



## **Cardiac Surgery: Bypass and Thoracotomy Enhanced Recovery After Surgery Pathway Synopsis**

---

### **Objective of ERAS Pathway**

The objectives of the Cardiac Surgery Enhanced Recovery After Surgery (ERAS) pathway are to minimize variation in care for patients undergoing cardiac surgery, from the pre-admission testing visit through discharge.

### **Background**

Over the past several decades, cardiac surgery in the pediatric population has significantly improved the quality of life and survival rates for patients with congenital heart disease. ERAS pathways have become mainstream in adult surgery and are now gaining recognition and use in pediatric surgery. Implementation of ERAS principles has shown significant improvements in various surgeries regarding length of stay, opioid use, pain control, and return to diet (Fearon, 2005; Thiele, 2014; Liu, 2017). Key elements to ERAS include:

- Preoperative education of patients and family with an introduction to ERAS
- Oral carbohydrate load 2-3 hours before surgery
- Avoidance of prolonged fasting
- No additional bowel preparation
- Standardized anesthesia protocol, including regional or neuraxial anesthesia when possible
- Goal-directed strict intraoperative intravenous fluid therapy guidelines to avoid hypo-or hypervolemia
- Minimize the use of long-acting opioids
- Minimize use of drains and NG tubes when possible
- Initiate early feeding and ambulation

### **Target Users**

- Physicians (Anesthesiologists, Cardiovascular Surgeons, Cardiac Intensivists, Cardiologists, Fellows, Residents)
- Advanced practice nurses (Cardiology, Anesthesiology)

### **Target Population**

#### **Inclusion Criteria**

- Bypass cases
- Coarctation of the aorta cases
- Vascular ring cases
- Patients > 6 months of age
- Patients with American Society of Anesthesiologists (ASA) Physical Status I, II, or III

#### **Exclusion Criteria**

- Repeat sternotomy cases
- Single ventricle physiology
- Pre-op inpatients

### **Core Principles of ERAS**

- Preoperative education of patients and their families with an introduction to ERAS
- Reduced pre-operative fasting, with clear liquid oral carbohydrate loading until 2 hours prior to surgery
- Goal-directed, strict intraoperative intravenous fluid therapy guidelines to avoid hypo-or hypervolemia
- Avoidance of pre-operative mechanical bowel preparation
- Avoidance of routine nasogastric tube use
- Minimizing long-acting opioid analgesia in favor of regional anesthesia with epidural and/or local anesthesia for intra-operative and postoperative pain control when appropriate and using alternative non-opioid medications when appropriate (e.g., non-steroidal anti-inflammatories or acetaminophen)
- Early postoperative mobilization
- Early postoperative enteral feeding

*\* These 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 pathway for each. Accordingly, these pathways should guide care with the understanding that departures from them may be required at times.*



## **ERAS Management Recommendations:**

### **Pre-Operative Care**

- This ERAS protocol begins well before the surgical date. The concept of ERAS is presented to the patient/family at the initial surgical appointment and pre-operative clinic visit and then reinforced during the pre-admission testing (PAT) clinic visit.
- Educational items, including pre-op diet restrictions, medication management, and the risks of anesthesia, are discussed at PAT.
- Also discussed some of the core concepts of ERAS, including the emphasis on early post-op PO intake and a multimodal pain management approach. Expectation management is crucial in the preoperative phase. The ERAS overview handout, approved by the Health Literacy Committee, is given to the family prior to departing PAT.
- On the morning of surgery, the patient drinks carbohydrate-rich liquids two hours before the start of surgery.

### **Intra-Operative Care**

- Pre-Incision Timeout
  - Discussion with surgeon and OR staff to determine if patient has been enrolled in ERAS pathway
- Prevention of Postoperative Nausea/Vomiting
  - Dexamethasone and ondansetron for patients > 2 years old
  - Avoid placement of NG tube
- Prevention of Postoperative Delirium
  - Dexmedetomidine infusion during case with goal of < 0.5 mcg/kg/hr upon handoff in Cardiac Intensive Care Unit (CICU)
- Multimodal Analgesia
  - Sufentanil infusion during procedure with discontinuation prior to exiting the operating room
  - IV acetaminophen 12.5 mg/kg (max 1000 mg)
  - Fentanyl boluses prn
  - Avoidance of long-acting opioids (morphine & hydromorphone)
  - Injection of local anesthetic at the incision site by the surgeon at the end of the procedure
- Coagulation
  - Standard tranexamic acid (TXA) bolus and infusion
  - Normal post-bypass ROTEM
  - No evidence of significant bleeding prior to leaving the operating room
- Temperature Management
  - Achieve normothermia prior to leaving the operating room
- Muscle Relaxants
  - Reversal of muscle relaxant prior to leaving the operating room with sugammadex or neostigmine/glycopyrrolate
  - Goal of spontaneous ventilation upon arrival to CICU

### **Post-Operative Care**

#### **CICU**

- Upon arrival to CICU, the anesthesiologist gives an in-depth hand-off to the CICU, including key ERAS components.
- The CICU team (attending intensivist, resident physicians, APRNs) and charge nurse assess the patient after the CICU handoff.
- Goals of care from CICU admission to enable transfer to the inpatient floor in the post-op period:
  - **Post CVOR Hand-off**
    - ✓ Pain Control
      - Continue dexmedetomidine: < 0.5 mcg/kg/hr, discontinue if unable to wean ventilator support
      - Acetaminophen 15 mg/kg/dose IV every 6 hours for 4 doses
      - Fentanyl 1 mcg/kg/dose every 1 hour as needed for severe pain
      - If appropriate (> 6 months, no anticoagulation), ketorolac 0.5 mg/kg/dose IV every 6 hours once chest tube output is stable, 3-6 hours after arrival from CVOR

*\* These 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 pathway for each. Accordingly, these pathways should guide care with the understanding that departures from them may be required at times.*



- Last line opioids: morphine and hydromorphone
- ✓ Management of Mechanical Ventilation
  - Wean Mechanical Ventilation as Tolerated
  - Extubate when clinically able
  - Goal: extubation time from arrival in CICU is less than 6 hours
- ✓ Imaging/Testing
  - Chest X-Ray
  - EKG
- ✓ Hemodynamic Management
  - Treatment of hypertension per the surgeon's recommended parameters
- ✓ Labs
  - Arterial/Venous Blood gas, Lactic Acid, Ionized Calcium q6h
  - BMP q12h
  - CBC q24h
  - Coagulation studies as clinically indicated
- ✓ Temperature Management
  - Room Temperature, maintain normothermia
- **Post Extubation**
  - ✓ Medications
    - Pain Control
      - Oxycodone 0.05-0.1 mg/kg/dose every 4 hours as needed for moderate-severe pain once tolerating PO intake
      - Morphine IV 0.05-0.1 mg/kg/dose every 2 hours as needed for breakthrough pain
  - ✓ Nausea and Vomiting Prophylaxis
    - If QTc appropriate – ondansetron 0.1 mg/kg/dose IV every 4-6 hours as needed
    - If QTc prolonged (> 480ms) – lorazepam 0.05 mg/kg/dose IV every 4-6 hours as needed
  - ✓ Discontinue famotidine upon resumption of normal diet
  - ✓ Respiratory Support
    - Incentive spirometry q2h while awake if developmentally appropriate
  - ✓ Imaging/Testing
    - Chest x-ray as clinically indicated
  - ✓ Labs
    - Thoracotomy patient - Post extubation Arterial Blood Gas as clinically indicated
    - Bypass patient - Can space out Arterial/Venous Blood gas, Lactic Acid, Ionized Calcium-
  - ✓ Diet
    - Advance diet as tolerated
- **Overnight POD 0-1**
  - ✓ Medications
    - Furosemide 1 mg/kg/dose IV every 8-12 hours
    - Bypass patient – Tylenol 10 – 15 mg/kg/dose every 4 –6 hours as needed
  - ✓ Management of Lines, Drains
    - Removal of Foley Catheter with first dose of Furosemide
    - Removal of Central Venous and Arterial Lines by 0700
  - ✓ Imaging
    - Chest X-ray every morning while chest tubes remain in place
  - ✓ Labs
    - Discontinue Blood Gases/Lactic Acid/Ionized Calcium

**Inpatient floor/Blue Team/4 Sutherland**

- In the ERAS patient population, the post-CV surgery patient will likely meet criteria to transfer from the CICU to the floor on POD1-2
- Once the patient meets the criteria to transfer from CICU to 4Sutherland, CICU gives a hand-off to the Blue Team

*\* These 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 pathway for each. Accordingly, these pathways should guide care with the understanding that departures from them may be required at times.*



- Blue Team providers (attending physicians, resident physicians, APRNs) and the charge nurse assess the patient in the CICU and meet the family in the CICU prior to transferring to the floor.
- Blue Team provides the family with information regarding expected progression towards discharge home and explains the difference in staffing/monitoring on the floor vs. the ICU setting
- Patient is transferred to the floor
- Goals of care on the floor to enable discharge home in the post-operative period:
  - **Wean oxygen** support to room air or home oxygen support. Consider using incentive spirometry if the patient qualifies.
  - **Monitoring of chest tube** output and removal of chest tubes once they meet criteria of less than 10 ml/kg in 24 hours, or 5 ml/kg in 12 hours, or less than 200 ml for older children/teens/young adults
  - **Monitoring of heart rhythm** and removal of temporary pacing wires if not removed in CICU prior to transfer to the floor
  - **Advancing to home diet** – treatment of nausea/vomiting as needed, initiation of bowel regimen to promote the return of bowel function in the post-op period by POD1-2, typically no IV fluids past POD1-2 to encourage PO intake
  - **Pain management**
    - Scheduled ketorolac q6hr in patients greater than six months if age
    - Transition to PO ibuprofen once taking PO – usually POD2, for a total of 7 days of NSAIDs for pain management and anti-inflammatory to prevent pericardial effusion
    - Acetaminophen PRN
    - Oxycodone PRN
    - Morphine PRN, but long-acting IV opioid use is discouraged over other PRN options once on the floor
  - **Physical Activity** – encourage holding of infants by caregivers, ambulation in patients who can walk by POD1-2; Physical therapy evaluation and intervention for older children/teens/young adults if needed
  - **Diuretics** – initially IV, transitioned to enteral once chest tubes are removed, BMPs trended, and electrolytes replaced as needed, kidney function monitored
  - **Discharge Testing** – post-op EKG and echocardiogram, usually the morning of discharge, and Chest X-ray after the removal of chest tubes (also likely AM of discharge)
  - **Discharge Teaching** for post-operative care provided via informational hand-outs in discharge paperwork, as well as through the Get-Well Network video, and reviewed by APRN with family
  - **Incision care** and chest tube site care, and assessment
  - **Follow-up appointments** arranged with CV surgery and primary outpatient cardiologist – email/phone communication made at the time of discharge to ensure a smooth transition of care

#### Additional Questions Posed by the ERAS Committee

No clinical questions were posed for this review.

#### Updates from Previous Versions of this ERAS Pathway

- Following review by content experts, no new updates were identified for the 2025 revision.

#### Key Metrics To Be Monitored:

| Pre-Op                  | Intra-Op                                                        | Post-Op                          |                                  |
|-------------------------|-----------------------------------------------------------------|----------------------------------|----------------------------------|
|                         |                                                                 | CICU                             | Inpatient                        |
| Carbohydrate-rich drink | Avoidance of long-acting opioids                                | Time until extubation            | Chest tube removal               |
|                         | Administration of PONV prophylaxis                              | Avoidance of long-acting opioids | Avoidance of long-acting opioids |
|                         | Neuraxial block/regional block by the surgeon prior to incision | Time to transfer from CICU       | Total length of stay             |
|                         | IV acetaminophen                                                |                                  |                                  |
|                         | Surgical time                                                   |                                  |                                  |

*\* These 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 pathway for each. Accordingly, these pathways should guide care with the understanding that departures from them may be required at times.*



### **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.

- Decreased inpatient length of stay
- Decreased unwarranted variation in care
- Improved communication between patients and care team throughout the perioperative period
- Improved post-operative pain control

### **Organizational Barriers and Facilitators**

#### **Potential Barriers**

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

#### **Potential Facilitators**

- Collaborative engagement across care continuum settings during ERAS development
- High rate of use of the ERAS pathway

### **Bias Awareness**

Bias awareness is our aim to recognize social determinants of health and minimize healthcare disparities, acknowledging that our unconscious biases can contribute to these inequities

### **Order Sets**

- There are no specific power plans associated with or developed for this ERAS pathway

### **Education Materials**

- ERAS overview handout
  - Intended to be a general handout encompassing the key concepts and plan for an ERAS pathway
  - Found on the CM external website for each ERAS pathway
  - Available in English and Spanish
- PT EDU Going Home After Cardiac Surgery (one for infants, one for toddler/school-aged children, and one for adolescents)
  - Intended to provide guidance to the caregiver for the patient following cardiac surgery once discharged home
  - Found in EPIC education
  - Available in English and Spanish

### **ERAS Pathway Preparation**

This ERAS pathway was prepared by the EBP Department in collaboration with the Cardiac ERAS Pathway Committee, composed of content experts at Children's Mercy Kansas City. If a conflict of interest is identified, the conflict will be disclosed next to the committee member's name.

### **ERAS Pathway Representation**

This clinical pathway was originally created in 2022 with representation from Anesthesiology, Cardiac Surgery, Critical Care Medicine, The Heart Center at Children's Mercy, and Evidence Based Practice.

### **Cardiac Surgery ERAS Pathway Revision Representation**

- Joseph Huffman, MD, FASA | Anesthesiology
- Christian Taylor, MD | Anesthesiology
- William Douglas, MD | Cardiac Surgery
- Apurva Panchal, MD | Critical Care Medicine
- Lindsey Malloy Walton, DO, MPH | Cardiology
- Rebecca Juhl, DNP, APRN, CPNP-AC, CCRN | Heart Center

*\* These 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 pathway for each. Accordingly, these pathways should guide care with the understanding that departures from them may be required at times.*



- Sarah Lagergren, APRN | Heart Center

**EBP Committee Members**

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

**ERAS Development Funding**

The development of this ERAS pathway was underwritten by the following departments/divisions: Anesthesiology, Cardiology, Cardiac Surgery, Critical Care Medicine, The Heart Center, and Evidence-Based Practice.

**Conflict of Interest**

The contributors to the Cardiac Surgery ERAS 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 EBP Department and the XX Committee, after the committee members garnered feedback from their respective divisions/departments.

**Version History**

| Date        | Comments                                                                                                                                |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| July 2022   | Version one – algorithms, synopsis, hand-outs for pre-surgery checklist, and surgery overview were developed                            |
| August 2023 | Version two – Updated medications for surgical care and formatted synopsis to include medication updates                                |
| August 2025 | Version three – algorithms and synopsis were updated to the current standard work. No other updates were deemed necessary at this time. |
| March 2026  | Version four – Updated the clinical pathway synopsis to reflect the EPIC patient education found in EPIC education                      |

**Date for Next Review:**

- **August 2028**

**Implementation & Follow-Up**

- Once approved, the ERAS pathway was presented to appropriate care teams and implemented.
- Key metrics will be assessed and shared with the appropriate care teams to determine if changes are needed.
- Pathways are reviewed every 3 years (or sooner) and updated as necessary within the EBP Department at CMKC. Pathway committees are involved with every review and update.

**Disclaimer**

When evidence is lacking or inconclusive, options in care are provided in the supporting documents that accompany the ERAS pathway.

These ERAS 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 to determine 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 ERAS pathways for each. Accordingly, these ERAS pathways should guide care with the understanding that departures from them may be required at times.

*\* These 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 pathway for each. Accordingly, these pathways should guide care with the understanding that departures from them may be required at times.*



## References

- Fearon, K.C., Ljungqvist, O., Von Meyenfeldt, M., Revhaug, C.H., Dejong, K. Lassen, et al. (2005). Enhanced recovery after surgery: a consensus review of clinical care for patients undergoing colonic resection. *Clin Nutr*, 24, 466–477. <https://doi.org/10.1016/j.clnu.2005.02>.
- Liu, V.X., Rosas, E., Hwang, J., Cain, E., Foss-Durant, A., Clopp, M., et al. (2017). Enhanced recovery after surgery program implementation in 2 surgical populations in an integrated health care delivery system. *JAMA Surg*, 152, e171032. <https://doi.org/10.1001/jamasurg.2017.1032>
- Thiele, R.H., Rea, K.M., Turrentine, F.E., Friel, C.M., Hassinger, T.E., McMurry, T.L. et al. (2015). Standardization of care: impact of an enhanced recovery protocol on length of stay, complications, and direct costs after colorectal surgery. *J Am Coll Surg*, 220, 430–443. <https://doi.org/10.1016/j.jamcollsurg.2014.12.042>
- Melnyk, M., Casey, R. G., Black, P., & Koupparis, A. J. (2011). Enhanced recovery after surgery (ERAS) protocols: time to change practice? *Canadian Urological Association Journal = Journal de l'Association des urologues du Canada*, 5(5), 342–348. <https://doi.org/10.5489/cuaj.11002>

\* These 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 pathway for each. Accordingly, these pathways should guide care with the understanding that departures from them may be required at times.