Koşuyolu Heart J 2021;24(Suppl 1):S30-S39 • DOI: 10.51645/khj.2021.m103

Disease Oriented ECMO Results; Specific Considerations for Different Pathologies

Ergin Arslanoğlu[1], Kenan Abdurrahman Kara[1], Fatih Yiğit[1], Babürhan Özbek[1], Yasemin Yavuz[2], Fatma Ukil Işıldak[2], Eylem Tunçer[1], Nihat Çine[1], Hakan Ceyran[1]

[1] Department of Pediatric Cardiovascular Surgery, Kartal Koşuyolu High Specialization Training and Research Hospital, Istanbul, Turkey

[2] Department of Anaesthesiology and Reanimation, Kartal Koşuyolu High Specialization Training and Research Hospital, Istanbul, Turkey

ABSTRACT

Introduction: Extracorporeal membrane oxygenation (ECMO), whose use has increased with technological developments in pediatric heart surgery, is a life-saving treatment modality that is used in patients with cardiac or pulmonary insufficiency who are unresponsive to medical treatment. We investigated the effect of operation technique and cardiac morphology of patients undergoing pediatric cardiac surgery in our clinic on ECMO prognosis in this retrospective cohort study.

Patients and Methods: Seventy patients in need of ECMO after pediatric heart surgery were enrolled between May 2010 and April 2020 in our clinic. 44.3% (n= 31) of patients were female and 55.7% (n= 39) were male. Their ages ranged from 0 to 575 months, with a mean of 32.59 ± 147.26. RACHS-1 was 25%, RACHS-2 was 23.07%, RACHS-3 was 33.33%, RACHS-4 was 35.71%, RACHS-5 was 100%, and RACHS-6 was 50% according to the ECMO result. No statistically significant difference was found between mortality and RACHS scoring.

Results: As a consequence, scoring systems used in the evaluation and measurement of ECMO use in the pediatric age group can be deceptive.

Conclusion: We attribute this to the fact that ECMO is a complex and complicated treatment that affects all systems in general and has a lot of mechanical and physiological complications. We think that the combination of scoring systems used in these patients with other scoring methods will give more accurate results than using them alone.

Key Words: Cardiac morphology; pediatric ECMO; RACHS score.

Ameliyat Tekniği ve Hasta Kardiyak Patolojisinin ECMO Prognozuna Etkisi

ÖZ

Giriş: Ekstrakorporeal membran oksijenasyon (ECMO) pediatrik kalp cerrahisinde teknolojik gelişmelerle beraber kullanımı artan, medikal tedaviye yanıtsız kardiyak veya pulmoner yetmezliği olan hastalarda kullanılan hayat kurtarıcı bir tedavi modalitesidir. Bu retrospektif kohort çalışmasında, pediatrik kalp cerrahisi geçiren hastaların operasyon tekniği ve kardiyak morfolojisinin ECMO prognozu üzerine etkisi araştırılmıştır.

Hastalar ve Yöntem: Çalışmaya, Mayıs 2010-Nisan 2020 tarihleri arasında pediatrik kalp cerrahisi sonrası ECMO ihtiyacı olan 70 hasta dahil edilmiştir. Hastaların %44.3'ü (n= 31) kadın, %55.7'si (n= 39) erkektir. Hastaların yaşları 0-575 ay arasında değişmekte olup, ortalama 32.59 ± 147.26 ay bulunmuştur.

Bulgular: ECMO sonucuna göre RACHS-1 %25, RACHS-2 %23.07, RACHS-3 %33.33, RACHS-4 %35.71, RACHS-5 %100, RACHS-6 %50 saptanmıştır. Mortalite ve RACHS skorlaması arasında istatistiksel anlamlı farklılık saptanmamıştır.

Sonuç: Pediatrik yaş grubunda ECMO kullanımı değerlendirme ve ölçmesinde kullanılan skorlama sistemleri yanıltıcı olabilmektedir. Bunu ECMO'nun genel olarak tüm sistemleri etkileyen kompleks ve karışık bir tedavi olmasına, mekanik ve fizyolojik komplikasyonlarının oldukça fazla olmasına bağlıyoruz. Bu hastalarda kullanılan skorlama sistemlerinin tek başına kullanılmasından ziyade diğer skorlama yöntemleri ile kombinasyonunun daha doğru sonuçlar vereceğini düşünüyoruz.

Anahtar Kelimeler: Kardiyak morfoloji; pediatrik ECMO; RACHS skoru.

INTRODUCTION

Extracorporeal membrane oxygenation (ECMO) is a life-saving treatment modality that is used in patients with cardiac or pulmonary insufficiency despite medical treatment after pediatric heart surgery[1]. The first use of ECMO in the pediatric population was used by Dr. Robert

Cite this article as: *Arslanoğlu E, Kara KA, Yiğit F, Özbek B, Yavuz Y, Ukil Işıldak F, et al. Disease oriented ECMO results; specific considerations for different pathologies. Koşuyolu Heart J 2021;24(2):S30-S39.*

Correspondence

Ergin Arslanoğlu

E-mail: erginarslanoglu@gmail.com
Submitted: 18.05.2021
Accepted: 02.07.2021
Available Online Date: 11.07.2021

Bartlet in meconium aspiration syndrome in 1975[2]. The use of ECMO is rapidly increasing in the pediatric patient population with technological developments[3].

ECMO treatment is considered the last option in patients with cardiopulmonary insufficiency due to its high mortality and morbidity complications such as infection, bleeding, and thrombosis[4]. Neonatal respiratory ECMO has the highest survival rate with 73%, followed by pediatric respiratory ECMO with 58% when we divide ECMO device insertion into two as those used for respiratory insufficiency and cardiac insufficiency considering indications according to the Extracorporeal Life Support Organization (ELSO) records. It has a 42% survival in newborns and a 52% survival in pediatric patients for ECMO inserted with cardiac indications[5].

The use and need of ECMO after pediatric heart surgery can be used as a surgical quality criterion in pediatric heart centres. ECMO success has been reported to increase with ECMO rates of centres performing more complex surgery and having more patient volume[6]. Increased interest and experience in pediatric ECMO are reflected positively in the literature with publications and the unknowns and unpredictables about pediatric ECMOs are rapidly decreasing[7].

We investigated the effect of operation technique and cardiac morphology of patients undergoing pediatric cardiac surgery in our clinic on ECMO prognosis in this retrospective cohort study.

PATIENTS and METHODS

Seventy patients in need of ECMO after pediatric heart surgery were screened retrospectively between May 2010 and April 2020 in our clinic and all patients were enrolled in the study. Medical information of the patients was obtained by scanning the hospital information system and archive files. The patients were classified according to RACHS scoring[8]. The postoperative VIS score of the patients was calculated and recorded[9].

Central venoarterial ECMO was used in our patient group and venovenous ECMO was used in 2 patients. ECMO (Medos, Medtronic, and Maquet ECMOs) was used in patients. The cannulation procedure was performed electively in the operating room. Fourteen patients were cannulated in the intensive care unit under emergency conditions and other patients were elective. A single arterial and a single venous cannula were placed in the ascendan aorta and right atrium for the venoarterial ECMO via median sternotomy. The patients were followed up as open-chest during the use of ECMO. ECMO heater was routinely used in the patients. Erythrocyte suspension was added routinley to the ECMO prime solution. ECMO flow was set to 100-150 mL/kg/min. All patients were followed up with ACT (activated clotting time) during ECMO use and ACT was followed up in the range of 150-200. Heparin perfusion was preferred to increase the ACT and keep it at the desired level. Regular mediastinal exploration and bleeding control were performed on patients with ECMO duration longer than 2 days and patients with bleeding diathesis.

The patients' RACHS scores, length of hospital stay, and biochemistry values (ALT, AST, PLT, creatinine) were correlated. NCSS [number descriptive statistical methods (mean, standard deviation, median, frequency, ratio, minimum, maximum)] were used to evaluate the study data, and the Shapiro-Wilk test was used in the evaluation of the distribution of the data. Kruskal Wallis test was used to compare three and more groups that did not show a normal distribution of quantitative data; Mann-Whitney-U test was used to compare two groups. Friedman test was used to compare 3 and above non-normally distributed periodic quantitative data and Wilcoxon test was used to determine differences. Spearman's correlation test was used to determine the relationship between quantitative data. Significance was evaluated as $p< 0.01$ and $p< 0.05$.

The study was conducted in accordance with the rules of the Declaration of Helsinki after obtaining the approval of the ethics committee of the hospital. Approval was obtained from the parents of all patients (2021/4/455).

RESULTS

Of the patients in this study, 44.3% (n= 31) were female and 55.7% (n= 39) were male. Their ages (months) ranged from 0 to 295, with a mean of 30.59 ± 147.26. The weight value ranged from 2.5 to 79 kilogram, with a mean of 13.17 ± 17.38. Cardiopulmoner bypass time value ranged from 0 to 410, with a mean of 172.72 ± 95.74. CC (aortic cross clamp time) time value ranged from 0 to 360 seconds, with a mean of 98.81 ± 78.33. ECMO time value ranged from 0.25 to 51 day, with a mean of 11.09 ± 10.27. VIS score values ranged from 5 to 102, with a mean of 29.81 ± 18.32. Day 1 drainage value ranged from 10 to 1500 cc, with a mean of 268.29 ± 250.94 cc (Table 1).

ECMO times did not show a statistically significant difference according to the RACHS score ($p> 0.05$). Bypass times did not show a statistically significant difference

Table 1. Measurement means

	Mean ± SD	Min-Max (median)
Age (months)	32.59 ± 147.26	0-575
Weight (kilogram)	13.17 ± 17.38	2.5-79
Cardiopulmoner bypass time (second)	172.72 ± 95.74	0-410
CC time (second)	98.81 ± 78.33	0-360
ECMO time (day)	11.09 ± 10.27	0.25-51
VIS score	29.81 ± 18.32	5-102
1st day drainage (cc)	268.29 ± 250.94	10-1500

according to the RACHS score (p> 0.05). CC times did not show a statistically significant difference according to the RACHS score (p> 0.05). VIS scores did not show a statistically significant difference according to the RACHS score (p> 0.05). Day 1 drainage did not show a statistically significant difference according to the RACHS score (p> 0.05) (Table 2). RACHS-1 was 25%, RACHS-2 was 23.07%, RACHS-3 was 33.33%, RACHS-4 was 35.71%, RACHS-5 was 100%, and RACHS-6 was 50% according to the ECMO result. No statistically significant difference was found between mortality and RACHS scoring (p> 0.05) (Table 3, Figure 1).

ECMO times did not show a statistically significant difference according to the ECMO result (p> 0.05). Bypass times did not show a statistically significant difference according to the ECMO result (p> 0.05). CC times did not show a statistically significant difference according to the ECMO result (p> 0.05). ECMO times did not show a statistically significant difference according to the VIS scores (p> 0.05). Day 1 drainage did not show a statistically significant difference according to the ECMO result (p> 0.05).

BUN value did not show a statistically significant difference according to the periods (p> 0.05). Creatinine value did not show a statistically significant difference according to the periods (p> 0.05). The ALT value did not show a statistically significant difference according to the periods (p> 0.05). AST value did not show a statistically significant difference according to the

Table 2. Comparison of parameters according to RACHS score

		n	Mean ± SD	Min-Max (median)	p
ECMO time (day)	1	4	9.25 ± 7.68	1-19	0.514
	2	26	12.42 ± 10.81	2-51	
	3	21	12.43 ± 10.78	0.25-34	
	4	14	8.25 ± 10.37	0.5-34	
	5	1	4 ± 0	4-4	
	6	4	9 ± 7.62	2-17	
Cardiopulmoner bypass time (second)	1	4	77.5 ± 111.28	0-236	0.085
	2	26	159.88 ± 82.87	0-360	
	3	21	160.16 ± 91.49	24-323	
	4	14	235.08 ± 100.04	104-410	
	5	1	196 ± 0	196-196	
	6	4	202.5 ± 95.29	145-345	
CC time (second)	1	4	51.25 ± 68.19	0-144	0.070
	2	26	82.77 ± 68.73	0-230	
	3	21	90.63 ± 77.11	0-266	
	4	14	155.46 ± 91.18	0-360	
	5	1	161 ± 0	161-161	
	6	4	89.75 ± 32.79	57-134	
VIS score	1	4	17.75 ± 5.56	11-24	0.108
	2	26	33.5 ± 20.55	5-102	
	3	21	23.57 ± 13.11	8-53	
	4	14	31.5 ± 19.18	11-74	
	5	1	40 ± 0	40-40	
	6	4	42.25 ± 24.25	25-78	
Day 1 drainage (cc)	1	4	117.5 ± 27.54	90-150	0.379
	2	26	260.38 ± 235.3	10-1200	
	3	21	266.19 ± 219.87	50-900	
	4	14	352.86 ± 362.65	120-1500	
	5	1	180 ± 0	180-180	
	6	4	207.5 ± 149.08	80-400	

Kruskal Wallis Test. * p< 0.05, ** p< 0.01.

Table 3. Comparison of parameters according to ECMO results

		n	Mean ± SD	Min-Max (median)	p
ECMO time	Death	22	9.25 ± 7.68	1-19	0.461
	Reserved	48	9 ± 7.62	2-17	
Bypass time	Death	22	77.5 ± 111.28	0-236	0.183
	Reserved	48	202.5 ± 95.29	145-345	
CC time	Death	22	51.25 ± 68.19	0-144	0.616
	Reserved	48	89.75 ± 32.79	57-134	
VIS score	Death	22	17.75 ± 5.56	11-24	0.352
	Reserved	48	42.25 ± 24.25	25-78	
Day 1 drainage	Death	22	117.5 ± 27.54	90-150	0.755
	Reserved	48	207.5 ± 149.08	80-400	

Mann Whitney-U Test. * p< 0.05, ** p< 0.01

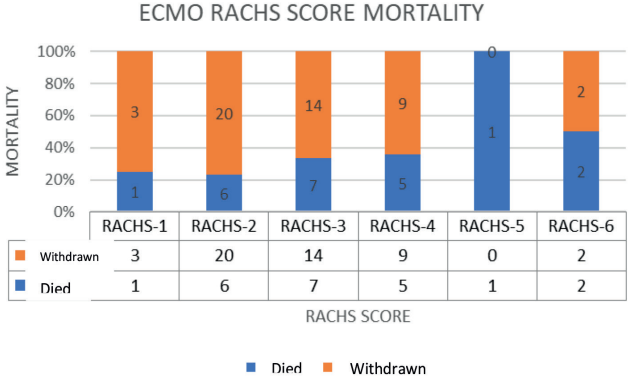

Figure 1. ECMO and RACHS score mortality.

periods (p> 0.05). WBC/CRP value did not show a statistically significant difference according to the periods (p> 0.05). The PLT value did not show a statistically significant difference according to the periods (p> 0.05). Neutrophil value did not show a statistically significant difference according to the periods (p> 0.05). Lymphocyte value did not show a statistically significant difference according to the periods (p> 0.05). Neutrophil/lymphocyte value did not show a statistically significant difference according to the periods (p> 0.05). PLT/lymphocyte value did not show a statistically significant difference according to the periods (p> 0.05) (Table 4).

BUN value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative BUN value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). Creatinine value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative creatinine value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). ALT value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative ALT value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). AST value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative AST value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). WBC/CRP value did not show a statistically significant difference according to the periods (p> 0.05). PLT value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative PLT value was high was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). The neutrophil value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative neutrophil value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). The lymphocyte value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative lymphocyte value was high was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). The neutrophil/lymphocyte value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative neutrophil/lymphocyte value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). PLT/lymphocyte value did not show a statistically significant difference according to the periods (p> 0.05) (Table 5).

BUN value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the

Table 4. Comparison for RACHS= 1

		Pre-op	Post-op	Day 1 post-op	p
BUN	Mean ± SD	25.75 ± 4.79	36.25 ± 16.01	57.33 ± 23.18	0.097
	Min-Max	19-30	18-57	42-84	
Creatinine	Mean ± SD	0.36 ± 0.24	0.5 ± 0.38	0.73 ± 0.41	0.097
	Min-Max	0.22-0.72	0.21-1.03	0.29-1.11	
ALT	Mean ± SD	18.15 ± 10.99	23.5 ± 10.79	31.67 ± 25.11	0.264
	Min-Max	8.6-30	12-35	8-58	
AST	Mean ± SD	44.55 ± 7.97	140.5 ± 110.01	231.67 ± 142.7	0.097
	Min-Max	33.2-51	40-296	78-360	
WBC/CRP	Mean ± SD	14.48 ± 8.08	6.85 ± 1.61	11.83 ± 6.4	0.529
	Min-Max	8.7-25.9	4.9-8.8	4.8-17.3	
PLT	Mean ± SD	314.5 ± 34.91	157.5 ± 33.31	186.33 ± 61.37	0.097
	Min-Max	273-357	127-192	116-229	
Neutrophil	Mean ± SD	7.55 ± 9.42	4.35 ± 1.37	8.53 ± 3.77	0.368
	Min-Max	1.8-21.6	3.1-6.3	4.2-11.1	
Lymphocytes	Mean ± SD	5.65 ± 3.78	1.88 ± 1.12	2.33 ± 2.08	0.097
	Min-Max	2.2-11	0.6-3	0.5-4.6	
Neutrophil/Lymphocyte	Mean ± SD	2.87 ± 4.65	3.49 ± 2.62	5.41 ± 3	0.368
	Min-Max	0.16-9.82	1.03-6.5	2.41-8.4	
PLT/Lymphocytes	Mean ± SD	74.3 ± 40.25	128.41 ± 116.46	188.52 ± 233.49	0.264
	Min-Max	29.27-124.09	48.85-300	46.52-458	

Friedman Test. ** p< 0.01

Table 5. Comparison for RACHS= 2

		Pre-op	Post-op	Day 1 post-op	p
BUN	Mean ± SD	23.95 ± 10.9	46.23 ± 22.39	52.82 ± 32.74	**0.001****
	Min-Max	8-49	14-113	9.57-138	
Creatinine	Mean ± SD	0.36 ± 0.3	2.39 ± 7.3	0.93 ± 0.93	**0.001****
	Min-Max	0.16-1.56	0.17-38	0.15-4.17	
ALT	Mean ± SD	29.84 ± 27.17	341.27 ± 732.44	589.72 ± 1329.97	**0.001****
	Min-Max	9-133	16-2543	8-6266	
AST	Mean ± SD	53.62 ± 25.3	1008.15 ± 1941.73	1421.4 ± 2144.1	**0.001****
	Min-Max	22-124	30-7428	32-7929	
WBC/CRP	Mean ± SD	11.84 ± 3.78	11.68 ± 4.87	10.64 ± 6.56	0.179
	Min-Max	5.2-19.6	1.8-24	0.7-26.6	
PLT	Mean ± SD	297.77 ± 84.6	131.31 ± 71.66	107.36 ± 54.57	**0.001****
	Min-Max	108-451	24-381	13-255	
Neutrophil	Mean ± SD	4.35 ± 2.09	8.87 ± 3.74	8.71 ± 5.85	**0.001****
	Min-Max	1-10.9	1.1-18.3	0.6-21.8	
Lymphocytes	Mean ± SD	5.93 ± 3.36	2.04 ± 2.3	1.25 ± 1.01	**0.001****
	Min-Max	1.7-14.8	0.3-11.5	0.1-4.6	
Neutrophil/Lymphocyte	Mean ± SD	1.02 ± 0.89	8.1 ± 6.79	10.32 ± 10.16	**0.001****
	Min-Max	0.23-3.59	0.64-28.25	1.4-40	
PLT/Lymphocytes	Mean ± SD	65.85 ± 43.67	136.35 ± 141.03	153.17 ± 161.1	0.102
	Min-Max	17.57-232.94	9.6-626.67	8.67-800	

Friedman Test. ** p< 0.01

preoperative BUN value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). The fact that the postoperative BUN value was low was found to be statistically significant compared to the postoperative 1st-day value (p= 0.001; p< 0.01). Creatinine value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative creatinine value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). The fact that the postoperative creatinine value was low was found to be statistically significant compared to the postoperative 1st-day value (p= 0.001; p< 0.01). ALT value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative ALT value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). AST value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative AST value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). WBC/CRP value did not show a statistically significant difference according to the periods (p> 0.05). PLT value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative PLT value was high was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). Neutrophil value did not show a statistically significant difference according to the periods (p> 0.05). The lymphocyte value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative lymphocyte value was high was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). The neutrophil/lymphocyte value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative neutrophil/lymphocyte value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01) (Table 6).

BUN value showed a statistically significant difference according to the periods (p= 0.006; p< 0.01). The fact that the preoperative BUN value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). Creatinine value did not show a statistically significant difference according to the periods (p> 0.05). ALT value showed a statistically significant difference according to the periods (p= 0.034; p< 0.01). The fact that the preoperative ALT value was low was found to

Table 6. Comparison for RACHS= 3

		Pre-op	Post-op	Day 1 post-op	p
BUN	Mean ± SD	23.33 ± 9.76	53.05 ± 22.89	74.67 ± 24.96	**0.001****
	Min-Max	13-44	16-91	32-114	
Creatinine	Mean ± SD	0.41 ± 0.28	0.87 ± 0.45	3.3 ± 8.43	**0.001****
	Min-Max	0.18-1.29	0.21-1.69	0.48-37	
ALT	Mean ± SD	21.31 ± 10.49	249.63 ± 713.5	327 ± 702.48	**0.004****
	Min-Max	7-53	3.7-3339	9-2855	
AST	Mean ± SD	42.46 ± 14.26	860.62 ± 1481.69	1927.78 ± 2547.09	**0.001****
	Min-Max	21-81	29-6855	60-8117	
WBC/CRP	Mean ± SD	10.9 ± 5.26	10.56 ± 4.71	10.55 ± 4.98	0.846
	Min-Max	5.4-27.7	3.3-23.6	5.4-25.6	
PLT	Mean ± SD	285.14 ± 119.23	156.57 ± 91.42	126.61 ± 66.48	**0.001****
	Min-Max	82-560	43-454	27-311	
Neutrophil	Mean ± SD	5.38 ± 2.8	8.48 ± 4.49	8.77 ± 4.14	0.154
	Min-Max	1-10.2	2.6-21	4.4-21.6	
Lymphocytes	Mean ± SD	3.93 ± 2.62	1.44 ± 0.95	1.16 ± 0.9	**0.001****
	Min-Max	0.7-10.3	0.2-3.8	0.3-3.5	
Neutrophil/Lymphocyte	Mean ± SD	2.55 ± 2.71	11.38 ± 14.63	9.55 ± 4.37	**0.001****
	Min-Max	0.19-10.29	1.92-65	2.56-20	
PLT/Lymphocytes	Mean ± SD	120.76 ± 134.38	187.39 ± 198.59	146.91 ± 104.87	0.128
	Min-Max	23.02-605.71	21.5-790	44.5-460	

Friedman Test. ** p< 0.01

be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). AST value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative AST value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). WBC/CRP value did not show a statistically significant difference according to the periods (p> 0.05). PLT value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative PLT value was high was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). Neutrophil value did not show a statistically significant difference according to the periods (p> 0.05). The lymphocyte value showed a statistically significant difference according to the periods (p= 0.001; p< 0.01). The fact that the preoperative lymphocyte value was high was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). The neutrophil/lymphocyte value showed a statistically significant difference according to the periods (p= 0.023; p< 0.05). The fact that the preoperative neutrophil/lymphocyte value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). The PLT/lymphocyte value showed a statistically significant difference according to the periods (p= 0.023; p< 0.05). The fact that the postoperative day 1 PLT/lymphocyte value was high was found to be statistically significant compared to the postoperative and preoperative values (p= 0.001; p< 0.01) (Table 7).

Creatinine value did not show a statistically significant difference according to the periods (p> 0.05). The ALT value did not show a statistically significant difference according to the periods (p> 0.05). AST value showed a statistically significant difference according to the periods (p= 0.039; p< 0.05). AST value showed a statistically significant difference according to the periods (p= 0.039; p< 0.05). The fact that the preoperative AST value was low was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). The WBC/CRP value showed a statistically significant difference according to the periods (p= 0.018; p< 0.05). The fact that the preoperative WBC/CRP value was high was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). PLT value showed a statistically significant difference according to the periods (p= 0.018; p< 0.05). The fact that the preoperative PLT value was high was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). The neutrophil value showed a

Table 7. Comparison for RACHS= 4

		Pre-op	Post-op	Day 1 post-op	p
BUN	Mean ± SD	24.43 ± 12	39.57 ± 25.98	45.92 ± 24.92	**0.006****
	Min-Max	10-53	17-117	10-110	
Creatinine	Mean ± SD	0.53 ± 0.24	0.88 ± 0.46	0.98 ± 0.73	0.058
	Min-Max	0.27-0.95	0.47-2.27	0.25-3	
ALT	Mean ± SD	17.59 ± 11.37	434.71 ± 1167.86	261.19 ± 404.28	**0.034***
	Min-Max	6.8-52	9-4366	7-1461	
AST	Mean ± SD	35.2 ± 16.45	1287.57 ± 2229.91	1471.15 ± 2068.46	**0.001****
	Min-Max	11-76	47-7410	116-7159	
WBC/CRP	Mean ± SD	10.93 ± 4.53	9.27 ± 8.73	7.42 ± 5.5	0.295
	Min-Max	5.8-20.9	1.8-35.1	1.2-20.5	
PLT	Mean ± SD	235.29 ± 61.77	95.29 ± 59.2	141.54 ± 66.73	**0.002****
	Min-Max	128-379	24-256	67-283	
Neutrophil	Mean ± SD	6.45 ± 4.69	11.69 ± 16.24	6.12 ± 5.01	0.735
	Min-Max	1.3-18.1	1.1-61	0.7-18.7	
Lymphocytes	Mean ± SD	3.07 ± 1.88	1.23 ± 0.7	0.95 ± 0.73	**0.001****
	Min-Max	1.4-8	0.16-2.8	0.4-3.2	
Neutrophil/Lymphocyte	Mean ± SD	3.04 ± 3.24	10.03 ± 10.64	7.61 ± 6.2	**0.023***
	Min-Max	0.16-12.93	1.62-40.67	1.75-18.7	
PLT/Lymphocytes	Mean ± SD	91.4 ± 35.49	139.45 ± 202.76	205.51 ± 147.36	**0.023***
	Min-Max	33.63-156.32	17.14-806.25	20.94-602.5	

Friedman Test. ** p< 0.01

Table 8. Comparison for RACHS= 6

		Pre-op	Post-op	Day 1 post-op	p
BUN	Mean ± SD	27 ± 4.97	51.5 ± 26.85	50.75 ± 18.12	0.189
	Min-Max	21-32	24-84	25-67	
Creatinine	Mean ± SD	0.76 ± 0.22	1.11 ± 0.44	1.11 ± 0.33	0.368
	Min-Max	0.43-0.89	0.68-1.59	0.78-1.53	
ALT	Mean ± SD	18.88 ± 12.6	215.7 ± 312.84	208.28 ± 362.33	0.936
	Min-Max	4.5-35	7.3-669	6.8-750	
AST	Mean ± SD	59 ± 35.57	912.75 ± 938.47	969.5 ± 963.87	**0.039***
	Min-Max	24-108	160-2122	205-2256	
WBC/CRP	Mean ± SD	19.55 ± 4.9	7.45 ± 5.71	9.18 ± 4.87	**0.018***
	Min-Max	14.9-26.1	1.4-14.5	2.9-14.8	
PLT	Mean ± SD	262.75 ± 45.37	82 ± 33.2	80.5 ± 71.23	**0.039***
	Min-Max	204-300	34-110	10-171	
Neutrophil	Mean ± SD	12.43 ± 4.54	5.93 ± 4.5	7.53 ± 4.47	**0.018***
	Min-Max	7.7-18.3	1.1-11.3	1.4-12.1	
Lymphocytes	Mean ± SD	5.23 ± 1.9	0.73 ± 0.54	0.95 ± 0.51	**0.038***
	Min-Max	2.4-6.5	0.2-1.4	0.3-1.4	
Neutrophil/Lymphocyte	Mean ± SD	2.7 ± 1.33	8.14 ± 3.38	12.65 ± 12.18	0.174
	Min-Max	1.18-4.33	5.5-12.56	1.08-28.67	
PLT/Lymphocytes	Mean ± SD	55.58 ± 19.87	146.24 ± 72.37	106.73 ± 87.88	0.105
	Min-Max	41.67-85	78.57-237.5	7.69-213.75	

Friedman Test. ** p< 0.01

statistically significant difference according to the periods (p= 0.018; p< 0.05). The fact that the preoperative neutrophil value was high was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). The lymphocyte value showed a statistically significant difference according to the periods (p= 0.018; p< 0.05). The fact that the preoperative lymphocyte value was high was found to be statistically significant compared to the postoperative and postoperative 1st-day value (p= 0.001; p< 0.01). Neutrophil/lymphocyte value did not show a statistically significant difference according to the periods (p> 0.05). PLT/lymphocyte value did not show a statistically significant difference according to the periods (p> 0.05) (Table 8).

DISCUSSION

Our experience and experience about ECMO treatment, which we started to use more frequently in the pediatric population, is increasing day by day with the increasing number of complex pediatric cardiac surgeries. We investigated the effect of operation technique and cardiac morphology of patients undergoing pediatric cardiac surgery in our clinic on ECMO prognosis.

Developments and innovations in ECMO technology bring along ethical dilemmas. Estimating how much benefit this costly device will provide each patient may also aid in determining ECMO indications[10]. In addition, this prediction will help us inform families about the prognosis of patients[6,11-13]. We provide the risk scoring and indications of the patients by interpreting the clinical signs of the patient together with our team of pediatric anaesthesiologists, pediatric cardiac surgeons, and pediatric cardiologists as well as routine scoring methods in our own clinical practice.

Anticoagulation is difficult in neonatal and pediatric patients because the development of the coagulation system has not yet been completed and the therapeutic effectiveness doses of the drugs are narrow. Heparin infusion to keep the ACT value high in treatment also contributes negatively to bleeding diathesis when ECMO is used in this age group. It is known that the increased risk of bleeding in these patients has a great effect on infection, morbidity, and mortality[14]. The precautions to be taken for patients undergoing bleeding diathesis are still limited if we do not prefer unfractionated heparin due to its antidote and rapid effect in our own clinical practice. We administered 50-100 UI/kg bolus and maintain it at 20-50 UI/kg/h in our clinical heparin use protocol.

Adjusting drug doses and bioavailability in patients undergoing ECMO treatment after pediatric heart surgery according to adult ECMO patient treatment models may be

misleading. Changes in renal and hepatic function maturation during neonatal and child development, differences in potential immune function and reaction to extracorporeal circulation, differences in relative blood volume, extracorporeal circuit volume, and different cardiac pathophysiology of this patient group are the variables limiting the feasibility of adult treatment modalities in these patients[14]. VIS score increased as RACHS score increased between pre-ECMO VIS score and RACHS scoring of patients, but we did not detect statistical significance due to inequality in possible group distribution.

Bleeding and thrombosis due to acquired platelet dysfunction are very common during ECMO treatment. Surgical bleeding foci are also important among the causes of bleeding even though bleeding is usually caused by impaired coagulation mechanisms[6,11]. The amount of postoperative bleeding increases as the RACHS score increases from 1 to 6 even though there was no statistically significant difference between the postoperative drainage of the patients when we categorized the patients undergoing pediatric cardiac surgery according to the RACHS score in our study.

Each centre has criteria for patient weaning from ECMO according to its own experience. The pulse pressure difference in the arterial trace, cardiac pulsation, and oxygen pressure in arterial blood gas are the most commonly used parameters used for weaning[11,12]. In our clinic, we apply our own weaning protocol using the above parameters. We make patient-based decisions. No statistically significant result was found due to the limited number of patient populations even though we predicted to find increased rates with the increasing score in which we compared the weaning period and mortality of patients with RACHS scoring in this study.

El Mahrouk et al. showed in their study that cardiopulmonary bypass and cross-clamp times had no statistically significant effect on ECMO results. In addition, they could not obtain a statistically significant result when they classified the patients as single ventricular and biventricular pathologies. They have stated that the most important bad prognostic factor in ECMO prognosis is renal problems and central nervous system damage[15]. The amount of creatinine was observed to increased gradually in the postoperative period in our study, indicating that poor prognosis was one of the renal problems in ECMO. It was observed that creatinine increased gradually to indicate poor prognostic factors in dead patients. In addition, prolonged cardiopulmonary bypass times and cross-clamp times of the patients could not be associated with a poor prognosis similar to that of El Mahrouk et al.[15].

Common hypoxia in pediatric heart patients, along with accompanying genetic and other diseases, disrupts platelet functions. The effect of pathological bleeding and clotting on morbidity and mortality is fairly high in this group of patients with various aetiologies and complications. In addition, platelets are cells that play a role not only in coagulation but also in immunity and inflammation[16]. There was a statistically significant decrease in platelet amount as the ECMO time increased in our study. However, RACHS scoring and platelet amount were not found to be statistically significant. This may be due to the fact that the immune response to extracorporeal circulation and the extracorporeal circuit volume of this patient group are very high compared to the patient blood volume.

Gupta et al. found that every 1-day increase in ECMO time increased 1-3% mortality and increased ventilation and intensive care time. They did not find a correlation between ECMO timing and complex cardiac surgery[17]. Successful withdrawal from ECMO was the shortest on the 2nd day and the longest on the 17th day in our study. There were no surveys in prolonged ECMOs after the 17th day, supporting the study of Gupta et al. We attribute this to bleeding diathesis, infection, and renal problems. However, we could not obtain a statistically significant result in terms of ECMO time when we compared it with the RACHS score we used as surgical procedure scoring.

Chan et al. showed in their study that racial differences were effective in ECMO prognosis, but they did not give a clear answer about its cause[18]. Timing of ECMO is very important. Taking a patient to ECMO will increase hospital costs and length of hospital stay while exposing the patient to unnecessary complications of ECMO. On the contrary, taking the patient late to ECMO may cause irreversible damage to the patient. The survival after veno-arterial-ECMO (SAVE)-score prognosis prediction is also successfully used in ECMO patients. However, the results alone are not as good as their combination with other tests[19,20]. In parallel, we made the RACHS and ECMO decisions we used together with our team in the patient groups of our study. There was no statistically significant result between the hospital stay and ECMO duration of our patients according to RACHS scoring.

As a consequence, scoring systems used in the evaluation and measurement of ECMO use in the pediatric age group can be deceptive. We attribute this to the fact that ECMO is a complex and complicated treatment that affects all systems in general and has a lot of mechanical and physiological complications. We think that the combination of scoring systems used in these patients with other scoring methods will give more accurate results than using them alone, as we mentioned in the source above. We used this in our study by combining the RACHS scoring system and VIS score in support of this.

LIMITATIONS

The retrospective nature of our study is limiting and the lack of a statistically significant result between RACHS scoring

and ECMO prognosis may be due to the inequality of group distribution. Larger population studies are needed to achieve statistical significance.

Ethics Committee Approval: The study protocol was approved by the local ethics committee. The study was conducted in accordance with the principles of the Declaration of Helsinki (2021/4/455).

Informed Consent: Informed consent was obtained.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept/Design - EA; Analysis/Interpretation - YY; Data Collection - KK; Writing - FI; Critical Revision - ET; Final Approval - EA, HC; Statistical Analysis - BÖ; Obtained funding - NÇ, HC; Overall Responsibility - HC.

Conflict of Interest: The authors have no conflicts of interest to declare

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Cashen K, Reeder R, Dalton HJ, Berg RA, Shanley TP, Newth CJL, et al. Acquired infection during neonatal and pediatric extracorporeal membrane oxygenation. Perfusion 2018;33:472-82.
2. Fletcher K, Chapman R, Keene S. An overview of medical ECMO for neonates. Semin Perinatol 2018;42:68-79.
3. Barrett CS, Chan TT, Wilkes J, Bratton SL, Thiagarajan RR. Association of pediatric cardiac surgical volume and mortality after cardiac ECMO. ASAIO J 2017;63:802-9.
4. Jenkins KJ, Gauvreau K. Center-specific differences in mortality: preliminary analyses using the Risk Adjustment in Congenital Heart Surgery (RACHS-1) method. J Thorac Cardiovasc Surg 2002;124:94-104.
5. Bembea MM, Felling RJ, Caprarola SD, Ng DK, Tekes A, Boyle K, et al. Neurologic outcomes in a two-center cohort of neonatal and pediatric patients supported on extracorporeal membrane oxygenation. ASAIO J 2020;66:79-88.
6. Cashen K, Meert K, Dalton HJ. Platelet count and function during pediatric extracorporeal membrane oxygenation. Semin Thromb Hemost 2020;46:357-65.
7. Roeleveld PP. What is new in pediatric ECMO? 2016, a year in review. Eur J Heart Fail 2017;19(Suppl 2):92-96.
8. Simsic JM, Cuadrado A, Kirshbom PM, Kanter KR. Risk adjustment for congenital heart surgery (RACHS): is it useful in a single-center series of newborns as a predictor of outcome in a high-risk population? Congenit Heart Dis 2006;1:148-51.
9. Koponen T, Karttunen J, Musialowicz T, Pietilainen L, Uusaro A, Lahtinen P. Vasoactive-inotropic score and the prediction of morbidity and mortality after cardiac surgery. Br J Anaesth 2019;122:428-36.
10. Shah SA, Shankar V, Churchwell KB, Taylor MB, Scott BP, Bartilson R, et al. Clinical outcomes of 84 children with congenital heart disease managed with extracorporeal membrane oxygenation after cardiac surgery. ASAIO J 2005;51:504-7.
11. Roeleveld PP. What is new in pediatric ECMO? 2016, a year in review. Eur J Heart Fail 2017;19(Suppl 2):92-6.
12. Gandolfo F, De Rita F, Hasan A, Griselli M. Mechanical circulatory support in pediatrics. Ann Cardiothorac Surg 2014;3:507-12.
13. Carlisle EM, Loeff DS. Emerging issues in the ethical utilization of pediatric extracorporeal membrane oxygenation. Curr Opin Pediatr 2020;32:411-5.
14. Himebauch AS, Kilbaugh TJ, Zuppa AF. Pharmacotherapy during pediatric extracorporeal membrane oxygenation: a review. Expert Opin Drug Metab Toxicol 2016;12:1133-42.
15. El Mahrouk A, Ismail M, Hamouda T, Shaikh R, Mahmoud A, Shihata M, et al. Extracorporeal membrane oxygenation in postcardiotomy pediatric patients-15 years of experience outside Europe and North America. Thorac Cardiovasc Surg 2019;67:28-36.
16. Yaw HP, Van Den Helm S, MacLaren G, Linden M, Monagle P, Ignjatovic V. Platelet phenotype and function in the setting of pediatric extracorporeal membrane oxygenation (ECMO): a systematic review. Front Cardiovasc Med 2019;6:137.
17. Gupta P, Robertson MJ, Rettiganti M, Seib PM, Wernovsky G, Markovitz BP, et al. Impact of timing of ECMO initiation on outcomes after pediatric heart surgery: a multi-institutional analysis. Pediatr Cardiol 2016;37:971-8.
18. Chan T, Barrett CS, Tjoeng YL, Wilkes J, Bratton SL, Thiagarajan RR. Racial variations in extracorporeal membrane oxygenation use following congenital heart surgery. J Thorac Cardiovasc Surg 2018;156:306-15.
19. Schmidt M, Burrell A, Roberts L, Bailey M, Sheldrake J, Rycus PT, et al. Predicting survival after ECMO for refractory cardiogenic shock: the survival after veno-arterial-ECMO (SAVE)-score. Eur Heart J 2015;36:2246-56.
20. Ergün S. Use of a new extracorporeal membran oxygenator system and first experiences. Dicle Tıp Dergisi 2020;47:755-62.