



Extracorporeal Membrane Oxygenation (ECMO) Neuromonitoring and Acute Brain Injury Clinical Pathway Synopsis

Objective of Clinical Pathway

This clinical pathway standardizes the approach to neuromonitoring for patients at high risk of acute brain injury, with the goal of early detection. The ECMO Neuromonitoring and Acute Brain Injury Clinical Pathway will outline special needs and considerations when an intracranial hemorrhage or ischemic brain injury is suspected, as the patient is supported on ECMO.

Background

ECMO supports critically ill patients with cardiopulmonary failure as an advanced lifesaving support technique.¹⁻⁴ Over the past 20 years, the use of ECMO in children has demonstrated a fourfold increase, particularly for those children with severe and refractory cardiac and pulmonary failure.^{2,4} While ECMO has life-saving benefits, this support intervention presents a risk of neurological complications, specifically intracranial hemorrhage, ischemic brain injury, cerebral edema, and seizures.²⁻⁵ Standard neurological monitoring for the early recognition of findings suggestive of a possible acute neurological injury is critical to preventing or limiting the extent of injury.^{1,5}

The ECMO Neuromonitoring and Acute Brain Injury Clinical Pathway Committee recognizes that a framework is needed to assist providers in complex decision-making when managing a child on ECMO support and an acute brain injury is detected. The ECMO Neuromonitoring and Acute Brain Injury Clinical Pathway aims to provide this framework by detailing standard neurological monitoring recommendations and the considerations surrounding the care of these patients.

Target Users

- Physicians (Intensivists [ICN, PICU, CICU], Neurosurgery, Neurology, Hematology, Fellows, Residents)
- Advanced Practice Neonatal/Pediatric Critical Care Nurses
- Nurses (ICN, PICU, CICU)
- ECMO Support Team (ECMO Physician, ECMO Specialist, ECMO Core Team Specialist)

Target Population

Inclusion Criteria

- Patients on ECMO, veno-venous or veno-arterial

AGREE II

The National Institute of Neurological Disorders and Stroke of the National Institutes of Health national guideline provided guidance to the ECMO Neuromonitoring and Acute Brain Injury Clinical Pathway Committee (Pandiyan et al., 2023). See Table 1 for AGREE II.

Table 1

AGREE II Summary for the Clinical Guidelines for Routine Neuromonitoring in Neonatal and Pediatric Patients Supported on Extracorporeal Membrane Oxygenation (Pandiyan et al., 2023)

Domain	Percent Agreement	Percent Justification [^]
Scope and purpose	77%	The aim of the guideline, the clinical questions posed, and the target populations were identified.
Stakeholder involvement	26%	The guideline did not include appropriate stakeholders (such as Hematology) nor the viewpoints of the intended user.
Rigor of development	21%	The guideline developers did not provide information on how the evidence was gathered and synthesized, how the recommendations were formulated, or how the guidelines would be updated.

These clinical pathways do not establish a standard of care to be followed in every case. It is recognized that each case is different, and those individuals involved in providing health care are expected to use their judgment in determining what is in the best interests of the patient based on the circumstances existing at the time. It is impossible to anticipate all possible situations that may exist and to prepare a clinical pathway for each. Accordingly, these clinical pathways should guide care with the understanding that departures from them may be required at times.



Clarity and presentation	81%	The guideline recommendations are clear, unambiguous, and easily identified; in addition, different management options are presented.
Applicability	50%	Barriers and facilitators to implementation and resource implications were addressed in the guideline. The guideline did not address utilization strategies.
Editorial independence	48%	It is unclear if the recommendations were biased by competing interests.
Overall guideline assessment	50%	
See Practice Recommendations		

Note: Four EBP Scholars completed the AGREE II on this guideline.

^ Percentage justification is an interpretation based on the Children's Mercy EBP Department standards.

Practice Recommendations

When a neonate or pediatric patient is supported on ECMO, please refer to the National Institute of Neurological Disorders and Stroke clinical guideline for neuromonitoring recommendations.⁵ However, in the absence of a clinical practice guideline that fully addresses the management of acute brain injury, hemorrhagic and/or ischemic, in ECMO-supported patients, guidance from the pediatric ECMO-associated brain injury literature was integrated with expert consensus from the ECMO Neuromonitoring and Acute Brain Injury Clinical Pathway Committee to inform the assessment, acute management, consults following ECMO decannulation, and discharge recommendations in this pathway. ¹⁻²⁸

Additional Questions Posed by the ECMO Neuromonitoring and Acute Brain Injury Clinical Pathway Committee

- For pediatric patients on ECMO, is tissue plasminogen activator (tPA) a safe and effective treatment for acute ischemic stroke?
 - A literature search was conducted with the assistance of a medical librarian on November 10, 2025, see Appendix 1 for search strategy and results. These results were shared with the committee on November 24, 2025. There is an absence of data modeling stroke management with tPA in this specific clinical context. Therefore, recommendations were not provided regarding the use of systemic tPA for arterial ischemic stroke management in pediatric patients receiving systemic anticoagulation while on ECMO
- For pediatric patients on ECMO, what are the timing and potential risk factors for hemorrhagic transformation after ischemic stroke?
 - A literature search was conducted with the assistance of a medical librarian on November 10, 2025, see Appendix 2 for search strategy and results. These results were shared with the committee on November 24, 2025. Data specific to pediatric patients supported on ECMO is lacking. Therefore, generally known risk factors were considered when developing the clinical pathway

Measures

- Use of the ECMO Neuromonitoring and Acute Brain Injury Clinical Pathway
- Process Metrics
 - Rates of electroencephalogram (EEG) monitoring
 - Rates of post-decannulation magnetic resonance imaging
- Outcome Metrics
 - Rates of brain death/withdrawal of life-sustaining therapy due to brain injury
 - Rates of herniation as surrogates for earlier detection of acute brain injury

Value Implications

The following improvements may increase value by reducing healthcare costs and non-monetary costs (e.g., missed school/work, loss of wages, stress) for patients and families and reducing costs and resource utilization for healthcare facilities.

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- Decreased delay of neuroprotective strategies
- Decreased unwarranted variation in care

Organizational Barriers and Facilitators

Potential Barriers

- Variability of the acceptable level of risk among providers
- Challenges with follow-up faced by some families

Potential Facilitators

- Collaborative engagement across care continuum settings during clinical pathway development
- Anticipated high rate of use of the clinical pathway

Order Sets

- ECMO Cannulation
- ECMO Maintenance
- PICU Post Cardiac Arrest
- PICU Stroke

Order Panels

- ECMO (ECPR) Resuscitation
- ECMO Decannulation

Clinical Pathway Preparation

This pathway was prepared by the Evidence Based Practice (EBP) Department in collaboration with the ECMO Neuromonitoring and Acute Brain Injury Clinical Pathway Committee, composed of content experts at Children's Mercy. If a conflict of interest is identified, the conflict will be disclosed next to the committee member's name.

ECMO Neuromonitoring and Acute Brain Injury Clinical Pathway Committee Members and Representation

- Jessica Wallisch, MD | Critical Care Medicine | Committee Co-Chair
- Jenna Miller, MD | Critical Care Medicine, Pediatric ECMO Director | Committee Co-Chair
- Asdis Finnsdottir Wagner, DO | Critical Care Medicine | Committee Member
- David Garcia, MD | Neurosurgery | Committee Member
- Christian Kaufman, MD, FAANS | Neurosurgery | Committee Member
- Yong Han, MD | Critical Care Medicine | Committee Member
- John Daniel, MD, MS | Neonatology, Neonatal ECMO Director | Committee Member
- Sara McElroy, MD | Hematology/Oncology/BMT | Committee Member
- Shannon Carpenter, MD, MS | Hematology/Oncology/BMT | Committee Member
- Ara Hall, MD | Neurology | Committee Member
- Marcie Files, MD | Neurology | Committee Member
- Jake Arends, MD | Neurology | Committee Member
- Allison Taber, MD | Critical Care Medicine | Committee Member
- Madeline Burdick, MD | Critical Care Medicine | Committee Member
- Kari Davidson, MSN, RN, CCRN | Critical Care Nursing, Extracorporeal Support Director | Committee Member
- Debra Newton, RN, MSN, CCRN | Critical Care Nursing, Extracorporeal Support Director | Committee Member
- Natalee Perrin, BSN, RN, CCRN | Critical Care Nursing, Pediatric Intensive Care Unit | Committee Member
- Kristin Wiegert, PharmD, BCPPS | Pharmacy | Committee Member
- Sarah Dierking, MSN, RN, CPHQ | Clinical Practice and Quality | Committee Member

EBP Committee Members

- Todd Glenski, MD, MSHA, FASA | Anesthesiology, Evidence Based Practice
- Kelli Ott, OTD, OTR/L | Evidence Based Practice

Clinical Pathway Development Funding

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The development of this clinical pathway was underwritten by the following departments/divisions: Critical Care Medicine, Neurosurgery, Neurology, Neonatology, Hematology/Oncology/BMT, ECMO Program, Pediatric Intensive Care Unit, Pharmacy, Clinical Practice and Quality, and Evidence Based Practice

Conflict of Interest

The contributors to the ECMO Neuromonitoring and Acute Brain Injury Clinical Pathway have no conflicts of interest to disclose related to the subject matter or materials discussed.

Approval Process

- This pathway was reviewed and approved by the ECMO Neuromonitoring and Acute Brain Injury Clinical Pathway Committee, content experts, departments/divisions, and the EBP Department; after which, it was approved by the Medical Executive Committee.
- Pathways are reviewed and updated as necessary every 3 years within the EBP Department at Children's Mercy. Content expert teams are involved with every review and update.

Review Requested

Department/Unit	Date Obtained
Critical Care Medicine	April 2026
Neurosurgery	April 2026
Neonatology	April 2026
Neurology	April 2026
Hematology/Oncology/BMT	May 2026
ECMO Program	April 2026
Pharmacy	April 2026
Pediatric Intensive Care Unit	April 2026
Clinical Practice and Quality	April 2026
Evidence Based Practice	April 2026

Version History

Date	Comments
March 2025	Version one: Neurological Monitoring algorithm developed; associated powerplans reviewed and updated
August 2025	Version two: Neurological Monitoring algorithm revised; Intracranial Hemorrhage on ECMO and Post-Neurosurgical Intervention on ECMO algorithms developed; associated order sets and order panels were reviewed; synopsis developed
November 2025	Version three: Neurological Monitoring algorithm revised to further clarify guidance for EEG monitoring
May 2026	Version four: Neurological Monitoring algorithm revised; Intracranial Hemorrhage on ECMO algorithm revised to include link to Neurological Monitoring algorithm; Ischemic Brain Injury on ECMO algorithm developed; associated order sets and order panels reviewed; synopsis revised

Date for Next Review

- May 2029

Implementation & Follow-Up

- Once approved, the pathway was presented to appropriate care teams and implemented. Care measurements will be assessed and shared with appropriate care teams to determine whether changes are needed.
- Order sets and order panels consistent with recommendations were reviewed, and updates were requested.
- Associated policies were reviewed and updated. The policies detail a process for ECMO anticoagulation and treatment for excessive bleeding in an infant or child while receiving ECMO
- Education was provided to all stakeholders:

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Nursing units where the ECMO Neuromonitoring and Acute Brain Injury Clinical Pathway is used
Departments of Neurology, Neurosurgery, and Hematology
Providers from ICN, PICU, and CICU
Resident physicians

- Additional institution-wide announcements were made via email, the hospital website, and relevant huddles.

Disclaimer

When evidence is lacking or inconclusive, options in care are provided in the supporting documents and the order set(s) and/or order panel(s) that accompany the clinical pathway.

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References

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Appendix

Appendix 1. Search Strategies and Results for Tissue Plasminogen Safety

Embase

- 1) 'extracorporeal oxygenation'/exp OR 'extracorporeal membrane oxygenation' OR ecmo
 - 2) 'tissue plasminogen activator'/exp OR 'tissue plasminogen activator'
 - 3) 'efficacy'/exp OR 'efficacy' OR 'drug safety'/exp OR 'drug safety' OR 'pharmacovigilance'/exp OR 'pharmacovigilance' OR 'effectiveness'/exp OR 'effectiveness' OR 'treatment outcome'/exp OR 'treatment outcome'
 - 4) #1 AND #2 AND #3
 - 5) #1 AND #2 AND #3 AND [2015-2025]/py
- Search Dates: 2015-Current
Records identified through Embase database searching, $n = 95$
Additional records identified through other sources, $n = 0$

PubMed

(efficacy OR "drug safety" OR pharmacovigilance OR effectiveness OR "treatment outcome" OR safety) AND "tissue plasminogen activator" AND ("extracorporeal oxygenation" OR "extracorporeal membrane oxygenation" OR ECMO) NOT medline[sb]
Records identified through PubMed database searching, $n = 0$

Appendix 2. Search Strategy and Results for Hemorrhagic Transformation Risk Factors

PubMed

(cerebral hemorrhage OR hemorrhagic transformation) AND stroke AND acute AND risk factors AND ("extracorporeal oxygenation" OR "extracorporeal membrane oxygenation" OR ECMO) AND pediatrics
Records identified through PubMed database searching, $n = 0$

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