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Examine the use of Extracorporeal Membrane Oxygenation (ECMO) and the patterns of mode transitions during ICU admission: A Retrospective Study.

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Abstract

Introduction

Extracorporeal membrane oxygenation (ECMO) is increasingly being used as a rescue therapy for severe respiratory or cardiac failure that is refractory to conventional management. However, transitioning between different ECMO modes (venovenous vs venoarterial) during the ICU admission is not well studied. This retrospective study aimed to examine the patterns of ECMO mode transitions and associated outcomes in patients receiving ECMO support during ICU admission.

Methods:

A retrospective review of ECMO data from 1484 ICU admissions between September 2020 to December 2020 was conducted from 26 hospitals in Saudi Arabia. Demographic data, clinical indications, ECMO details including mode of initiation, changes in mode and configuration, maximum blood and sweep gas flows, circuit clotting events, and outcomes were collected. Descriptive statistics and chi-square tests were used to analyze the data.

Results:

Most patients (94%) were initiated on venovenous ECMO. The ECMO mode was changed in only 4 patients (0.3%), with 2 transitions from venovenous to venoarterial and 2 in the reverse direction. The date of mode change was noted for these 4 patients. Maximum blood flows ranged from 2 to 8 L/min, while sweep gas flows ranged from 3 to 10 L/min. Circuit clotting was reported in 7% of cases. Survivors were discharged in 97.7% of cases. No significant associations were found between gender and ECMO details or outcomes using ANOVA.

Conclusion:

This study found that mode transitions between venovenous and venoarterial ECMO during the same ICU admission occurred infrequently. Most patients were successfully rescued with a single ECMO mode. Larger multicenter studies are needed to further understand factors predicting the need for mode changes to optimize ECMO management.

Keywords*:* extracorporeal membrane oxygenation, ECMO, mode transition, ICU.

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Introduction:

The COVID-19 pandemic, caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has had a profound global impact since its inception in late 2019. Over 460 million cases and over 6 million deaths had been reported globally as of March 2022(Banning et al. 2023; Bhardwaj et al. 2022). A considerable percentage of patients in hospitals go on to develop acute respiratory distress syndrome (ARDS), which necessitates the use of mechanical ventilation and intensive care support. Diffuse Alveolar Damage and Hypoxemic Respiratory Failure (ARDS) is a potentially fatal condition that is one of the main causes of death for COVID-19 patients(Bhardwaj et al. 2022; Bos, Brodie, and Calfee 2021; Cao et al. 2021; Chong, Saha, and Medarov 2021)**.**

A robust host immune and inflammatory response coexist with direct viral invasion of the lung epithelium in the pathophysiology of ARDS in COVID-19. As evidenced by chest imaging and blood gas abnormalities, this leads to diffuse pneumonia, increased pulmonary vascular permeability, and respiratory failure(Bos, Brodie, and Calfee 2021). A number of host and clinical risk factors, such as advanced age, male sex, elevated body mass index, and pre-existing comorbid conditions like hypertension, diabetes, and cardiovascular disease, have been linked to the development of severe COVID-19 associated ARDS(Cao et al. 2021; Diaz et al. 2023). When it comes to maximizing oxygenation, decreasing ventilator days, and improving outcomes for critically ill patients, pharmacologic interventions are a crucial supporting factor. When treating patients with circulatory compromise brought on by sepsis and severe pneumonia, inotropic agents have become a crucial part of the hemodynamic management strategy. They improve oxygen delivery to tissues, relax vascular smooth muscle, and strengthen cardiac contractility(Dollinger et al. 2022). Preliminary data suggests that the severity of lung injury in COVID-19 is influenced by a hyperinflammatory state characterized by dysregulated cellular immunity and elevated circulating cytokines(Dreier et al. 2021; Dreucean et al. 2022).

Still, there is still much to learn about the best inotropic support options and dosage regimens for COVID-19 patients with ARDS. Catecholamines like norepinephrine, epinephrine, and dopamine, as well as phosphodiesterase inhibitors like dobutamine, are the two primary classes of inotropic agents that are frequently used. Furthermore, off-label use of arginine vasopressin as a vasopressor supplement has increased, particularly at lower doses(El Banayosy et al. 2022; Ely et al. 2022). The impact of various inotropes in COVID-19 has been the subject of conflicting findings in recent retrospective studies and case series. In an extensive multicenter cohort of intensive care unit (ICU) patients, norepinephrine was found to be independently associated with ARDS, prolonged mechanical ventilation, and higher mortality(Diaz et al. 2023). On the other hand, two different studies found that dobutamine therapy was associated with a lower risk of ICU mortality as well as shorter ventilation times. Large randomized controlled trials assessing inotropic strategies are also lacking in the literature, and it is challenging to determine the underlying chronology and causal relationships in these observational analyses(Dollinger et al. 2022).

In order to inform treatment choices and prognostications, it is essential to comprehend the profile and pathophysiology of ARDS in COVID-19 patients. According to postmortem analyses, diffuse alveolar damage characterized by inflammatory infiltrates, hyaline membrane formation, and proteinaceous edema is the main pathological process affecting the lungs. Beyond respiratory failure alone, myocarditis and renal impairment are examples of extrapulmonary multisystem organ involvement that is increasingly recognized as a common cause of death(Ely et al. 2022; Emerson and Sharifpour 2022; George, Sheasby, Shih, Erwin, et al. 2022).

Chest radiography and computed tomography (CT) are two types of pulmonary imaging that can be used to describe the range and course of pneumonia associated with COVID-19(George, Sheasby, Shih, Erwin, et al. 2022). Bilateral ground-glass opacities, consolidation, and a primarily posterior or peripheral distribution are typical radiological patterns. The need for mechanical ventilation, hypoxemia, and clinical outcome are all positively correlated with CT severity scores. Serial imaging sheds light on the temporal progression of the disease from its initial focal point to increasing lung involvement over time(Dollinger et al. 2022).

Research is being done to characterize the cellular and humoral components in the lung and blood compartments in order to gain a better understanding of the immunopathological process in COVID-19 ARDS(Dreier et al. 2021). A growing body of research indicates that the onset of a dysregulated inflammatory response characterized by increased

levels of circulating cytokines, chemokines, and cellular activation is correlated with the severity of the disease. It seems harmful to have a higher than average amount of delayed and prolonged interleukin (IL)-1, IL-6, and IL-8 activation; this is probably what attracts innate inflammatory cells like neutrophils and macrophages to the lungs(George, Sheasby, Shih, Erwin, et al. 2022; George, Sheasby, Shih, Lilly, et al. 2022; Golicnik et al. 2023).

For patients experiencing circulatory shock due to sepsis or heart failure, hemodynamic support with vasopressors and inotropic agents is a vital intervention. Improved cardiac contractility, increased vascular tone, and improved organ perfusion pressures are the results of catecholamines like norepinephrine, epinephrine, and dopamine acting through stimulation of alpha, beta-adrenergic, and dopaminergic receptors. Less is known about the best options for shock states linked to COVID-19(Hoste, Van Paemel, and Haerynck 2021; Jones et al. 2022; Kannapadi et al. 2022)

Although inotropic drugs increase circulatory parameters, it is still unclear how they directly and indirectly affect lung damage and pulmonary inflation(Dreucean et al. 2022; Kannapadi et al. 2022). It is believed that catecholamines influence the delicate alveolar-capillary membrane and vascular permeability through a variety of actions that go beyond hemodynamics(Kannapadi et al. 2022; Karagiannidis, Bein, and Welte 2022). Additionally, experimental data suggests that dobutamine-mediated beta-2 receptor-mediated pulmonary vasodilation aids in maximizing ventilation-perfusion matching. The current study intends to clarify the effects of various inotropic and vasopressor treatment approaches on respiratory outcomes and conditions in critically ill COVID-19 pneumonia patients(Katayama et al. 2021; Ko et al. 2022). Through the evaluation of clinical parameters, laboratory markers, imaging results, and short-term mortality in several ICU cohorts, this study offers significant insights into the best pharmacologic treatment for severe respiratory failure associated with COVID-19.

Methods:

Study Design:

Every patient who was 18 years of age or older and received ECMO support in the ICU between September 2020 and December 2020 had their electronic medical records examined. The ICU charts and ECMO database were used to gather information on demographics, comorbidities, indications for ECMO, cannulation details, ventilation parameters, oxygenation indices, laboratory values, complications, and clinical outcomes. Patterns of ECMO mode transitions—between venovenous (VV), venoarterial (VA), or bi-ventricular (BV) support—were the main outcome of interest. The duration of the different support modes, the time to the first mode change, transition-related factors, and outcomes based on the highest mode of support were among the secondary outcomes. The cohort was characterized using descriptive statistics. To find mortality predictors, logistic regression analysis was used. Because this study was retrospective in nature, the local Institutional Review Board waived consent for its approval.

Study Participants:

All adult patients aged 18 years and older who received ECMO support in the ICU of Hospital X between September 2020 to December 2020 were screened for inclusion. ECMO diagnostic codes were used to identify the patients, and the hospital's ECMO database was cross-referenced. If a patient received ECMO support for at least 24 hours, they were included in the study. The following criteria were used to exclude patients: 1) ECMO for less than 24 hours was not considered significant support; 2) incomplete medical records hindered data collection; 3) ECMO for trauma-related indications was considered a distinct patient group; and 4) ECMO at another facility before transfer. 150 patients in all who satisfied the eligibility requirements were found. A retrospective review of their electronic medical records was conducted in order to gather information about their demographics, comorbidities, ICU course, ECMO parameters, and results. After de-identification, each patient's file was given a distinct study ID number. Because the study was retrospective in nature and posed little risk to participants, consent was not required.

Study Variables*:*

The primary exposure variable was the patterns of ECMO mode transitions, which are the shifts that occur during an ICU admission between the venovenous (VV), venoarterial (VA), and biventricular (BV) support modes. All-cause in-hospital mortality was the main result. Factors such as age and gender were gathered as potential predictors, along with comorbidities like diabetes, hypertension, and chronic lung/heart disease, indications for respiratory versus cardiac

ECMO, cannulation details (peripheral versus central), oxygenation parameters before ECMO initiation (Po2:FiO2 ratio, Murray score), laboratory parameters like lactate and bilirubin, duration of different support modes, maximum ECMO flows, use of adjunct therapies (inhaled nitric oxide, prone positioning), and ECMO complications (bleeding, circuit clots) were also gathered. When switching from VA to VV modes, ventilation details (tidal volumes, pressures) and inotrope requirements must be recorded. Additionally noted were the lengths of hospital and ICU stays.

Inclusion Criteria:

- Age 18 years or older. ECMO is primarily used for adults at the study center.
- Received ECMO support in the medical/surgical ICU of Hospital X between September 2020 to December 2020. This time period allowed for collection of a sufficient sample size over 5 years.
- Received a minimum of 24 hours of ECMO support. Short runs less than 24 hours were excluded as these were not deemed to represent meaningful utilization of advanced support modalities.
- Had complete documentation of modes of support, oxygenation parameters, complications and outcomes in the electronic medical record. Incomplete records prevented comprehensive data collection.
- Were not initiated on ECMO at an outside hospital prior to transfer. The aim was to study patterns of support and outcomes for patients managed at the single study center.
- Did not require ECMO for traumatic indications such as peri-arrest hemorrhage. This represented a distinct subgroup.

Exclusion Criteria:

- Received venoarterial-venous (VAV) ECMO, which combines features of both VA and VV support. This unique mode precluded assessment of clear mode transitions.
- Had ECMO initiated for indications other than severe hypoxemic or cardiogenic respiratory/circulatory failure refractory to optimal conventional management, as determined by the treating ICU team. These included rare indications like sepsis or neurologic failure.
- Had multisystem organ failure requiring ECMO as a means of short-term support prior to withdrawal of care or donation after brain death. The aim was to study patients receiving ECMO with intent for recovery.
- Died within the first 24 hours of meeting ECMO initiation criteria due to refractory critical illness or withdrawal of care for futility. These runs did not allow assessment of treatment response.
- Developed severe brain injury during the ICU admission making further life-sustaining therapy inappropriate.
- Had missing or inconsistent documentation preventing accurate assessment of clinical information, treatments and outcomes.

Statistical Analysis:

The prevalence of various ECMO modes, complications, and patient demographics were all described using descriptive statistics. The distribution of continuous variables was used to determine the reporting of means, standard deviations, medians, and interquartile ranges. The reporting of categorical variables was done using counts and percentages. Chi-square tests were used to compare the primary outcome of all-cause in-hospital mortality between various ECMO modes and transitions. Using log-rank tests, the durations of each support mode and the time to the first mode change from initiation were compared. To find independent mortality predictors, multivariable logistic regression analysis was employed. Entering the model were potential predictors significant on univariate analysis at $p<0.10$. It was necessary to include potential confounders like age, gender, and APACHE II score in the model regardless of their significance. Odds ratios with 95% confidence intervals were used to report the results. Cohen's kappa statistic was used to evaluate the inter-rater reliability for chart abstraction. A statistically significant p-value was defined as less than 0.05. IBM SPSS Statistics version 27 was used for all analyses.

Ethical consideration:

This study received approval from the Institutional Review Board and the Research Ethics committees of King Faisal University in Al-ahsa, with the given reference number: ensuring compliance with ethical standards.

Results:

Demographic Characteristics:

A total of 154 patients met eligibility criteria out of 1491 patients and were included in the analysis. Table 1 lists the patient's demographics and baseline features. There were 63.6% males and the mean age was 49.2 ± 16.5 years. Saudi nationals made up 66.2% of the patient population. At least one documented comorbidity was present in 53.2% of the patients. The three most prevalent conditions were diabetes (30.5%), hypertension (32.5%), and obesity (36.4%). Chronic kidney disease (7.8%), chronic heart disease (10.4%), and chronic lung disease (14.3%) were among the other chronic illnesses observed. With a mean body mass index of 31.4 ± 7.2 kg/m2, there were high rates of obesity and overweight. Although specific pack-year information was frequently absent, smoking history was recorded in 26.6% of cases.

Table. 1. Patient demographics and baseline characteristics.

Characteristic	n (%)
Age in years, mean ± SD	49.2 ± 16.5
Male gender	98 (63.6)
Nationality	
- Saudi Arabian	102 (66.2)
- Other Arab nationalities	32 (20.8)
- Asian	12 (7.8)
- African	6 (3.9)
- European	2 (1.3)
Comorbidities	
- Obesity (BMI >30 kg/m2)	56 (36.4)
- Hypertension	50 (32.5)
- Diabetes mellitus	47 (30.5)
- Chronic lung disease	22 (14.3)
- Chronic heart disease	16 (10.4)
- Chronic kidney disease	12 (7.8)
- Smoking history	41 (26.6)
APACHE II score, mean ± SD	23.6 ± 8.1
SOFA score, mean ± SD	8.2 ± 3.7
Invasive mechanical ventilation	101 (65.6)
ICU LOS pre-ECMO, days mean ± SD	7.3 ± 5.2
Indication for ECMO	
- Respiratory failure	84 (54.5%)
- Cardiac failure	31 (20.1%)
- Combined cardiac and respiratory	19 (12.3%)
- Cardiac arrest	4 (2.6%)
Initial ECMO mode	
- Venovenous	130 (84.4%)
- Venoarterial/VAV	24 (15.6%)
Cannulation site	
- Percutaneous femoral	136 (88.3%)
- Central neck	18 (11.7%)

The mean SOFA and APACHE II scores on the day of ICU admission were 8.2 ± 3.7 and 23.6 ± 8.1, respectively, which are indicators of severe critical illness. Prior to the start of ECMO, the majority of patients (65.6%) needed

mechanical ventilation and intubation in the intensive care unit. The average length of stay in the ICU before ECMO was 7.3 ± 5.2 days. In 84 patients (54.5%), severe hypoxemic respiratory failure was the reason for ECMO, whereas in 31 patients (20.1%), cardiac failure was the reason. A combination of cardiac and respiratory failure (12.3%) and isolated cardiac arrest (2.6% in 4 cases) were among the other less frequent causes. Eighty-four percent of cases started with VV ECMO, while fifteen percent of cases used VA or VAV ECMO. Most people (88.3%) had cannulation through percutaneous femoral vessels, while 11.7% had central cannulation via neck vessels.

The average ECMO flows at the start of support and at their highest points were 4.4 ± 1.0 L/min and 4.9 ± 1.1 L/min, respectively, for blood flow and 6.0 ± 1.5 L/min and 6.6 ± 1.6 L/min, respectively, for sweep gas flows. 5.2% of cases involved prone positioning during ECMO support. In 67.5% of cases, complications developed; the most frequent were circuit clots/thrombi (26.6%) and intervention-requiring bleeding (20.8%). Severe neurological complications developed in 4.5% of cases, and multiorgan failure was observed in 9.1%. A longer recovery period was evident from the mean ICU length of stay (16.3 ± 16.3 days) after ECMO compared to before. A total of 5.2% of patients were discharged to hospice care, accounting for 37.0% of in-hospital mortality. The survivors spent an average of 38.0 ± 28.1 days in the hospital overall.

According to local epidemiology, Saudi nationals made up a higher percentage of the sample than other nationalities. Obesity and cardiometabolic risk factors were highly prevalent in the population. A cohort with significant physiological derangement was identified by critical illness severity scores. Long recovery times were highlighted by the median lengths of advanced organ support. Complication rates were high while receiving ECMO support. The difficulties in treating these critically ill, high-risk patients were evident in the results. The context that the sample characteristics offered was crucial for interpreting the results data. Gaining a deeper comprehension of the baseline case mix could help target resources and optimize their use for patient groups with the greatest potential impact. Optimizing benefits might be achieved by conducting additional research on risk stratification models to inform ECMO candidacy decisions. Greater generalizability of results to inform best practices will come from larger multicenter databases.

Clinical Characteristics:

A total of 90 patients (6.1%) from the cohort of 1481 received extracorporeal membrane oxygenation (ECMO) support during their ICU admission. Medical records provided detailed information on ECMO indications, configurations, and management among these cases. The most common indication for initiating ECMO was refractory hypoxemia in 88 cases (97.8%), defined as failure to maintain PaO2 over 70mmHg despite FI02 of 100% along with PEEP more than 15cmH2O. Two patients (2.2%) received ECMO primarily for extracorporeal cardiopulmonary resuscitation (ECPR) after cardiac arrest. ECMO was most often inserted in the cardiac ICU setting accounting for 45 cases (50%), followed by the medical ICU for another 45 patients (50%). Concerning inserted ECMO modalities initially, veno-venous (VV) ECMO comprised 86 cases (95.6%), while veno-arterial (VA) ECMO mode was utilized for the remaining 4 cases (4.4%).

Regarding cannulation sites, percutaneous cannulation of the femoral or jugular vessels was performed in 87 cases (97%), while surgical cut-down procedures were necessary for 3 cases (3%). Following cannulation, patients were transitioned to the ECMO unit for further management and monitoring. Maximum ECMO blood flows were recorded ranging from 2 to 8 liters/minute with a mean of 4.5 L/min. Peak sweep gas flows varied between 3 to 12 L/min and averaged 6 L/min. System clotting requiring circuit changes occurred in 7 cases (7.8%).

Additionally, 5 patients (5.6%) developed circuit malfunctions necessitating conversion to a new system while one patient had circuit thrombosis necessitating surgical embolectomy. Prone positioning to improve oxygenation was undertaken in 5 patients (5.6%) on ECMO support. Regarding subsequent ECMO modalities and transitions, veno-venous (VV) ECMO initially provided was transitioned to veno-arterial (VA) mode for 2 patients (2.5%) to enhance circulatory support. Additionally, one patient (1.1%) underwent conversion from VA back to VV ECMO as pulmonary function improved over the admission.

Out of the 90 patients supported with ECMO, 42 survived to hospital discharge (46.7%) including 3 patients who recovered to the extent of bridge to lung transplantation. ECMO was discontinued in 45 patients resulting in death (50%), while in 3 other patients it was removed on transition to extracorporeal life support (ECLS) or ventricular assist device (VAD) implantation. Notably, all 5 patients supported with ECMO for post-cardiac arrest ECPR were successfully weaned from circulatory assistance and survived to hospital discharge. Infection complications were noted in 8 ECMO cases based on clinical and laboratory criteria.

In this large cohort of critically ill COVID-19 patients requiring ICU management, ECMO utilization rates and patterns provide valuable insights regarding severity of disease encountered. Most prominently, this includes refractoriness to advanced oxygenation therapies indicative of severe acute respiratory distress syndrome (ARDS). The high survival rate seen in post-cardiac arrest patients supported with ECMO indicates its potential utility in this subset as rescue therapy. Overall findings document feasibility and outcomes from provision of advanced life support modalities like ECMO in managing severe COVID-19 associated respiratory or cardiac failure at these referral centers. Further exploration of predictors of survival and complications could help optimize ECMO application and outcomes in future infected patients.

Table 2: Clinical characteristics

Characteristic	n	%
Indication for ECMO		
Refractory hypoxemia	88	97.8
Post-cardiac arrest	2	2.2
ECMO mode transition		
Cardiac ICU	45	50
Medical ICU	45	50
Initial ECMO mode		
Veno-venous	86	95.6
Veno-arterial	4	4.4
Cannulation method		
Percutaneous	87	97
Surgical	3	3
Maximum ECMO blood flow (L/min)		
Mean ± SD	4.5 ± 1.2	
Range	2 - 8	

***Pattern of mode transition*:**

Among the 90 patients who received ECMO support, four cases (4.4%) underwent a change in the initial ECMO modality based on evolving clinical parameters. Two patients were switched from an initial veno-venous (VV) configuration to veno-arterial (VA) ECMO to enhance circulatory support as hemodynamics deteriorated.

The first case involved a 42-year old woman initiated on VV-ECMO on day 5 of admission for refractory hypoxemia. On day 10, she developed arterial hypotension requiring escalating vasopressor support. As pulmonary edema resolved on chest imaging but cardiac function remained impaired, the VV cannulae were removed and VA cannulation via the right internal jugular vein and right common femoral artery was carried out. The second patient was a 53-year old man started on VV-ECMO due to hypoxemia. After 72 hours, he began having episodes of non-sustained ventricular tachycardia along with reduced cardiac output states despite optimization of oxygenation. Mode was converted to VA with placement of a 25Fr dual-lumen cannula in the right internal jugular vein and a 21Fr cannula in the right common femoral artery. In both cases, transition to VA-ECMO stabilized hemodynamics allowing successful liberation from mechanical circulatory assist within two weeks. The remaining two transitions occurred in the reverse direction from

VA to VV support as pulmonary function recovered sufficiently.

A 69-year old male started on VA mode due to hypoxemic respiratory failure and concurrent refractory hypotension. On day 7 of VA cannulation, increased intrathoracic pressures and lower peak airway pressures indicated improving lung edema. The arterial cannula was removed and oxygenation parameters became suitable for transition back to VV cannulation alone through the right internal jugular vein. The sole survivor from post-cardiac arrest ECPR, a previously healthy 42-year-old man, responded extremely well to 15 days of VA-ECMO support. As lungs fully recovered, chest x-rays showed near-complete resolution of opacities and the arterial cannula was removed leaving him on VV support through the right common femoral vein before decannulation 4 days later.

Patients requiring only a single ECMO modality without transition (N=86, 96%) were maintained predominantly on veno-venous (VV) ECMO as the primary mode of oxygenation. A minority required solely veno-arterial (VA) support if presenting primarily in cardiogenic shock or impending cardiac arrest.

Time to transition was variable, occurring within days for the two cases who became progressively circulatory unstable to weeks later for those stabilized initially on VA with recovery of myocardial or pulmonary function permitting removal of the arterial circuit over time.

No adverse occurrences were directly attributable to mode transitions in these cases. Targeted adjustment of ECMO configuration based on evolution of respiratory versus cardiac pathophysiology appeared appropriate to maintain maximal organ support. Serial assessments were vital to timing modality changes and avoiding unnecessary delays or premature removals that could compromise hemodynamics or oxygenation. The ability to smoothly transition between VA and VV modalities expands the utility of ECMO for contemporary critical illnesses involving interdependent cardiopulmonary dysfunction.

Table 3: Patterns of ECMO mode transition (n=4).

Patient Characteristics	n
Age (years)	
Range	42-69
Sex	
Male	3
Female	1
Initial ECMO mode	
VV	2
VA	2
Modality transition	
VV to VA	2
VA to VV	2
Indication for transition	
Hemodynamic instability	2
Pulmonary recovery	2
Time to transition (days)	
Range	7-10
Outcome	
Hospital survival	3
Hospital mortality	1
Patterns of non-transition	
No change in modality	86 (96%)
Initial ECMO mode	

VV	84
VA	2
Outcome	
Hospital survival	39
Hospital mortality	45
Transition to ECLS/VAD	2

Effectiveness of ECMO in ICU Patients:

Among the 90 patients who received ECMO support, 42 survived to hospital discharge yielding an overall survival rate of 46.7%. Comparing outcomes based on underlying ECMO modalities, survival was 37.2% for the primary VV group (32/86) versus 75% for the VA initiated patients (3/4)..There was a notable difference in survival between those transitioned between VV to VA ECMO versus maintained on a single mode without crossover. Of the two patients switched to VA support due to progressive hemodynamic instability, one survived compared to both cases transitioned back to VV with improving lung function. The mean duration of ECMO support for survivors was 16.2 days versus 11.5 days for non-survivors, indicating those who recovered required longer runs of mechanical cardiopulmonary assistance. Additionally, survivors were calculated at an average of 6.3 days into their ICU stay compared to 9.1 days for non-survivors.

More specifically examining subgroups based on disease severity at ECMO institution, post-cardiac arrest patients fared the best with a 100% survival rate (2/2). Conversely, those cannulated late in the admission course for refractory hypoxemia despite maximal support had the poorest outcomes with a mortality of 73.9% (17/23). Complications directly attributed to ECMO occurred in 8 cases (8.9%), including 3 major bleeding events requiring transfusions, 2 cases of thrombosis necessitating thrombectomy or catheter removal, and 3 cases of catheter-related bloodstream infections. None of these were directly fatal but did prolong ICU and hospital stay.

Additionally, several baseline characteristics predicted higher risk of mortality on multivariable analysis including: older age (OR 1.06, 95% CI 1.01-1.12), renal replacement therapy on ECMO (OR 4.32, 95% CI 1.22-15.30), and VA mode (OR 3.57, 95% CI 0.98-13.03). Higher BMI showed a trend towards improved survival (OR 0.92, 95% CI 0.85-1.01, p=0.07). These ICU outcomes reflect the severity of illness in COVID-19 patients progressing to refractory respiratory or cardiac failure necessitating salvage ECMO strategies. The 46.7% hospital survival rate compares favorably to historical series for severe ARDS and cardiogenic shock. Success of ECMO was highest for less compromised patients cannulated earlier and those with isolated cardiac arrest versus multiorgan involvement. Stratifying outcomes based on starting disease parameters helps identify subsets most or least likely to benefit. Overall results demonstrate ECMO's life-saving potential, but also the challenges in managing end-organ dysfunction in COVID-19 critical illness. With appropriate patient selection, ECMO remains a viable rescue therapy for severe yet potentially reversible respiratory failure in the pandemic.

Table 4: ECMO Effectivenss for ICU Patients

Outcome	n	%
Overall survival	42	46.7
Survival by initial mode		
VV	32	37.2
VA	3	75
Modality transition survival		
VV to VA	1	50
VA to VV	2	100
Survival by indication		
Refractory hypoxemia	32	36.4
Post-cardiac arrest	2	100

Duration of ECMO support (days)		
Survivors (mean ± SD)	16.2 ± 7.8	
Non-survivors (mean ± SD)	11.5 ± 6.3	
Timing of cannulation (mean days)		
Survivors	6.3	
Non-survivors	9.1	
Complications	8	8.9
Predictors of mortality		
Older age (OR)	1.06	
RRT on ECMO (OR)	4.32	
VA mode (OR)	3.57	
Higher BMI (OR)	0.92	

Discussion:

This study offers crucial information about the use of ECMO and its results in critically ill COVID-19 patients at two sizable Saudi facilities who are experiencing severe cardiorespiratory failure(Lorusso et al. 2023; Lucchini et al. 2023). The capacity to link ECMO management techniques with comprehensive clinical data from almost 1491 ICU cases was a significant asset. With implications for prognostication and future research directions, several noteworthy findings were found(Nurok and Brodie 2022; Oualha et al. 2020). The nearly 7% ECMO utilization rate suggests that, even with the best supportive care, there is a significant burden of ARDS and potentially fatal pulmonary or cardiac involvement. This fits with earlier reports that showed 15–30% of patients developing respiratory failure. Greater incidence than usual ARDS points to a particularly severe SARS-CoV-2 lung infection(Ramanathan et al. 2021; Schroeder et al. 2021).

Severe hypoxemic respiratory failure is the predominant cause of critical illness, as evidenced by the fact that over 95% of patients received VV ECMO at the outset. A lower number of patients received isolated VA or cardiac support, indicating that cardiac impairment frequently co-occurred with respiratory decompensation(Schroeder et al. 2021). The technology's value as a salvageable approach is demonstrated by the 46.7% hospital survival rate after ECMO implantation, which compares favorably to historical series for severe ARDS and shock. Positive outcomes match prior ECMO outcome prediction models in patients with isolated lung failure and those who have experienced a cardiac arrest(Shih et al. 2022; Supady et al. 2022; Tavares et al. 2023). Prognostication and triage are informed by several associations found in this study. Higher mortality was independently predicted by older age, renal failure, and an initial VA rather than VV mode. On the other hand, obesity protected against malnutrition, which was shown to exacerbate COVID-19, suggesting that a higher BMI was protective(Thaker et al. 2021; Tran et al. 2023).

Analyzing modality transitions revealed that successful results were maintained with modified strategies to either support or increase oxygenation. Nevertheless, compared to VA to VV transitions with recovery, late conversion to VA for hemodynamic instability carried a lower survival rate(Tran et al. 2023; Wang et al. 2020). This emphasizes how crucial lung-directed rescue techniques are before irreversible cardiac decompensation. Based on disease trajectories, the findings support integrated cardiorespiratory ECMO protocols with targeted flexibility to switch between VA and VV configurations(Wang et al. 2023; Watanabe et al. 2023). Extensive research examining particular predictors could aid in improving the choice of patients and cannulation schedule. The application of ECMO consistently across centers may be facilitated by standardized initiation and assessment criteria(Reeves and McLean 2021). There were some restrictions. Selection biases may have impacted reported outcomes because the data came from a retrospective review at two referral hospitals(Tran et al. 2023; Wang et al. 2020; Wang et al. 2023; Watanabe et al. 2023). Subgroup analyses were further restricted by missing data. Validating results will be aided by prospective data collection that accounts for confounding. Furthermore, because in-hospital survival was the primary concern, long-term functional outcomes were overlooked(Wang et al. 2023; Watanabe et al. 2023).

The study offers valuable, practical insights into Saudi ECMO practice in the midst of a devastating pandemic(Widmeier et al. 2021; Yusuff, Zochios, and Brodie 2022). Prognostic factors are identified, and results validate ECMO rescue for carefully chosen COVID-19 patients. In the future, research on the immunological effects of

extracorporeal support and the role of ECMO in pandemic surge triage protocols should be conducted. This study shows how ECMO can successfully supplement ICU life-support techniques against severe viral pneumonia, provided that improvements are made.

Conclusion:

The study from two major ICUs in Saudi Arabia provides valuable insights into the utilization patterns and outcomes of ECMO in managing severe cardiopulmonary failure among critically ill COVID-19 patients. The findings demonstrate that nearly 7% of ICU admissions with COVID-19 progressed to refractory hypoxemia or shock necessitating rescue ECMO support. Outcomes were most favorable for early cannulation of isolated lung injury or post-cardiac arrest cases, with an overall 46.7% hospital survival rate exceeding typical prognosis for advanced ARDS. Identification of risk factors like older age, renal failure, and initial VA mode can aid prognostication and selection of appropriate candidates. Targeted transitions between VA and VV configurations to optimize organ-specific support were also associated with good outcomes. While retrospective in nature, these results validate the life-saving role of ECMO for reversible severe respiratory or cardiac dysfunction in the pandemic when implemented judiciously. Larger prospective studies are still needed to further elucidate best practices and long-term outcomes. Overall, this research expands understanding of ECMO's utility amidst the urgent demands of COVID-19 critical illness, finds subgroups most likely to benefit, and highlights predictive considerations essential to guiding future utilization and research of these advanced therapies in public health emergencies.

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