9)	1.8 (1.7–1.9)	0.875
Transferred	5 (33.3)	31 (62.0)	0.096
COVID-19 to admission (day)	0.0 (0.0–7.0)	1.0 (0.0–5.0)	0.741
COVID-19 to mechanical ventilation (day)	9.0 (3.5–12.0)	9.0 (1.0–13.0)	0.953
COVID to ECMO (day)	11.0 (6.5–20.0)	14 (3.0–22.0)	0.646
Mechanical ventilation to ECMO (day)	1.0 (0.0–1.5)	2.0 (1.0–8.0)	0.066
Follow-up duration (day)	405.0 (341.0–613.5)	45.5 (23.0–65.0)	<0.001
Hypertension	8 (53.3)	23 (46.0)	0.838
Diabetes	6 (40.0)	18 (36.0)	1.000
Chronic kidney disease	1 (6.7)	3 (6.0)	1.000
pH before ECMO	7.3 (7.3–7.4)	7.3 (7.3–7.4)	0.824
PaO_2 before ECMO (mm Hg)	73.8 (61.8–91.9)	69.0 (56.1–84.8)	0.354
$PaCO_2$ before ECMO (mm Hg)	46.6 (40.4–49.9)	43.8 (37.0–55.5)	0.969
P/F ratio before ECMO	74.8 (63.5–96.0)	68.1 (56.1–85.9)	0.285
Sepsis-related organ failure assessment	10.5±2.3	11.1±3.1	0.489
Simplified acute physiological score	58.3±16.8	61.4±13.9	0.501
Respiratory ECMO survival prediction			0.014
1	2 (15.4)	3 (7.9)	
2	9 (69.2)	15 (39.5)	
3	0	16 (42.1)	
4	2 (15.4)	4 (10.5)	
ECMO weaning success	15 (100.0)	7 (14.0)	<0.001

Values are presented as median (interquartile range), number (%), or mean±standard deviation.
COVID-19, coronavirus disease 19; ECMO, extracorporeal membrane oxygenation; PaO_2, partial pressure of arterial oxygen; $PaCO_2$, partial pressure of arterial carbon dioxide; P/F, partial pressure of arterial oxygen/inspired fraction of oxygen.

Table 2. Laboratory data after extracorporeal membrane oxygenation initiation

Variable	Survival (n=15)	Mortality (n=50)	p-value
White blood cell (×10³/μL)	15.4 (11.9–22.6)	12.5 (9.3–18.2)	0.139
Hemoglobin (d/dL)	11.1±2.7	10.8±2.1	0.669
Platelet (×10³/μL)	257.0 (208.0–312.5)	159.0 (134.0–189.0)	<0.001
C-reactive protein (mg/L)	125.9 (64.9–170.6)	107.1 (65.3–156.5)	0.839
Blood urea nitrogen (mg/dL)	16.1 (13.4–29.8)	24.4 (15.4–34.4)	0.080
Creatinine (mg/dL)	0.9 (0.5–1.2)	0.8 (0.6–1.4)	0.926
Cr eGFR (mL/min/1.73 m²)	84.0 (58.0–90.0)	90.0 (47.0–90.0)	0.580
Albumin (mg/dL)	2.8 (2.3–3.2)	2.7 (2.0–2.9)	0.115
Procalcitonin (ng/mL)	0.2 (0.1–0.5)	0.4 (0.2–1.6)	0.121
Lactate dehydrogenase (U/L)	440.0 (381.0–618.5)	494.0 (424.0–552.0)	0.884
Aspartate transaminase (IU/L)	38.0 (25.0–86.5)	40.0 (29.0–59.0)	0.860
Alanine transferase (IU/L)	22.0 (14.5–58.0)	27.0 (18.0–43.0)	0.488
Creatine kinase (IU/L)	61.0 (28.5–305.5)	102.0 (55.0–274.0)	0.355
Cholesterol (mg/dL)	127.0 (85.5–159.0)	87.0 (73.0–104.0)	0.043
Amylase (U/L)	58.0 (51.5–89.0)	56.0 (32.0–122.0)	0.725
Lipase (U/L)	27.5 (19.0–127.0)	32.0 (20.0–67.0)	0.750
Uric acid (mg/dL)	2.6 (1.8–3.5)	2.1 (1.5–4.6)	0.753
Creatine kinase-myocardial band (mg/mL)	1.8 (1.2–4.5)	2.7 (1.2–3.8)	0.993
Troponin-I (pg/mL)	27.8 (11.3–60.0)	93.9 (28.2–369.7)	0.082
Brain natriuretic peptide (pg/mL)	31.0 (16.9–100.8)	76.1 (28.4–290.3)	0.083
Glucose (mg/dL)	251.5±73.6	244.3±89.3	0.782

Values are presented as median (interquartile range) or mean±standard deviation.
Cr eGFR, creatinine estimated glomerular filtration rate.

Table 3. Extracorporeal membrane oxygenation data

Variable	Survival (n=15)	Mortality (n=50)	p-value
Initial ECMO mode			0.706
Veno-venous	12 (80.0)	42 (84.0)	
Veno-arterial	3 (20.0)	8 (16.0)	
ECMO duration (day)	21.0 (18.5–32.5)	41.5 (22.0–60.0)	0.009
ECMO mode change	1 (6.7)	28 (56.0)	0.002
Continuous renal replacement therapy	4 (26.7)	47 (94.0)	<0.001
Complication			
Pneumothorax	1 (6.7)	17 (34.0)	0.049
Bleeding	0	15 (30.0)	0.014
Limb ischemia	1 (6.7)	1 (2.0)	0.411

Values are presented as number (%) or median (interquartile range).
ECMO, extracorporeal membrane oxygenation.

maining patients began with veno-arterial ECMO. The femoro-femoral cannulation approach was used for all veno-arterial ECMO cases. The majority of veno-venous ECMO cases involved either femoro-jugular (35 of 54 patients, 66.7%) or femoro-femoral (18 of 54 patients, 33.3%) cannulation. One patient who received veno-venous ECMO underwent femoro-axillary cannulation.

Six patients required a second round of ECMO treatment, comprising 1 individual from the survival group and 5 who did not survive. Additionally, 5 patients underwent lung transplantation, 1 of whom survived.

During ECMO management, a change in the ECMO mode was required for 29 patients (44.6%) due to either RV failure or septic shock. Of these 29 patients, 5 transitioned from veno-venous ECMO to Oxy-RVAD, while 22 were switched to veno-arterial-venous ECMO (17 from veno-venous ECMO and 5 from veno-arterial ECMO). The remaining 2 patients were transitioned from veno-venous ECMO to veno-arterial ECMO (Fig. 1).

In the univariate analyses, several factors were found to be significantly associated with mortality, including age (odds ratio [OR], 1.07; 95% confidence interval [CI], 1.01–

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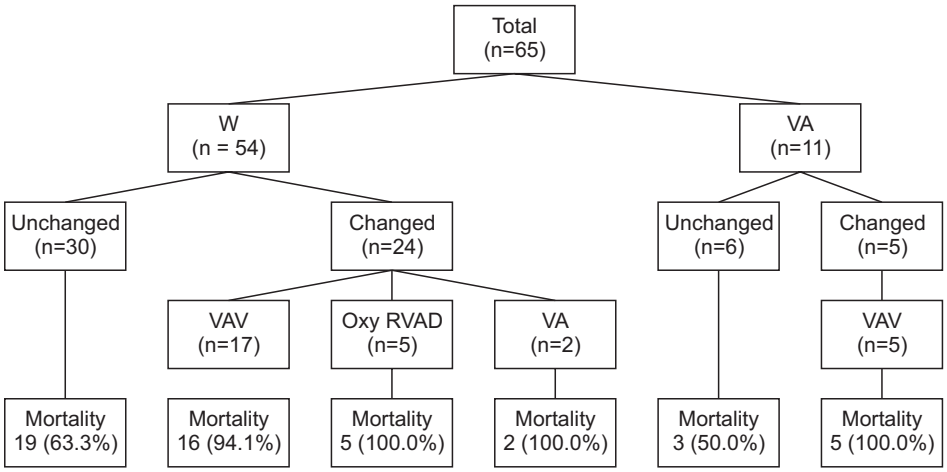

Fig. 1. Schematic diagram of the initial extracorporeal membrane oxygenation mode and changes throughout management. VV, veno-venous; VA, veno-arterial; VAV, veno-arterial-venous; Oxy-RVAD, oxygenated right ventricular assist device.

Table 4. Univariate logistic regression analysis for mortality risk factors

Characteristic	OR (95% CI)	p-value
Age	1.07 (1.01–1.13)	0.0327
ECMO mode change	17.82 (2.17–146.12)	0.0073
ECMO duration	1.05 (1.01–1.09)	0.0149
Platelet count	0.99 (0.98–1.00)	0.0079
Cholesterol	0.99 (0.98–1.00)	0.0628
CRRT initiation	43.08 (8.4–220.9)	<0.0001
Pneumothorax	7.21 (0.87–59.57)	0.0666

OR, odds ratio; CI, confidence interval; ECMO, extracorporeal membrane oxygenation; CRRT, continuous renal replacement therapy.

Table 5. Multivariable logistic regression analysis for mortality risk factors

Characteristic	OR (95% CI)	p-value
Age	1.11 (0.99–1.25)	0.0762
ECMO mode change	366.77 (1.92–69911.92)	0.0275
ECMO duration	1.14 (0.97–1.34)	0.1064
Platelet count	0.98 (0.96–1.00)	0.0828
CRRT	139.15 (1.95–9910.14)	0.0233

OR, odds ratio; CI, confidence interval; ECMO, extracorporeal membrane oxygenation; CRRT, continuous renal replacement therapy.

1.13; p=0.0327), ECMO duration (OR, 1.05; 95% CI, 1.01–1.09; p=0.0149), the requirement of an ECMO mode change (OR, 17.82; 95% CI, 2.17–146.12; p=0.0073), platelet count (OR, 0.99; 95% CI, 0.98–1.00; p=0.0079), and concomitant CRRT (OR, 43.08; 95% CI, 8.4–220.9; p<0.0001) (Table 4). Subsequently, a multivariable logistic regression analysis was conducted to identify independent predictors of mortality. This analysis revealed that the need for an ECMO mode change and CRRT were significantly associated with mortality (Table 5).

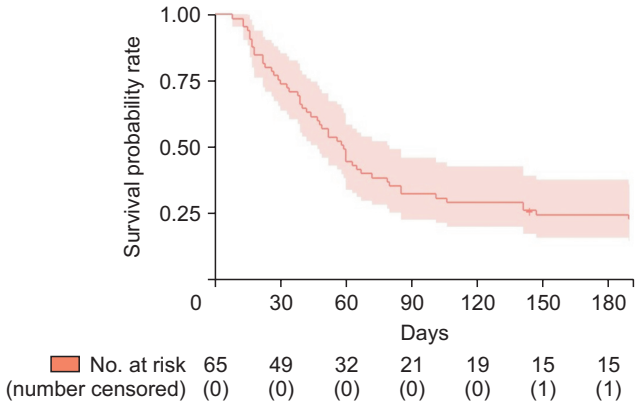

Fig. 2. Kaplan-Meier survival curves of all patients with coronavirus disease 2019 managed with extracorporeal membrane oxygenation.

Kaplan-Meier survival analysis was performed to assess the outcomes of all patients (Fig. 2). To evaluate the impact of changes in ECMO configuration on mortality risk, we conducted additional assessments.

Discussion

During the early stages of treating patients with COVID-19 using ECMO, concerns were raised over the high mortality rate and unfavorable patient prognosis observed [13,14]. To enhance patient outcomes, experts shared their knowledge and experiences, which resulted in improved management strategies. Extensive research has been undertaken to pinpoint the primary risk factors linked to ECMO treatment in patients with COVID-19. Several studies have consistently identified older age as a risk factor for mortality [5,8,11,12].

Platelets, while primarily known for their role in hemo-

stasis, also have critical functions in inflammation and host defense responses [15]. Consequently, the platelet count is associated with mortality among critically ill patients, including those undergoing ECMO treatment for COVID-19 [11,16,17]. Kieninger et al. [11] observed a significant difference in the mean platelet count, with mortality group exhibiting lower platelet counts than survival group both before and during veno-venous ECMO management. Similarly, Zaaqoq et al. [17] compared the time-group interaction for platelet count during the first 7 days of ECMO management between survival and mortality groups, finding that the platelet count was significantly lower in mortality group. The precise mechanism causing thrombocytopenia in patients with COVID-19 is not yet fully understood, but several theories have been proposed. Specifically, inflammation can cause tissue damage and endothelial dysfunction, triggering the activation of a coagulation cascade and causing platelet activation and consumption [16,17]. Furthermore, since the lungs may contribute to platelet production, lung damage could result in a production decrease. The formation of thrombi at the site of injury can also contribute to the consumption of platelets and megakaryocytes [15,18].

In line with prior research, significant differences were found in age and platelet count between the survival and mortality groups. However, these associations did not reach statistical significance in the multivariable analysis. The limited sample size of this study could account for these inconclusive findings. Consequently, studies with larger sample sizes, such as multicenter studies or meta-analyses, are necessary.

Acute renal failure necessitating CRRT has been identified as a risk factor for mortality in patients with COVID-19 who receive ECMO [8,17]. In line with this finding, our observations revealed a significantly higher rate of CRRT initiation in mortality group than in survival group (94% versus 26.7%, respectively; $p<0.001$). Multivariate analysis additionally demonstrated that CRRT was an independent predictor of mortality. Notably, as highlighted in the previously mentioned studies, CRRT should not be considered a direct cause of death. Rather, it serves as an indicator of critical illness and is associated with relatively poor prognosis in these patients.

Notably, we found that the requirement of a change in ECMO mode was associated with mortality, a finding not previously reported. The primary drivers for changes in ECMO mode were RV failure and septic shock. However, other factors such as worsening infection and inflammation, along with multiple organ failure, could contribute to the necessity for an ECMO mode change. Consequently, it is challenging to determine whether the change in ECMO mode itself directly impacts mortality. This observation can be interpreted in the context of patients with acute renal failure who require CRRT. Both changes in ECMO mode and the need for CRRT reflect the complexity and severity of the patient's condition, highlighting the importance of close monitoring and early intervention in the management of critically ill patients.

Previous studies have reported a range of 3 to 7 days for the duration of mechanical ventilation prior to the initiation of ECMO [3,8,11,19]. Makhoul et al. [8] and Kieninger et al. [11] found that mortality group experienced a longer duration of mechanical ventilation, and a meta-analysis by Tran et al. [12] suggested that a longer period might be associated with increased mortality. However, our study did not reveal a significant difference in the pre-ECMO duration of mechanical ventilation between the survival and mortality groups, with durations of 1 day (IQR, 0.0–1.5) and 2 days (IQR, 1.0–8.0), respectively. Furthermore, we observed a shorter interval between intubation and cannulation in our patient cohort compared to previous studies. Among the 65 patients included in our analysis, 35 (53.8%) underwent cannulation within 48 hours of intubation, and 17 were cannulated on the same day. These findings can be interpreted in several ways. First, our patient cohort, including those with COVID-19, primarily consisted of referred patients. During the study period, 36 of 65 patients (55.4%) were transferred from surrounding hospitals. Due to a national shortage of resources, including equipment for ECMO, mechanical ventilators, isolation rooms, protective devices, and human resources, hospitals without specialized centers had to delay patient transfers as long as possible, necessitating rapid intervention upon arrival. As a result, approximately half of the patients referred for ECMO insertion were transferred within 24 hours of intubation. In addition, the rapid progression of COVID-19 may have contributed to the short interval between intubation and cannulation. To fully understand the factors contributing to this quick deterioration, multi-institutional studies are required. Future research should explore whether this pattern is specific to Asian populations, as most previous studies have focused on American and European populations, or whether it is associated with a specific variant. This is particularly relevant given the rapid increase in COVID-19 cases in Korea following the emergence of the Omicron variant.

In 2014, we published a report detailing similar outcomes for veno-venous ECMO in patients with acute respi-

ratory failure, revealing a mortality rate of 32.3%. Concurrently, the mortality rate for patients with non–COVID-19–related acute respiratory failure who required any form of ECMO, including veno-arterial ECMO, was approximately 57.6% (19/33) [20]. However, in this current study, the in-hospital mortality rate for patients with COVID-19 who were supported by ECMO (76.9%) exceeded both this pre-pandemic mortality rate and the mortality rates previously reported for COVID-19 patients receiving ECMO (37%–55%) [8,21]. Most prior studies have primarily been focused on patients receiving veno-venous ECMO support. According to the updated 2021 Guidelines of the Extracorporeal Life Support Organization, limited data are available on veno-arterial ECMO for COVID-19, and pre-pandemic data indicate higher mortality rates associated with veno-arterial ECMO compared to veno-venous ECMO [6]. In our patient cohort, 11 patients (16.9%) were initially put on veno-arterial ECMO, and 29 patients required a change in ECMO mode, suggesting a critically ill state. Furthermore, 18 patients were registered for lung transplantation, but only 5 received a donor lung, while 13 (representing 26% of all deaths) died while on the waiting list. The high mortality rate observed in our study may be attributed to a combination of factors, including patient characteristics requiring circulatory support, limited resources (including a shortage of organs) during the pandemic, and the potentially aggressive nature of the viral infection.

This study has some limitations. First, the research design was retrospective, and the study was conducted at a single center, potentially limiting the generalizability of the findings to a broader population. Second, the sample size was relatively small, which may have affected the statistical power and precision of the results.

In conclusion, changes in ECMO mode due to RV failure and/or septic shock, as well as CRRT—which represent critical conditions—were found to be associated with mortality in patients with COVID-19 supported by ECMO. Patients exhibiting these factors necessitate careful monitoring for adverse outcomes. Further research, preferably in the form of larger multicenter studies, is needed to confirm the uncertain results of this study, particularly in relation to platelet count and age. These findings, along with future endeavors to identify other factors that could influence patient outcomes, may aid in refining patient selection and management strategies. This could ultimately improve outcomes for critically ill patients with COVID-19 who require ECMO intervention.

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Conflict of interest

No potential conflict of interest relevant to this article has been reported.

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