Journal of Pediatric Surgery 56 (2021) 187–191

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Beyond survival: Readmissions and late mortality in pediatric ECMO survivors

Amy E. Lawrence, Yuri V. Sebastião, Katherine J. Deans, Peter C. Minneci *

Center for Surgical Outcomes Research, Nationwide Children's Hospital, Columbus, OH
Division of Pediatric Surgery, Nationwide Children's Hospital, Columbus, OH

ARTICLE INFO

Article history:
Received 15 September 2020
Accepted 23 September 2020

Key words:
ECMO
Readmissions
Mortality

ABSTRACT

Introduction: The objective of our study was to identify rates of readmission and late mortality in pediatric extracorporeal membrane oxygenation (ECMO) patients after discharge from their ECMO hospitalization.
Methods: We conducted a population-based retrospective cohort study of children who were discharged after ECMO. Data were obtained from the State Inpatient Databases for 10 states. Time-to-event analyses were used to estimate the risk of readmission and to identify factors predictive of readmission and late mortality, including characteristics of initial hospital course and ECMO center volume.
Results: A total of 1603 pediatric ECMO patients were identified, and 42.4% of these patients died prior to discharge. Of the 924 ECMO survivors, 35.6% had an unplanned readmission, and 3% died during readmission within 1 year. The risk of readmission was significantly related to the indication for ECMO, number of complex chronic conditions, transfer status, and discharge destination (all $p<0.05$). The risk of late mortality was significantly related to health insurance, transfer status, number of complex chronic conditions, and indication for ECMO (all $p<0.05$).
Conclusions: Pediatric ECMO survivors have a high risk of hospital readmission with approximately 3% mortality during readmissions within 1 year of initial discharge.
Type of Study: Retrospective Cohort Study
Level of Evidence: Level III

Extracorporeal membrane oxygenation (ECMO) is a highly specialized life support measure that is used in neonatal and pediatric patients for a variety of critical conditions. Reported in-hospital mortality rates from pediatric ECMO vary from 40–50% [1,2]. However, the care of patients who survive ECMO is not standardized, and less is known about the risk of subsequent severe illnesses warranting re-hospitalization after initial discharge from ECMO. The objective of our study was to describe the rates and risk factors for unplanned readmission after ECMO. Secondarily, we sought to describe the rate of in-hospital mortality that occurred during readmissions.

1. Methods

We conducted a population-based retrospective cohort study using data from the Healthcare Cost and Utilization Project's (HCUP) State Inpatient Databases (SID). The SID contain data from all inpatient encounters in all or nearly all acute care hospitals in participating states [3]. Data use agreements with HCUP were completed by the research team. SID data are de-identified by HCUP, which qualified for exemption from human subjects review by the Nationwide Children's Hospital Institutional Review Board. Data were obtained for the period of 2005–2016 from the following states: Arkansas, California, Florida, Georgia, Iowa, Maryland, North Carolina, Nebraska, New York, and Wisconsin. These 10 states were selected because they all provided unique, encrypted patient identifiers that were consistent for at least 2 consecutive calendar years during the study period [4]. We initially identified admissions for patients aged 0–18 years with an International Classification of Diseases, 9th revision, who had a procedure code for ECMO (39.65) and a discharge date between January 1st, 2005 and September 30th, 2015. Admissions without available patient identifiers were excluded. For each patient, the first admission with an ECMO procedure code during the study period was designated as the index admission. Patients who did not survive or who had unknown discharge destination from the index admission were excluded.

1.1. Measures

The primary outcome of interest was the risk of unplanned readmission over time. Readmissions were identified by tracking patient identifiers across all institutions in each participating state. Readmissions following initial discharge from ECMO were identified by tracking inpatient admissions that followed the index admission in January 1, 2005 through December 31, 2016 in the SID. Transfers or readmissions for aftercare were not considered unplanned readmissions. The following readmissions were considered to be planned rather than unplanned:

* Corresponding author at: Nationwide Children's Hospital, 700 Children's Drive, Columbus, OH 43205. Tel.: +1 614 722 5922.
E-mail address: peter.minneci@nationwidechildrens.org (P.C. Minneci).

https://doi.org/10.1016/j.jpedsurg.2020.09.035
0022-3468/

admissions classified by HCUP as "elective"; admissions occurring within 1 day of initial discharge from the index ECMO admission among patients with an initial discharge status of "transfer"; admissions with a principal diagnosis code for elective surgery, aftercare, of follow-up examination. For patients who had an unplanned readmission, follow-up time was defined as time from initial ECMO discharge to first unplanned readmission. For patients without an unplanned readmission, follow-up time ended at last month of data availability or inpatient death at a planned readmission (whichever occurred first). We also examined the risk of in-hospital death at a readmission (planned or unplanned) over time. Follow-up time for the outcome of death at a readmission was defined as time from initial ECMO discharge to date of final discharge, or last month of data availability (for patients who did not have a readmission).

The following patient and hospital characteristics were selected based on clinical relevance and availability in the database to be examined as risk factors for the study outcomes: age at index admission, race and ethnicity, health insurance, elective admission, transfer admission, presence of one or more pediatric complex chronic conditions, indication for ECMO, discharge disposition (e.g., home or self-care, transfer to short-term hospital or other type of facility, home health care) hospital ECMO volume and percentage of pediatric ECMO patients. [5] Indication for ECMO was determined by adapting a previously published, hierarchical classification for hospital discharge data, which emulates indications for ECMO used by ELSO [1,6]. Using patient age and all available diagnosis and procedure codes from the index admission, patients were classified into the following seven mutually exclusive groups: congenital diaphragmatic hernia, neonatal or pediatric cardiac arrest, neonatal or pediatric cardiac disease, and neonatal or pediatric respiratory failure. Patients whom after review of all diagnosis and procedure codes available in the admission record could not be classified into one of the seven indication for ECMO groups were excluded from the analysis (less than 1.5% of the study population). Based on previous literature, the following ECMO center volume categories were initially used for the study: <6, 6–14, 15–30, and >30 cases/year [7]. Due to the small number of patients alive at discharge in hospitals with <6 cases/year, the two lowest ECMO volume categories were combined resulting in three final groups for comparison: <15, 15–30, and >30 cases/year. Hospitals for which >90% of their ECMO patients were aged ≤18 years were considered pediatric ECMO centers.

1.2. Statistical analysis

Frequencies and percentages were used to characterize the study population at index admission, describe the overall occurrence of unplanned readmissions and deaths during readmission, and principal diagnoses for readmission. Time-to-event analyses were used to estimate the risk of unplanned readmission, and the risk of death at a readmission over time [8]. All patients discharged alive from the index ECMO admission were included in the risk estimation of outcomes up until the time they experienced the outcome or data availability for the state ended, at which point patients who did not experience the outcome were censored from the analysis. For the outcome of unplanned readmission, patients who died at a planned readmission before experiencing the outcome were censored at the time of death. For these patients, follow-up time for time-to-event analyses ended at the date of discharge from the admission during which they died. First, the cumulative risk of each outcome over time was estimated using Kaplan-Meier "survival" curves. Second, Cox proportional hazards regression with random hospital intercepts (shared frailty model) was used to estimate the unadjusted and adjusted hazard ratios (HRs) of each outcome associated with patient and hospital factors. Unadjusted HRs were estimated by running a model that included each study factor as the single predictor variable. Factors associated with the outcome at $p < 0.20$ in univariable models were all included in an initial multivariable model. Backward elimination was then used to select a final multivariable model that retained indication for ECMO, hospital volume of ECMO, pediatric vs. non-pediatric hospital status, and any other factors found to be significantly associated with the risk of re-operation at $p < 0.05$ in the multivariable model. To examine effect measure modification by indication for ECMO, we tested for statistical interaction by separately introducing interaction terms between indication for ECMO and each of the variables in the final models for each outcome. Statistical significance for mains effects and interaction terms was set at $p < 0.05$ and $p < 0.008$ (applying a Bonferroni correction for multiple comparisons), respectively. All regression models had a random hospital-level intercept to account for patient clustering by hospital.

2. Results

A total of 924 patients discharged alive from the index ECMO admission in 50 hospitals were included in the study. From the initial 1634 admissions with available patient identifiers, 678 were excluded due to in-hospital death during index admission, and an additional 32 were excluded due to unknown discharge destination or unknown indication for ECMO. Baseline characteristics at index ECMO admission are

Table 1
Baseline characteristics and overall outcomes among patients discharged alive from ECMO. State Inpatient Databases 2005–2015.

		N or median	% or IQR
All hospitals, N		50	100.0
Pediatric hospitals, N		17	34.0
All patients, n		924	100.0
Age, years	<1	616	66.7
	1–10	186	20.1
	11–18	122	13.2
Female		420	45.5
Race and ethnicity	White	320	34.6
	Black	149	16.1
	Hispanic	133	14.4
	Other	169	18.3
	Unknown	153	16.6
Health insurance	Medicaid	517	56.0
	Private	355	38.4
	Other	52	5.6
Transferred in		366	39.6
Number of complex chronic conditions		2	1–3
Indication for ECMO	Neonatal, Congenital diaphragmatic hernia	92	10.0
	Neonatal, Cardiac arrest	78	8.4
	Neonatal, Cardiac disease	111	12.0
	Neonatal, Respiratory failure	207	22.4
	Pediatric, Cardiac arrest	168	18.2
	Pediatric, Cardiac disease	128	13.9
	Pediatric, Respiratory failure	140	15.2
ECMO center volume (average admissions/yr)	<15	226	24.5
	15–30	358	38.7
	>30	340	36.8
Pediatric hospital		435	47.1
Post-cannulation length of stay	Less than 8d	50	5.4
	8–14 d	86	9.3
	15–30 d	254	27.5
	More than 30d	469	50.8
	Unknown/before admission	65	7.0
Discharge disposition	Home or self-care	453	49.0
	Transfer: short-term hospital	176	19.1
	Transfer: other type of facility	134	14.5
	Home health care	161	17.4
Outcomes			
Follow-up duration, months[a]		20	4–48
Any unplanned readmission		412	44.6
Time to readmission, months		3	1–10
Total unplanned readmissions (n = 412)		2	1–4
Died at a readmission (planned or unplanned)		45	4.9

[a] Time from ECMO discharge to first unplanned readmission or last month of state data availability for patients without an unplanned readmission.

Table 2
Risk and hazard ratios (HR) of unplanned readmission following discharge from ECMO.

	Patients	1-year unplanned readmission, %[a]	Adjusted HR (95% CI)[b]	p
Transferred in				
No	558	38.7	1.00	Reference
Yes	366	31.4	**0.78 (0.62–0.97)**	0.027
Number of complex chronic conditions			**1.35 (1.24–1.46)**	<.0001
Indication for ECMO				
Neonatal, Congenital diaphragmatic hernia	92	44.6	**1.81 (1.17–2.80)**	0.008
Neonatal, Cardiac arrest	78	51.3	**2.57 (1.67–3.94)**	<.0001
Neonatal, Cardiac disease	111	32.4	**1.61 (1.05–2.48)**	0.030
Neonatal, Respiratory failure	207	16.9	1.00	Reference
Pediatric, Cardiac arrest	168	45.2	**2.79 (1.91–4.06)**	<.0001
Pediatric, Cardiac disease	128	49.2	**2.51 (1.70–3.71)**	<.0001
Pediatric, Respiratory failure	140	27.9	**1.84 (1.23–2.75)**	0.003
Discharge disposition				
Discharged to home or self-care	453	37.5	1.00	Reference
Transfer: short-term hospital	176	24.4	**0.69 (0.50–0.96)**	0.029
Transfer: other type of facility	134	38.1	1.07 (0.80–1.43)	0.649
Home health care	161	39.8	1.12 (0.84–1.50)	0.438

[a] Kaplan-Meier estimates for the cumulative proportion of patients having a first readmission over time
[b] Estimates of the relative risk of unplanned readmission associated with each study factor; from a random-intercept proportional hazards regression model. Unadjusted estimates are from univariable models (single predictor variable); adjusted estimates are from a multivariable model that retained the factors with displayed estimates, in addition to hospital volume of ECMO and pediatric vs. non-pediatric hospital status.

described in Table 1. Among the 924 patients in the final cohort, 66.7% were infants, 45.5% female, and just under 40% were transferred in from another hospital. The leading indication for ECMO was respiratory failure (37.6% overall; 22.4% neonatal), followed by cardiac arrest (26.6%; 8.4% neonatal) and cardiac disease (25.9%; 12% neonatal). Pediatric hospitals accounted for 47.1% (n = 435) of the patients and 34% (N = 17) of hospitals. In subsequent analyses, hospital volume of ECMO and pediatric hospital status were combined into one variable because very few hospitals were identified as both high-volume and pediatric (N = 2). Overall, 49% of patients were initially discharged to home or self-care, and 19% were transferred to another short-term hospital (19.1%) from the index ECMO admission. A total of 412 (44.6%) patients had at least one unplanned readmission, with a median follow-up time of 20 months (IQR: 4–48), a median time to first unplanned readmission of 88 days (IQR: 23–288), and a median total of 2 (IQR: 1–4) unplanned readmissions; 45 (4.9%) patients died at a readmission (Table 1).

The unadjusted 1-year risk of unplanned readmission in the overall study cohort was 35.6%. Among specific groups by indication for ECMO, the unadjusted 1-year risk varied from 16.9% among neonates with respiratory failure to 49.2% and 51.3% among pediatric and neonatal patients with cardiac arrest, respectively. As shown in Table 2, the following factors were significantly associated with the risk of unplanned readmission: transfer admission [22% decreased risk compared to non-transfers; adjusted HR (95% CI): 0.78 (0.62–0.97)], number of complex chronic conditions [35% increased risk with each additional condition; aHR: 1.35 (1.24–1.46)], indication for ECMO [aHR ranging from 1.61 (1.05–2.48) for neonatal cardiac disease to 2.79 (1.91–4.06) for pediatric cardiac arrest, compared to neonatal respiratory failure group], and transfer to a short-term hospital upon discharge [31% decreased risk compared to patients discharged to home or self-care; aHR: 0.69 (0.50–0.96)]. There was no significant difference in risk of readmission by patient sex, race and ethnicity, health insurance, hospital ECMO volume, or pediatric hospital status (results not shown). Estimates of the 1-year risk and hazard ratios for death at a readmission are summarized in Table 3. The overall, unadjusted 1-year risk of death at a readmission was 3.1%, with ECMO indication group-specific risks ranging from 0.5% for neonatal respiratory failure to 4.9% and 8.3% for pediatric and neonatal cardiac arrest, respectively. The following factors were significantly associated with the risk of death at a read-

Table 3
Risk and hazard ratios (HR) of death at a readmission following discharge from ECMO.

	Patients	1-year mortality, % [a]	Adjusted HR (95% CI)[b]	p
Overall	924	3.1		
Health insurance				
Medicaid	517	3.9	**2.76 (1.25–6.11)**	0.012
Private	355	0.3	1	Reference
Other	52	6.5	1.71 (0.48–6.15)	0.412
Transferred in				
No	558	4.2	1.00	Reference
Yes	366	0.6	**0.36 (0.16–0.81)**	0.013
Number of complex chronic conditions			**1.37 (1.05–1.78)**	0.021
Indication for ECMO				
Neonatal, Congenital diaphragmatic hernia	92	4.2	1.07 (0.25–4.57)	0.928
Neonatal, Cardiac arrest	78	8.3	3.61 (0.98–13.35)	0.054
Neonatal, Cardiac disease	111	1.0	1.00	Reference
Neonatal, Respiratory failure	207	0.5	0.17 (0.02–1.53)	0.113
Pediatric, Cardiac arrest	168	4.9	**3.35 (1.03–10.83)**	0.044
Pediatric, Cardiac disease	128	2.3	2.69 (0.76–9.49)	0.125
Pediatric, Respiratory failure	140	2.8	2.47 (0.67–9.12)	0.176

[a] Kaplan-Meier estimates for the cumulative incidence of in-hospital mortality after initial discharge from ECMO
[b] Estimates of the relative risk of in-hospital mortality at a readmission associated with each study factor, from a multivariable proportional hazards regression model that retained the factors with displayed estimates, in addition to hospital volume of ECMO and pediatric vs. non-pediatric hospital status.

Table 4
Principal diagnosis groups during the first unplanned readmission after discharge from pediatric ECMO.

	Patients, n	% among the readmitted (n = 412)
Respiratory infection	92	22.3
Respiratory, other	51	12.4
Gastrointestinal, other	39	9.5
Cardiac, other	38	9.2
Infectious disease	33	8.0
Failure to thrive/dehydration/feeding issue	29	7.0
Cardiac, congenital	27	6.6
Genitourinary	15	3.6
Neurologic	15	3.6
Heme/Onc	13	3.2
Gastrointestinal infection	11	2.7
Other/undetermined	49	11.9

mission: health insurance [76% increased risk for Medicaid vs private aHR: 2.76 (1.25–6.11)], transfer admission [64% decreased risk compared to non-transfers; aHR: 0.36 (0.16–0.81)], number of complex chronic conditions [37% increased risk with each additional condition; aHR: 1.35 (1.05–1.78)], and indication for ECMO [aHR: 3.35 (1.03–10.83) for pediatric cardiac arrest vs. neonatal cardiac disease]. No significant interactions were found between indication for ECMO and the risk factors in the final models for either outcome. There was no significant difference in the risk of late mortality by patient sex, race and ethnicity, hospital ECMO volume and pediatric hospital status, or discharge destination (results not shown). Hospital volume of ECMO and pediatric hospital status were not significantly associated with either the risk of unplanned readmission (Table 2) or death at a readmission (Table 3).

The principal diagnosis groupings associated with the first unplanned readmission are summarized in Table 4. Respiratory infection (22.3% of readmissions) was the most common cause for readmission, with other respiratory problems (e.g. respiratory failure, asthma) being the second most common (12.4%).

3. Discussion

In this cohort of 924 pediatric and neonatal patients who survived ECMO, 35.6% experienced a readmission and 3% died during readmission within one year. While hospital ECMO volume was not found to be a significant risk factor for readmission or late mortality, patient factors such as indication for ECMO, comorbidities, and insurance status were.

This study adds to the literature of long-term outcomes for pediatric ECMO patients by reporting outcomes from a representative, multistate cohort. A previous study by Jen et al. found that 5% of non-neonatal pediatric ECMO patients in California died during readmission over a median 3.7 years of follow-up [9]. Other studies have shown similar rates, and those that have tracked patients for as long as 15 years found that the majority (78%) of late deaths occurred within three years of ECMO [10,11]. The late deaths in the Jen et al. cohort only occurred in patients with acquired heart disease (n = 3), and a study by von Bahr et al. using the United Kingdom registry found increased risk of late death in congenital heart disease and acquired heart disease. [9,11] Our results showed that late mortality was significantly more likely in pediatric patients who were placed on ECMO for cardiac arrest, but not neonatal cardiac disease or arrest. While the von Bahr study also found congenital diaphragmatic hernia patients were at higher risk for late death, our study did not find that association. Other factors associated with increased late mortality in our study included patients on Medicaid and patients with an increased number of complex chronic conditions. These two factors may represent a similar cohort given that patients with multiple chronic conditions are often covered by Medicaid and may be at an increased risk of later mortality due to their comorbidities. In contrast to the study by Jen et al., our data did not show a relationship between hospital ECMO volume and risk of late mortality.

Over a median follow-up period of 1.7 years, we found a readmission rate of 44.6% with a median of two admissions over this period. This is slightly lower than the reported rate of 62% in the study by Jen et al., likely due to their longer median follow-up period of 3.7 years. We found that all indications for ECMO except for neonatal respiratory failure were associated with an increased risk of readmission. The highest risks of readmission were in patients with pediatric cardiac disease, pediatric cardiac arrest, and neonatal cardiac arrest. Patients with more complex chronic conditions were also more likely to be readmitted. The most common indication for readmission was respiratory infection. Previous studies have shown that patients who go on ECMO during the neonatal period have long-term effects on their pulmonary performance, even as far as 12 years later [4,12]. In addition to recovery from their underlying critical illness, it is apparent that ECMO patients remain at high risk even after discharge and heightened care and awareness are required [13]. We did find that patients who were discharged to a short-term hospital had lower risk of readmission, which may be due to the increased level of care provided in these facilities as compared to rehab facilities, long-term care facilities, or patients' homes.

Following initial recommendations for follow-up of neonatal and pediatric patients after discharge from ECMO by ELSO that were last reviewed in 1997, improvements in technology and changes in indications for ECMO have led to calls for more standardized and universal follow-up measures in ECMO patient [14–16]. In the Netherlands, follow-up after ECMO is standardized and after discharge patients are seen at a regular schedule until they are 16–18 years of age, with high compliance, and ability to track detailed outcomes such as motor performance, hearing loss, and brain injury. [15,17–20] While there are no studies comparing outcomes in the Netherlands versus other countries without standardized follow-up, it is clear from our results and those published previously that ECMO patients are at high risk for a number of subsequent significant medical issues. Results from our study may aid in identifying factors that put patients at increased risk of later complications and mortality. Close follow-up for these patients may mitigate more serious consequences and allow for earlier intervention to improve developmental issues [14]. Future research should focus on clinical elements that may lead to an increased risk of readmissions or late mortality. Results from database studies such as ours in addition to more focused clinical data can be used together to develop standardized follow-up protocols to best improve long-term outcomes for patients who survive ECMO.

This study had several limitations. Since we utilized a large database, there were several patient and clinical characteristics that we could not account for, such as type of ECMO or length of ECMO run. Additionally, because patient identifiers in the SID are only consistent within each state, readmissions or deaths that may have occurred at a hospital located in a different state than the state in which the index admission occurred were not detected [4].

4. Conclusions

Neonatal and pediatric patients who survive ECMO experience high risk of unplanned readmissions and death during readmission. Further research is needed to standardize follow-up and mitigate risks for readmission and death.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpedsurg.2020.09.035.

References

[1] Gonzalez DO, Sebastião YV, Cooper JN, et al. Pediatric extracorporeal membrane oxygenation mortality is related to extracorporeal membrane oxygenation volume in US hospitals. Journal of Surgical Research. 2019; 236:159–65.

[2] Karamlou T, Vafaeezadeh M, Parrish AM, et al. Increased extracorporeal membrane oxygenation center case volume is associated with improved extracorporeal membrane oxygenation survival among pediatric patients. The Journal of thoracic and cardiovascular surgery. 2013;145(2):470–5.

[3] Zwiers AJ, de Wildt SN, Hop WC, et al. Acute kidney injury is a frequent complication in critically ill neonates receiving extracorporeal membrane oxygenation: a 14-year cohort study. Critical care. 2013;17(4):R151.

[4] Spoel M, Laas R, Gischler SJ, et al. Diagnosis-related deterioration of lung function after extracorporeal membrane oxygenation. European Respiratory Journal. 2012; 40(6):1531–7.

[5] Feudtner C, Feinstein JA, Zhong W, et al. Pediatric complex chronic conditions classification system version 2: updated for ICD-10 and complex medical technology dependence and transplantation. BMC Pediatrics. 2014;14:199.

[6] Freeman CL, Bennett TD, Casper TC, et al. Pediatric and neonatal extracorporeal membrane oxygenation: does center volume impact mortality?*. Critical care medicine. 2014;42(3):512–9.

[7] Barbaro RP, Odetola FO, Kidwell KM, et al. Association of hospital-level volume of extracorporeal membrane oxygenation cases and mortality. Analysis of the extracorporeal life support organization registry. American journal of respiratory and critical care medicine. 2015;191(8):894–901.

[8] Sebastião YV, St. Peter SD. An overview of commonly used statistical methods in clinical research. Seminars in Pediatric Surgery. 2018;27(6):367–74.

[9] Jen HC, Shew SB. Hospital readmissions and survival after nonneonatal pediatric ECMO. Pediatrics. 2010;125(6):1217–23.

[10] Iguchi A, Ridout DA, Galan S, et al. Long-term survival outcomes and causes of late death in neonates, infants, and children treated with extracorporeal life support. Pediatric Critical Care Medicine. 2013;14(6):580–6.

[11] Von Bahr V, Hultman J, Eksborg S, et al. Long-term survival and causes of late death in children treated with extracorporeal membrane oxygenation. Pediatric Critical Care Medicine. 2017;18(3):272–80.

[12] Hamutcu R, Nield TA, Garg M, et al. Long-term pulmonary sequelae in children who were treated with extracorporeal membrane oxygenation for neonatal respiratory failure. Pediatrics. 2004;114(5):1292–6.

[13] IJsselstijn H, van Heijst AF. Long-term outcome of children treated with neonatal extracorporeal membrane oxygenation: increasing problems with increasing age. Seminars in perinatology. Elsevier; 2014. p. 114–21.

[14] IJsselstijn H, Hunfeld M, Schiller RM, et al. Improving long-term outcomes after extracorporeal membrane oxygenation: from observational follow-up programs toward risk stratification. Frontiers in pediatrics. 2018;6:177.

[15] Mac Laren G, Fortenberry J, Tibboel D, et al. Universal follow-up after extracorporeal membrane oxygenation: baby steps toward establishing an international standard of care. Pediatric Critical Care Medicine. 2017;18(11):1070–2.

[16] (ELSO) ELSO. ELSO Recommendations for Follow-Up for ECMO Patients; 1994.

[17] van der Cammen-van MH, Janssen AJ, Raets MM, et al. Motor performance after neonatal extracorporeal membrane oxygenation: a longitudinal evaluation. Pediatrics. 2014;134(2):e427 e35.

[18] Raets MM, Dudink J, IJsselstijn H, et al. Brain injury associated with neonatal extracorporeal membrane oxygenation in the Netherlands: a nationwide evaluation spanning two decades. Pediatric Critical Care Medicine. 2013;14(9):884–92.

[19] van den Hondel D, Madderom MJ, Goedegebure A, et al. Sensorineural hearing loss and language development following neonatal extracorporeal membrane oxygenation. Pediatric Critical Care Medicine. 2013;14(1):62–9.

[20] Madderom MJ, Schiller RM, Gischler SJ, et al. Growing up after critical illness: verbal, visual-spatial, and working memory problems in neonatal extracorporeal membrane oxygenation survivors. Critical care medicine. 2016;44(6):1182–90.