Turkish Archives of Pediatrics

ORIGINAL ARTICLE
DOI: 10.5152/TurkArchPediatr.2023.23025

Venovenous Versus Venoarterial Extracorporeal Membrane Oxygenation: Pediatric Acute Respiratory Distress Syndrome

Fevzi Kahveci[1], Gülçin Karaçoban[2], Nur Ayça Çelik[2], Anar Gurbanov[1], Hacer Uçmak[1], Hasan Özen[1], Burak Balaban[1], Edin Botan[1], Nur Dikmen[3], Merve Havan[1], Mehmet Gökhan Ramoğlu[4], Zeynep Eyileten[3], Tayfun Uçar[4], Tanıl Kendirli[1]

[1]Division of Pediatrics, Department of Pediatric Intensive Care, Ankara University Faculty of Medicine, Ankara, Turkey
[2]Department of Pediatrics, Ankara University Faculty of Medicine, Ankara, Turkey
[3]Department of Cardiovascular Surgery, Ankara University Faculty of Medicine, Ankara, Turkey
[4]Division of Pediatrics, Department of Pediatric Cardiology, Ankara University Faculty of Medicine, Ankara, Turkey

What is already known on this topic?

- *The main indication for venovenous (VV) extracorporeal membrane oxygenation (ECMO) in children is pediatric acute respiratory distress syndrome (PARDS).*
- *When cannulation techniques are ranked from high survival to low survival in hospital, double-lumen VV ECMO was found in 70%, 2-catheter VV ECMO in 66%, and venoarterial (VA) ECMO in 51%.*

What this study adds on this topic?

- *History of continuous renal replacement therapy and chronic disease, pH values before ECMO cannulation, and lactate values measured in the first 6 hours after ECMO cannulation were found to be associated with mortality.*
- *The highest survival rate was found in the VV ECMO patient group established with double-lumen cannulas similar to the literature.*

ABSTRACT

Objective: This study aimed to compare the efficacy, complication, and mortality of patients who were supported by venovenous (VV) extracorporeal membrane oxygenation (ECMO) and venoarterial (VA) ECMO for pediatric acute respiratory distress syndrome (PARDS).

Materials and Methods: This study is a single-center, retrospective cohort study between 2014 and 2022. We evaluated to indication of ECMO support, ECMO type, patients' demographic features, complications, and children's outcomes supported by ECMO for PARDS.

Results: Twenty-two patients with PARDS, 12 (54%) with VV, and 10 (46%) with VA ECMO were selected. The median number of days to be intubated before ECMO cannulation was 5 (0-16) days. The distribution of intubated days before the patients underwent ECMO was as follows: 0-1 days, 7 (31.8%) patients; 2-3 days, 2 (9.1%) patients; 4-7 days, 7 (31.8%) patients; 8-14 days, 5 (22.8%) patients; >14 days, 1 (4.5%) patient. The median ECMO cannulation day after admission to the pediatric intensive care unit was 3 (range, 1-9) days in the VV ECMO patient group, whereas it was 8 (range, 0-19) days in the VA ECMO group (P = .02). Considering hospital survival, 4 (45%) patients who underwent double-lumen VV ECMO, 1 (33%) patient who underwent VV ECMO, and 3 (30%) patients who supported by VAECMO survived. There was no difference between the groups in terms of hospital discharge rates.

Conclusion: The highest survival rate was found in the VV ECMO patient group established with double-lumen cannulas, similar to the literature. There was no difference in mortality between the groups whose intubation time before ECMO was 14 days or less.

Keywords: Children, ARDS, extracorporeal membrane oxygenation, pediatric intensive care, VV versus VA

INTRODUCTION

Extracorporeal life support (ECLS) has an indispensable place in modern invasive support systems. Extracorporeal membrane oxygenation (ECMO) is 2 types according to the type of support needed: venovenous (VV) ECMO and venoarterial (VA) ECMO. VV ECMO is preferred in cases of respiratory failure, while VA ECMO may be preferred according to the existing cardiac failure.[1,2] The main indication for VV ECMO in children is pediatric acute respiratory distress syndrome (PARDS). Also, respiratory ECMO support can be delivered by venopulmonary (VP) cannulation.[3]

PARDS is defined as the development of hypoxia with newly developing infiltration on chest x-ray in the last 7 days.[4] The etiology of PARDS includes infection, direct lung injury,

Corresponding author:
Fevzi Kahveci
✉ fevziikahvecii@gmail.com
Received: February 24, 2023
Accepted: August 16, 2023
Publication Date: October 6, 2023

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Cite this article as: Kahveci F, Karaçoban G, Çelik NA, et al. Venovenous versus venoarterial extracorporeal membrane oxygenation: Pediatric acute respiratory distress syndrome. *Turk Arch Pediatr.* 2023;58(6):600-606.

aspiration of gastric contents, and other causes.[4] The Berlin criteria established for adult acute respiratory distress syndrome (ARDS) in 2011 show differences in disease patterns and etiologies in children. Khemani et al[5] (the PALICC group) made some adjustments for PARDS; the changes were made in 3 items: using pulse oximetry if PaO_2 cannot be used, using oxygen index (OI) and oxygen saturation index (OSI) instead of PaO_2/FiO_2 (PF), and pulmonary parenchymal disease instead of bilateral infiltration on chest x-ray. In their study, PARDS affected 3% of 145 patients in the pediatric intensive care unit (PICU), with a mortality rate of 30% due to hypoxia and 30% due to neurological damage.[2] López-Fernández et al[6] reported the incidence of PARDS as 9.5/10 000 case years. In PARDS, when oxygenation is severely impaired or the patient is predicted to deteriorate rapidly, support with ECMO within 14 days of disease onset should be considered.

There are few studies comparing VV and VA ECMO survival, complications, and efficacy in patients with PARDS. In this study, we aimed to evaluate the clinical features, complications, and outcomes of patients who were supported by VV or VA ECMO in our PICU for PARDS.

MATERIALS AND METHODS

Setting

This study was conducted in the PICU of Ankara University Faculty of Medicine. In our PICU, intensive care services are provided to patients in internal and surgical departments, and approximately 700 patients are followed up annually. Our PICU is a combined unit, offering both pediatric critical care and cardiac critical care. Our center is a pediatric heart transplant center and is a reference center in this field. A mean of 100 congenital cardiac surgeries were performed and 20 patients were supported by ECMO annually in our clinical center. This retrospective was approved by the Ethics Committee of Ankara University Faculty of Medicine (ethics committee number I09-568-22). Before the procedures, patients were informed about the procedural risks and therapeutic benefits. Written informed consent was obtained from all patients' relatives or legal authorities when necessary. Our study was conducted in accordance with the ethical principles of the World Medical Association Declaration of Helsinki.

Study Population and Protocol

This study was conducted by scanning the files of all patients diagnosed as having PARDS who underwent ECMO in our PICU of a university hospital between January 2014 and January 2022. The study was a retrospective, single-center study.

Intervention and Extracorporeal Membrane Oxygenation Circuit

In our study, patients are supported by VV ECMO with a VIS of <50 if there is no accompanying organ failure. In patients with 50< Vasoactive Inotrope Score (VIS) <100, VV ECMO or VA ECMO support is given considering the accompanying organ failure. VA ECMO is considered in the foreground in patients with a VIS of >100 and in whom cardiac decompensation is not predicted to improve with VV ECMO and who do not have cardiac decompensation caused by the oxygenation problem. In our clinic, the most common sites for peripheral ECMO cannulation for establishing are the femoral artery, femoral vein, internal jugular vein, and arteria carotis communis. With peripheral femoral cannulation, distal perfusion ipsilateral to the femoral artery cannulation is used. All patients were performed surgical ECMO cannulation by a cardiac surgeon. The ECMO circuit element used in this study was a continuous flow centrifugal pump (JostraRotaflow®; Maquet Cardiopulmonary, Rastatt, Germany or Stockert Instrumente GmbH, Munich, Germany), a hollow fiber oxygenator (JostraQuadrox; Maquet Cardiopulmonary, Rastatt, Germany), and a polymethylene membrane (Dideco, Sorin Group, Mirandola, Italy).

Follow-up

Demographic and clinical data of all study patients were recorded on study-specific forms. In this form, the patient's age, sex, weight, diagnosis, reason for admission to the PICU, ECMO indication, Pediatric Risk of Mortality score (PRISM III), and Pediatric Logistic Organ Dysfunction Score 2 (PELOD 2), Pediatric-Risk Estimates Score for Children Using Extracorporeal Respiratory Support (Ped-RESCUERS),[7] pediatric sequential organ failure assessment (pSOFA) scores, and Vasoactive Inotrope Score (VIS)[8] were used. ECMO type VISs were recorded before undergoing ECMO. The number of days the patient received ECMO, the ECMO mode, plasma exchange (PEX) usage (in case of multiple-organ dysfunction syndrome), the number of days to be intubated before ECMO, the last ventilator mode without ECMO, the use of nitric oxide (NO) usage (in cases of pulmonary hypertension or pulmonary hypertensive crisis that cause clinical deterioration in echocardiographic evaluation by cardiology), the indication of ECMO, and the presence of chronic lung disease was recorded.

Complications observed during ECMO, ECMO circuit problems (thrombosis, oxygenator malfunction, and membrane lung failure) were recorded. Changes in ventilator settings, vitals, and blood gas parameters were recorded before undergoing ECMO. Blood gas parameters within the first 6 hours of ECMO were recorded. Thrombocytopenia was defined as <150 000 cells/mL. Hemolysis was considered in the case of free hemoglobin, hematuric urine, and elevated lactate dehydrogenase values.

Statistical Analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS) version 25.0 software package (IBM Corp, Armonk, NY, USA). Mean, SD, median, frequency distribution, and percentage values were determined as descriptive statistics of the variables. Mean values were used in parametric tests, and median values were used in nonparametric tests. Pearson's chi-square test and Fisher's exact test were used to analyze categorical variables. The data were tested for normal distribution using visual (histogram and probability graphs) and analytical methods (Kolmogorov–Smirnov/Shapiro–Wilk tests). The independent samples *t*-test was used to analyze differences in normally distributed variables between 2 independent groups. Mann–Whitney *U* test was used for nonparametric data, and the results were given as median (minimum, maximum). A *P*-value of <.05 was considered statistically significant.

RESULTS

Patients' Demographic Data in the Overall Extracorporeal Membrane Oxygenation Group (22 Patients)

In our study, there were a total of 22 patients with PARDS, 12 (54.5%) with VV and 10 (45.5%) with VA ECMO. The median age of the patients was 10.5 (range, 1-212) months. The median number of days of being intubated before ECMO cannulation was 5 (range, 0-16) days. On the day of ECMO cannulation, the median day of hospitalization in the PICU was 5 (range, 0-19). Eight (36.4%) of the patients had vena jugularis interna–arteria carotis communis, 9 (40.9%) had vena jugularis interna double-lumen cannulas, 3 (13.6%) had femoral vein–femoral vein cannulas, and 2 (9.1%) patients had femoral artery–femoral vein ECMO cannulations. In the etiology of PARDS, 19 (86.3%) patients had pneumonia, 2 (9.1%) had sepsis, and 1 (4.5%) had food aspiration.

Before ECMO cannulation, 12 (54.5%) patients were in pressure-controlled synchronized intermittent mandatory ventilation (P-SIMV) mode, 3 (13.6%) were in pressure-regulated volume control (PRVC) mode, 2 (9.1%) were in volume-controlled synchronized intermittent mandatory ventilation (V-SIMV), 17 (77.3%) were in conventional mechanical ventilation mode, and 5 (22.7%) were in high-frequency oscillation (HFO) mode. The distribution of intubated days before the patients underwent ECMO was as follows: 0-1 days, 7 (31.8%) patients; 2-3 days, 2 (9.1%) patients; 4-7 days, 7 (31.8%) patients; 8-14 days, 5 (22.8%) patients; >14 days, 1 (4.5%) patient (Figure 1).

Respiratory Polymerase Chain Reaction Results of Patients Who Were Supported by Extracorporeal Membrane Oxygenation

When the respiratory tract viral and bacterial polymerase chain reaction (PCR) growths of the patients who underwent VV ECMO were examined, PCR was negative in 3 (25.0%) patients, respiratory syncytial virus (RSV) A and B were positive in 2 (16.6%) patients, parainfluenza virus type 3 was positive in 2 (16.6%) patients, and 1 (8.3%) patient was Klebsiella pneumoniae positive. One (8.3%) patient had multiple growths: influenza type A, human metapneumovirus A and B, bocavirus, *Mycoplasma pneumoniae*, and *Streptococcus pneumoniae*. Multiple growths of another single (8.3%) patient were *Haemophilus influenzae*, H1N1, and human metapneumovirus A and B. A further single patient (8.3%) had multiple growths of rhinovirus and *Staphylococcus aureus*. Considering the respiratory viral and bacterial PCR growths of the patients who underwent VA ECMO, 5 (50.0%) patients had negative PCR results, 1 (10.0%) had *Staphylococcus aureus*, 1 (10.0%) had rhinovirus, and 1 (10.0%) had parainfluenza virus type 1. Respiratory PCR was negative in 4 (50.0%) patients in the surviving group, and the respiratory PCR was negative in 4 (28.6%) patients in the deceased group. Four (66.7%) of the multiple growths were in the group of patients who died.

A Comparison of the Characteristics of Venovenous Extracorporeal Membrane Oxygenation and Venoarterial Extracorporeal Membrane Oxygenation

The median number of PEX sessions performed in the VA ECMO group was 0 (range, 0-6) and was found to be statistically significant between the VA ECMO group and the VV ECMO group (P = .047). Considering the number of days of follow-up of the patients under ECMO, the median follow-up on VV ECMO was 9.5 (range, 2-35) days, and the median follow-up days on VA ECMO was 15.5 (range, 1-56) days (P = .46). There was no difference between the pre-ECMO ventilator parameters, peak inspiratory pressure, and positive end-expiratory pressure (PEEP), between the VV and VA ECMO groups (P = .52 and P = .36, respectively). The median pH value in blood gas measured within the first 6 hours after ECMO cannulation was 7.4 (range, 7.35-7.68) in the VV ECMO group, and 7.4 (range, 7.1-7.52) in the VA ECMO group (P = .01) (Table 1).

A Comparison of the Patient Groups According to Complications and Outcomes

The mean day of hospitalization in the PICU was 24.3 ± 20.2 in the VV ECMO group and 43.5 ± 43.6 in the VA ECMO group (P = .32). Seven (58.3%) patients who were followed up on VV ECMO died, and 7 (70.0%) patients followed up on VA ECMO died (P = .67). There was no difference between the groups in terms of hospital discharge rates (P = .16) (Table 2).

A Comparison of the Characteristics of Survivors and Non-Survivors Among Patients Supported by ECMO

The Ped-RESCUERS score and the mortality estimates of the patients were not statistically significant between the groups

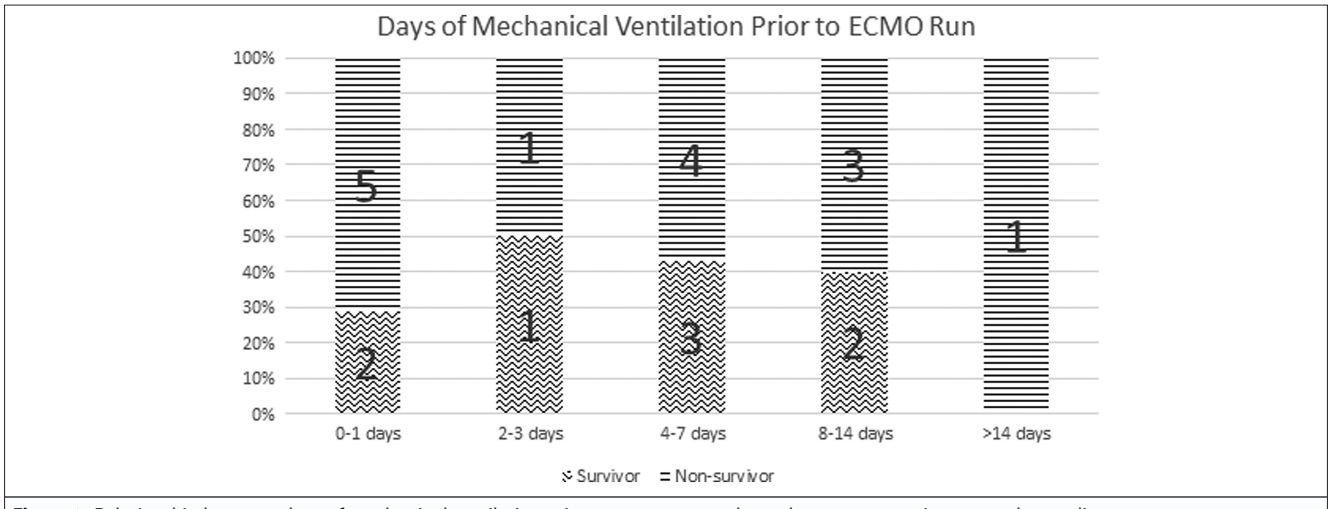


Figure 1. Relationship between days of mechanical ventilation prior to extracorporeal membrane oxygenation run and mortality.

Table 1. Comparison of Characteristics of Venovenous Extracorporeal Membrane Oxygenation and Venoarterial Extracorporeal Membrane Oxygenation

Patient Characteristic Median (IQ range), n (%)	Total (n = 22)	VV ECMO (n = 12)	VA ECMO (n = 10)	*P*
Age, months	10.5 (1-212)	10.5 (5-212)	14.5 (1-183)	.8*
Sex, female	11 (50%)	7 (58%)	4 (40%)	.39**
Indication, pneumonia	17 (77%)	10 (83%)	7 (70%)	.62**
Number of days to be intubated PE	5 (0-16)	2 (0-9)	7.5 (1-16)	**.004***
ECMO cannulation day	5 (0-19)	3 (1-9)	8 (0-19)	**.02***
PE MV mode, conventional	17 (77%)	10 (83%)	7 (70%)	.62**
Ped-RESCUERS score	−0.3 ± 0.57	−0.5 ± 0.5	−0.06 ± 0.5	.05***
Ped-RESCUERS prediction mortality	42.5 ± 12.6	37 ± 12.2	48 ± 11.3	.05***
VIS	32.5 (0-366)	29.1 ± 32	90 ± 108	.09*
PRISM III score	16.4 ± 8.9	14.5 ± 5.8	18.7 ± 10.9	.26***
PELOD score	17 (8-58)	11 (10-30)	21 (8-58)	.3*
pSOFA score	11.5 ± 2.7	11 ± 2.4	12.2 ± 2.9	.3***
Milrinone usage	7 (31%)	3 (25%)	4 (40%)	.65**
Chronic lung disease	8 (36%)	4 (33%)	4 (40%)	.999**
NO usage	12 (54%)	7 (58%)	5 (50%)	.999**
CRRT, usage	10 (45%)	5 (41%)	5 (50%)	.51**
PEX, usage	3 (13%)	0	3 (30%)	.078**
PEX, sessions	0 (0-6)	0	0 (0-6)	**.047***
Prematurity	8 (36%)	5 (41%)	3 (30%)	.67**
Genetic anomaly	3 (13%)	1 (8%)	2 (25%)	.57**
Tracheostomy	2 (9%)	0	2 (20%)	.19**
Prone position	9 (40%)	5 (41%)	4 (40%)	.999**
Pneumothorax	7 (31%)	3 (25%)	4 (40%)	.65**
ECMO, days	10.5 (1-56)	9.5 (2-35)	15.5 (1-56)	.46*
Pre-cannulation mechanic ventilator settings				
Peak pressure	32 (28-44)	32 (28-44)	32 (28-36)	.52*
PEEP	10 (6-12)	10 (6-12)	10 (6-10)	.36*
Pre-cannulation laboratory values				
pH	7.30 (6.82-7.48)	7.29 (6.82-7.48)	7.30 (6.90-7.45)	.84*
PCO_2 (mm Hg)	45 (21-217)	58 (31-217)	45 (21-65)	.08***
Lactate (mmol/L)	5.6 (1-27)	5.1 (1-19)	7.2 (1.7-27)	.32*
Creatinine (mg/dL)	0.33 (0.1-0.9)	0.24 (0.1-0.9)	0.48 (0.13-0.87)	.09*
After ECMO cannulation laboratory values (first 6 hours)				
PH	7.42 (7.10-7.68)	7.4 (7.35-7.68)	7.4 (7.1-7.52)	**.01***
PCO_2 (mm Hg)	36 (22-79)	36 (22-50)	37 (27-79)	.12*
Lactate (mmol/L)	4.9 (1.2-19)	4.4 (1.3-19)	5.1 (1.2-17)	.5*

CRRT, continuous renal replacement therapy; ECMO, extracorporeal membrane oxygenation; MV, mechanic ventilation; NO, nitric oxide; PE, pre-ECMO; Ped-RESCUERS, pediatric risk estimate score for children using extracorporeal respiratory support; PELOD, pediatric logistic organ dysfunction; PEX, plasma exchange; PICU, pediatric intensive care unit; PRISM III, pediatric risk of mortality; pSOFA, pediatric sequential organ failure assessment; VA, venoarterial; VIS, vasoactive inotropic score; VV, venovenous.

*Mann-Whitney *U* test.**Fisher exact test.***Independent samples *t*-test.Bold numbers are statistically significant.

(*P* = .79 and *P* = .84, respectively). A statistically significant difference was found between the survivor and non-survivors in favor of the non-survivor group regarding PRISM III scores, PELOD 2 scores, pSOFA scores, chronic lung disease, and whether continuous renal replacement therapy (CRRT) was used (*P* = .02, *P* = .009, *P* = .02, *P* = .02, and *P* = .03, respectively). The pH value of the patients before ECMO cannulation and the lactate values measured in the first 6 hours after ECMO cannulation were found to be significantly different between the groups (*P* = .02 and *P* = .009, respectively). In our study, no difference was found between VV ECMO, VA ECMO, and double-lumen VV ECMO cannulas using double catheters in terms of hospital survival and mortality in ECMO (*P* = .35 and *P* = .6, respectively). Considering hospital survival, 5 (55%) patients who underwent double-lumen VV ECMO, 2 (66%) patients who underwent VV ECMO, and 7 (70.0%) patients who underwent VA ECMO died (Table 3).

DISCUSSION

Although VV ECMO improves lung perfusion and systemic oxygenation, it seems more benign because it does not increase cardiac afterload and decreases cerebral blood flow.[9] If a patient needs a low-dose inotropic agent or vasopressor, VV ECMO can also be started initially.[10] Or, if a patient with respiratory failure needs a high inotropic agent, VA ECMO can be started and then converted to VV ECMO.[9] No relationship was found between the

Table 2. Comparison of Patient Groups According to Complications Versus Outcomes

Patient Characteristics, n (%)	Total (n = 22)	VV ECMO (n = 12)	VA ECMO (n = 10)	*P*
Bleeding	14 (63%)	7 (58%)	7 (70%)	.67*
Thrombosis	7 (31%)	4 (33%)	3 (30%)	.999*
Thrombocytopenia	15 (68%)	8 (66%)	7 (70%)	.999*
Sepsis	11 (50%)	6 (50%)	5 (50%)	.999**
Seizure	3 (13%)	0	3 (30%)	**.04***
Embolism	1 (4%)	0	1 (10%)	.45*
Circulatory disorder (%)	6 (27%)	1 (8%)	5 (50%)	*.05***
Hemolysis	4 (18%)	0	4 (40%)	**.02***
Air entering the ECMO (%)	5 (22%)	0	5 (50%)	**.01***
Intracranial hemorrhage (%)	1 (4%)	0	1 (10%)	.45*
Number of set changes	0 (0-5)	0 (0-4)	1 (0-5)	.15***
Set problem	10 (45%)	4 (33%)	6 (60%)	.39*
Pneumothorax while ECMO run (%)	7 (31%)	3 (25%)	4 (40%)	.38
Awake ECMO (%)	3 (13%)	1 (8%)	2 (20%)	.57*
Tracheostomy (%)	2 (9%)	0	2 (20%)	.195*
PICU days	26 (1-127)	20 (4-71)	28 (1-127)	.32***
28-day mortality (%)	14 (63%)	8 (66%)	6 (60%)	.999*
Mortality during ECMO (%)	14 (63%)	7 (58%)	7 (70%)	.67*
Hospital mortality (%)	16 (72%)	7 (58%)	9 (90%)	.16*

ECMO, extracorporeal membrane oxygenation; PICU, pediatric intensive care unit; VA, venoarterial; VV, venovenous.
*Fisher exact test. **chi-square test.***Mann–Whitney *U* test.Bold numbers are statistically significant.

cannulation type and mortality in patients who needed inotropes.[11,12] In adults, the survival rate and discharge rate in ARDS were higher in the VV ECMO group than in the VA ECMO group, but complication rates were similar. There are almost no studies examining the results, complications, and mortality rates between VV ECMO and VA ECMO due to PARDS in children.

In the study by Jaber et al,[13] which retrospectively examined the data of 103 pediatric patients followed on VV and VA ECMO due to PARDS, 55% of patients were followed on VV ECMO. Patients on VV ECMO received more NO therapy and had a higher oxygenation index (median 41.5 vs. 19.5). In the study, VA ECMO cannulation was performed if there were severe cardiac dysfunction and cardiac arrest before ECMO. In univariate analyses, the rate of hospital discharge was found to be significantly higher in the VV ECMO group than in the VA ECMO group (72% vs. 44%, *P* = .005). However, in multivariate models, cannulation type was associated with cardiopulmonary resuscitation and not independently with survival. The number of days of stay on VV ECMO was higher than the number of days of stay on VA ECMO, and the length of PICU stay and total hospital stay was similar (median, 7 vs. 4.5 days; *P* = .036). There was no difference between functional outcomes and comorbidities at discharge. In multivariate models, cardiopulmonary resuscitation before ECMO cannulation was associated with ECMO type selection and survival.[13] In our study, the median number of follow-up days was higher in the VA ECMO group than in the VV ECMO group. The median PICU stay was longer in the VA ECMO group in our study.

In Kon et al[12] study of 717 adult patients with ARDS, 591 received VV ECMO and 126 had VA ECMO support. The conversion rate from VV ECMO to VA ECMO was 4%. VV ECMO was associated with less gastrointestinal bleeding and hemolysis, and the rates of bleeding, stroke, and renal failure were similar between the 2 modalities. In neonatal and pediatric studies, VA ECMO has been associated with increased neurologic damage, stroke, and bleeding compared with VV ECMO. When hospital discharge rates were compared in Kon et al[12] studies, the rate for VV ECMO was 58% and VA ECMO was 43% (*P* = .002). In multivariate analyses, being on VV ECMO was found to be an independent factor for hospital discharge. In our study, seizures and hemolysis were more common in patients undergoing VA ECMO than in the patients on VV ECMO.

In our study, PRISM III, PELOD 2, and pSOFA scores were found to be significantly higher in the deceased group. These scoring systems are for the general patient population admitted to the PICU. Although disease severity and mortality estimation scores based on the first 24 hours of intensive care admission are widely used, these scoring systems have not been validated in patients who followed up on ECMO. When Pinto et al[14] retrospectively evaluated the data of 655 patients aged under 18 years who underwent ECMO in the 4-year PEDECOR study, PRISM III and PELOD scores were not associated with mortality. In the retrospective validation study conducted by Barbaro et al[7] with 2458 patients admitted to ECMO for respiratory indication, the mortality rate was found as 39.8%. The data set developed in 1611 pediatric patients was developed by conducting a validation study on 438 patients. The area under the curve (AUC) of the Ped-RESCUERS Bayesian logistic regression model in the development dataset was 0.690 and the AUC of the validation dataset was 0.634.[7] Contrary to what we expected when we applied the Ped-RESCUERS scoring system to the patients in our study, we found that the Ped-RESCUERS score and mortality markers were not associated with mortality.

Due to the fact that double-lumen ECMO cannulae have not been available in our country in recent years, VV ECMO setup cannot be performed on young children and infants, patients who need to be taken to VV ECMO due to PARDS should be followed up with VA configuration ECMO cannulation. Despite the VA ECMO configuration for some infants who are more suitable for VV ECMO due to problems with equipment supply in recent years, and although the disease severity and organ dysfunction scores of the patients who were taken to VA ECMO in our study group were higher, no correlation was found between the 2 groups regarding mortality. The number of days of hospitalization in the PICU under ECMO was found to be higher in patients in VA ECMO than in patients who were followed up on VV ECMO. Similar to the literature, seizures and hemolysis were statistically significantly higher in patients followed under VA ECMO.[15,16] We thought that these 2 complications were related to the application of arterial cannulation and concomitant multiorgan failure in the majority of the patients, respectively. Continuous renal

Table 3. Comparison of the Characteristics of Survivors and Non-Survivors in Patients Undergoing Extracorporeal Membrane Oxygenation

Patient Characteristic Median (IQ range), n (%)	**Total (n = 22)**	**Survivors (n = 8)**	**Non-survivors (n = 14)**	***P***
ECMO, days	10.5 (1-56)	20.5 (4-56)	8.5 (1-38)	.035**
Age, months	10.5 (1-212)	11.5 (5-183)	10.5 (1-212)	.999**
Age, <12 months	12 (54%)	4 (50%)	8 (57%)	.54***
VV ECMO usage	12 (54%)	5 (62.5%)	7 (50%)	.67***
VV ECMO usage	3 (14%)	1 (12.5%)	2 (15%)	.6****
VA ECMO usage	10 (46%)	3 (37.5%)	7 (50%)	
DL VV ECMO usage	9 (40%)	4 (50%)	5 (35%)	
Number of days intubated PE	5 (0-16)	5.5 (1-13)	4.5 (0-16)	.73**
ECMO cannulation day	5 (0-19)	5.5 (1-13)	4.5 (0-19)	.75**
Malignancy	5 (22%)	2 (25%)	3 (21.4%)	.999***
Milrinone usage	7 (31%)	5 (62.5%)	2 (14%)	.052***
VIS	32.5 (0-366)	12.5 (0-140)	42.5 (0-366)	.27**
PRISM III score	16.4 ± 8.5	12 ± 3.5	18.9 ± 9.6	**.02***
PELOD II score	17 (8-58)	11 (8-21)	25 (10-58)	**.009****
pSOFA score	11 (7-17)	10 (7-12)	13 (7-17)	**.029****
Chronic lung disease	15 (68%)	8 (100%)	7 (50%)	**.02****
NO usage	12 (54%)	5 (62.5%)	7 (50%)	.67***
CRRT usage	10 (45%)	1 (12.5%)	9 (64%)	**.03****
PEX usage	3 (13%)	3 (37.5%)	0	.36***
Prematurity	8 (36%)	2 (25%)	6 (42%)	.64***
Prone position	9 (40%)	2 (25%)	7 (50%)	.38***
Awake ECMO	3 (13%)	3 (37.5%)	0	**.03****
Tracheostomy	2 (9%)	2 (25%)	0	.12***
Pneumothorax while ECMO run	7 (31%)	2 (25%)	5 (35%)	.49***
Pre-cannulation mechanic ventilator settings				
Peak pressure	32 (28-44)	31.5 (28-34)	32 (30-44)	.2**
PEEP	10 (6-12)	9.5 (6-12)	10 (6-12)	.86**
Pre-cannulation laboratory values				
pH	7.3 (6.82-7.48)	7.4 (7.02-7.48)	7.27 (6.8-7.41)	**.02****
PCO_2 (mm Hg)	45 (20-217)	44 (20-89)	45 (32-217)	.5**
Lactate (mmol/L)	5.6 (1-27)	3.9 (1-18)	7.2 (1.2-27)	.23**
Creatinine (mg/dL)	0.33 (0.1-0.9)	0.24 (0.18-0.52)	0.4 (0.1-0.9)	.27**
After ECMO cannulation laboratory values (first 6 hours)				
pH	7.42 (7.10-7.68)	7.47 (7.35-7.57)	7.40 (7.10-7.68)	.48**
PCO_2 (mm Hg)	36 (22.3-79)	37.7 (30-51)	35 (22-79)	.25**
Lactate (mmol/L)	4.9 (1.2-19)	1.9 (1.2-5)	6.4 (1.3-19)	**.009****

CRRT, continuous renal replacement therapy; DL, double lümen; ECMO, extracorporeal membrane oxygenation; MV, mechanic ventilation; NO, nitric oxide; PE, pre-ECMO; Ped-RESCUERS, pediatric risk estimate score for children using extracorporeal respiratory support; PELOD, pediatric logistic organ dysfunction; PEX, plasma exchange; PICU, pediatric intensive care unit; PRISM III, pediatric risk of mortality; pSOFA, pediatric sequential organ failure assessment; VA, venoarterial; VV, venovenous; VIS, vasoactive inotropic score.
*Independent samples *t*-test.**Mann–Whitney *U* test. ***Fisher Exact test.****Pearson chi-square test.Bold numbers are statistically significant.

replacement therapy and PEX sessions and days were higher in this patient group. In VA ECMO, we thought that air entering the set was greater because we applied techniques such as PEX and CRRT through the ECMO circuit in our unit.

In the study by Zabrocki et al,[17] with the participation of 115 centers, using the Extracorporeal Life Support Organization (ELSO) database, the predictors of survival and mortality were examined in 3213 pediatric patients aged 1 month to 18 years who underwent ECMO for respiratory failure. The authors found that survival decreased to 33% in patients with acute or chronic renal failure, and 16% of patients with liver failure survived. In our study, CRRT was used in 9 (90%) patients who died and it was associated with mortality. In our study, PEX was used on 3 patients and all 3 died, but there was no statistical relationship between mortality and PEX use. In the study of Zabrocki et al,[17] no serious association between chronic lung disease with survival was found. Similarly, 8 (53%) of the surviving patients in our study had chronic lung disease, and although a significant difference was found between the 2 groups, chronic lung disease was more common in survivors. In the study of Zabrocki et al,[17] 64% of their patients were followed up with VA ECMO and 36% with VV ECMO. When cannulation techniques are ranked from high survival to low survival in hospital, double-lumen VV ECMO was found in 70%, 2-catheter VV ECMO in 66%, and VA ECMO in 51%. In our study, VV ECMO using double catheters

was detected. There was no difference in hospital survival between VA ECMO and double-lumen VV ECMO. In our study, 45% of the patients underwent double-lumen VV ECMO, 34% of the patients who were followed up under VV ECMO were cannulated using double catheters, and 10% of the patients who were followed under VA ECMO survived. The trend of decreasing rates was similar to the study of Zabrocki et al.[17] In our study, we could not find a cutoff value related to patient age and mortality similar to the study of Zabrocki et al.[17] Similarly, the pH value in blood gas measured before cannulation was found to be associated with mortality.

The relatively small size of the study group and the retrospective and single-center nature are limiting factors of the study.

CONCLUSION

The clinical characteristics of the patients and the technological background determine which mode to choose. Although PRISM III scores, PELOD 2 scores, and pSOFA scores are used as predictors of disease severity and mortality in patients hospitalized in the PICU, we found that these 3 scores were significant in predicting mortality in our patients followed on ECMO. History of CRRT and chronic disease, pH values before ECMO cannulation, and lactate values measured in the first 6 hours after ECMO cannulation were found to be associated with mortality. In patients followed up under VA ECMO, seizures and hemolysis were found to be significant, as expected, compared with patients followed up under VV ECMO. The highest survival rate was found in the VV ECMO patient group established with double-lumen cannulas, similar to the literature. There was no difference in mortality between the groups whose intubation time before ECMO was 14 days or less. In conclusion, in cases of PARDS in children who do not respond to standard treatments, VV, VA, or ECMO is life saving.

Ethics Committee Approval: This retrospective study was approved by the Ethics Committee of Ankara University Faculty of Medicine (approval number: I09-568-22).

Informed Consent: Written informed consent was obtained from all patients' relatives or their representatives, where necessary, from their legal authority.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – F.K., A.G., T.K.; Design – F.K., A.G.; Supervision – Z.E., T.U., T.K.; Materials – F.K., N.D., M.H., M.R.; Data Collection and/or Processing – G.Ç., N.A.Ç., H.U., H.Ö., B.B.; Analysis and/or Interpretation – F.K., E.B., T.K.; Literature Search – F.K., G.Ç., N.A.Ç.; Writing Manuscript – F.K., T.K.; Critical Review – T.U., T.K.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: This study received no funding.

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