



# Enhanced Recovery After Surgery: Pectus Excavatum

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## Definition

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### Enhanced Recovery After Surgery (ERAS)

Multimodal enhanced recovery after surgery (ERAS) protocols introduce an integrated, multidisciplinary approach that requires participation and commitment from the patient, surgeons, anesthesiologists, pain specialists, nursing staff, physical and occupational therapists, social services, and hospital administration [8,9,10,11]. Initially, ERAS protocols converted many operations performed as inpatient to outpatient "day surgery" procedures. As experience developed with these protocols, principles of enhanced recovery were applied to increasingly complex procedures to reduce hospital length of stay and expedite return to baseline health and functional status [10,11].

ERAS protocols have been developed to reduce physiological stress and postoperative organ dysfunction through optimization of perioperative care and recovery [10,11,13]. Typically, such protocols include perioperative opioid-sparing analgesia, a laparoscopic approach for the surgical intervention, avoidance of nasogastric tubes and drains, aggressive management of postoperative nausea and vomiting, and early oral feedings and ambulation [6,11,13].

The direct implementation of ERAS protocols in children has been limited, primarily by a lack of evidence for extrapolation to the pediatric population. The only meta-analysis performed on ERAS programs used in children found a total of five prior studies that specifically implemented perioperative recovery protocols which included at least four elements of ERAS. The most comprehensive of these only included six components, and none had appropriate controls [13,14]. ERAS protocol development is not about creating new hypotheses for better care but rather focused on organizing the best available scientific evidence into an implementable bundle that helps to standardize care across a practice [6,7]. This guideline describes a standardized approach to the preoperative, intraoperative, and postoperative strategies for pectus excavatum repair surgery in the pediatric patient.

### Pectus Excavatum

Pectus excavatum (PE), or "funnel chest," is a deformity of the chest wall characterized by a sternal depression typically beginning over the midportion of the manubrium and progressing inward through the xiphoid process. The deformity may be symmetric or asymmetric [1,2].

## Epidemiology

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Pectus excavatum (PE) accounts for 90 percent of anterior chest wall disorders [1]. The incidence of pectus excavatum is 1 in every 400 to 1000 live births [1,2]. It is three to five times more prevalent in males than females. It is usually sporadic, but may be associated with connective tissue disorders, neuromuscular disease, and some genetic conditions.

## Etiology

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While there is no consensus for what causes pectus excavatum (PE), there have been a number of hypotheses, ranging from disproportionate muscular force putting abnormal stress and strain on the sternum and costal cartilages, to defective cartilage structure and growth, abnormal rib growth, or combinations thereof [3].

An early theory that PE is caused by abnormal diaphragmatic connections was discarded, because surgical interventions to release the central tendon and substernal ligament in early childhood were not effective [4].

PE is usually sporadic [1], but it has been associated with connective tissue disorders (particularly Marfan syndrome, Ehlers Danlos syndrome, and osteogenesis imperfecta) [5] and neuromuscular disease (i.e., spinal muscular atrophy). It also can be seen in a variety of other genetic conditions, including Noonan syndrome, Turner syndrome, and multiple endocrine neoplasia type 2b [6].

The increased prevalence of PE in connective tissue disorders suggests the possibility that it is caused by abnormal cartilage development [7]. In particular, some authors have hypothesized that the deformity is caused by abnormalities of cartilage remodeling due to an imbalance between cartilage growth-promoting and growth-inhibiting genes [1].

PE may also occur in response to underlying pulmonary conditions. Patients with a repaired congenital diaphragmatic hernia are prone to PE, presumably because the axis of contraction of the diaphragm is more horizontal than vertical, so that the diaphragm pulls the lower edge of the sternum inward [1]. Patients with spinal muscular atrophy type 1 are also prone to developing PE, presumably because the chest wall is highly compliant and unable to resist intrapleural pressure variation during respiration; these forces gradually deform the sternum over time. PE also can occur in children with subglottic stenosis and bronchopulmonary dysplasia [1].

## Guideline Inclusion Criteria

All patients undergoing surgical repair of pectus excavatum

## Guideline Exclusion Criteria

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None

# Evidence for implementing ERAS for Surgical Repair of Pectus Excavatum

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The goals of enhanced recovery after surgery (ERAS) protocols include attenuating the surgical stress response and reducing end organ dysfunction through integrated preoperative, intraoperative, and postoperative pathways. Discharge criteria with ERAS are similar to those of traditional care, but patients receiving ERAS care meet these discharge criteria sooner [6,7,8,9].

ERAS protocols typically include 15 to 20 elements combined to form a multimodal pathway. These elements span through the continuum of the preoperative, intraoperative, and postoperative periods. Separately, individual elements result in modest gains, but when used together in a complementary fashion, they can decrease postoperative stress responses, thereby reducing duration of postoperative ileus, surgical complications, incisional pain, recovery time, and length of hospital stay [6,7,8,9]. Of the 15 to 20 recommended elements, the relative contribution of each individual element is unknown [6,7,8,9].

Preoperative strategies — Preoperative strategies of ERAS protocols involve medical risk evaluation, interventions, patient education, and fasting policies.

- Medical risk evaluation and interventions — ERAS programs require optimization of medical comorbidities, including cardiovascular, respiratory, and/or renal disease, as indicated by the surgical condition.
- Social and behavioral factors, such as illicit drug use, tobacco smoking, and alcohol dependency should be addressed.
- Patient education — Patient education, including discussions regarding physical and occupational health, routine postoperative care, recovery milestones, and a review of signs and symptoms that warrant a post-discharge surgical evaluation, helps patients adhere to an ERAS program [11].
- Fasting guidelines — Fasting reduces the risk of aspiration of gastric contents during a general anesthetic by reducing gastric volume and acidity. Preoperative fasting guidelines have been established by the American Society of Anesthesiologists (ASA) and are based upon randomized trials and nonrandomized comparative studies [14,15,16].
- Clear liquids — The ASA guidelines recommend fasting for at least two hours from clear liquids and all other intake, including medicines [15]. Patients may consume clear liquids include nonalcoholic beverages such as water, juices without pulp, coffee or tea without milk, and carbohydrate drinks up until two hours before surgery. This approach to fasting helps avoid symptoms of dehydration, hypoglycemia, and caffeine withdrawal. For ERAS protocols, it is critical to minimize the fasting period; thus, we encourage patients to consume clear liquids until two hours prior to surgery to remain hydrated. Typically, we advise patients to drink at least two glasses of water before going to bed the night before surgery and two glasses of water before traveling to the hospital on the morning

of surgery. There is no evidence that restriction of the volume of clear liquids is beneficial [16].

- Carbohydrate-rich drink — Many ERAS protocols prescribe a carbohydrate-rich drink two hours prior to surgery. This practice has been suggested as a method to convert the patient from the "fasted" to the "fed" state, reducing postoperative insulin resistance and postoperative weight loss [17].
- Optimization of patient's body temperature through convective warming measures with a forced-air warming system such as Bair-Hugger®.

Intraoperative strategies — Intraoperative strategies in ERAS protocols include selection of anesthetic and adjuvant agents, lung-protective ventilation, fluid management, temperature regulation, and choice of the surgical approach.

- Selection of anesthetic agents — Multimodal analgesic strategies are preferred.
  - Typical anesthetic regimens include:
    - General anesthesia with sevoflurane, desflurane, or Propofol infusion.
    - Minimization of total intraoperative opioid doses.
    - Use of short-acting neuromuscular blocking agents (NMBAs) and use of a peripheral nerve stimulator to avoid profound muscle paralysis. Residual effects of an NMBA should be appropriately reversed at the end of surgery. Persistent muscle weakness often leads to postoperative respiratory complications.
- Selection of adjuvant medications – Including ketamine (0.5-1.0 mg/kg); ketorolac (0.5mg/kg); IV opioids for analgesia and Zofran; dexamethasone for control of nausea.
- Lung-protective ventilation — The primary goals for intraoperative ventilation are to provide nonharmful ventilation that opens the lungs and keeps them open into the postoperative period. We suggest the use of lung-protective ventilation for all patients who receive mechanical ventilation during anesthesia. For most patients, we suggest low tidal volumes of 6 to 8 mL/kg, initial positive end-expiratory pressure (PEEP) of 5 cm H<sub>2</sub>O (10 cm H<sub>2</sub>O during laparoscopy), and plateau pressures ≤16 mmHg.
- Intraoperative fluid management — Intraoperative fluid management is aimed at restoring and maintaining euvolemia.
  - Restrictive fluid therapy (i.e., zero-balance approach) avoids fluid overload by replacing only the fluid that is lost during surgery. Given that the ERAS goals for perioperative fluid management include avoidance of either hypovolemia or excessive fluid administration that may result in pulmonary complications, we typically use restrictive fluid therapy to minimize fluid administration, rather than the other two strategies.
- Temperature regulation — Changes in body temperature that occur with exposure during the procedure and alterations in temperature regulation due to anesthetic agents may lead to coagulopathy, adverse cardiac events, and decreased resistance to surgical wound infections [24]. Data from a randomized trial demonstrated that intraoperative hypothermia prolonged the duration of time in the recovery room compared with routine thermal management (mean 94 versus 53 minutes) [25]. Hypothermia is most likely

to occur when procedures are longer than two hours, in the extremes of age, in those with little body fat, and in those with comorbid illnesses [24-27]. Body temperature monitoring and routinely use body warmers for all patients undergoing surgical procedure is a component of ERAS protocol.

- Surgical approach — Minimally invasive techniques are central to ERAS protocols because they decrease inflammatory mediator release, improve pulmonary function, expedite return of bowel function, and reduce length of hospital stay [28-35].
- Intercostal nerve cryoablation — Cryoablation temporarily blocks nerves from transmitting pain signals for several months giving the body time to heal. When used as an adjunct to other pain management modalities, patients undergoing thoracic surgical procedures have reported improvement in overall management of post-operative pain, recovery times, and satisfaction [46-51].

Postoperative strategies — Postoperative goals in ERAS protocols include prevention and relief of pain or nausea and vomiting, and facilitation of early nutrition and mobilization.

- Pain management — Optimal perioperative pain management enhances recovery after surgery by facilitating postoperative ambulation and rehabilitation. Procedure-specific multimodal analgesia that minimizes opioid use is ideal [36,37].
  - For patients undergoing laparoscopic procedures, non-opioid analgesics (i.e., acetaminophen and a nonsteroidal anti-inflammatory drug [NSAID] or cyclooxygenase [COX]-2 specific inhibitor) in combination with local anesthetic infiltration at the portal sites or selective regional anesthesia[38].
- Postoperative fluid management — There is little consensus regarding optimal strategies for fluid management after surgical procedure in children and adolescents. Before oral intake is allowed, patients typically receive an infusion of a balanced salt solution (i.e., Lactated Ringers) at maintenance rate, with boluses of 20 mL/kg if necessary to treat hemodynamic instability and/or inadequate urine output. Intravenous fluid administration should be discontinued as soon as the patient can tolerate oral liquids. Although maintenance of a minimum hourly UO of 1.0 mL/kg is a common goal, limited data support this practice.
- Diet — ERAS programs incorporate resumption of a diet within a few hours after surgery and can be supplemented with high-calorie drinks to minimize the negative protein balance after surgery. This contrasts with the traditional approach where oral feedings were withheld until signs of bowel activity (i.e., bowel sounds, flatus, bowel movement) were evident.
- Early mobilization — Early mobilization is a key element of ERAS protocols for all post-operative patients capable of ambulation [42]. Early mobilization is essential to reducing the risk of postoperative pneumonia [43,44] and venous thromboembolism. Involving hospital resources such as physical and occupational therapists can help achieve the goal of early mobilization.

# Clinical Management: ERAS Components for Surgical Repair of Pectus Excavatum

Phase of Care	ERAS Element	Additional details
Preoperative	Presurgical counseling and education	Surgeon and/or Advanced Practice Provider will discuss the following: <ul style="list-style-type: none"> <li>□ Optimization of health prior to surgery</li> <li>□ Managing pain</li> <li>□ Post-op mobility challenges</li> <li>□ Referral to DCMC Outpatient PT/OT</li> <li>□ Distribution of ERAS Education Booklet and chlorhexidine soap</li> </ul>
Preoperative	Fluid and carbohydrate loading	Gatorade or Powerade 2 hours prior to surgery
Preoperative	No prolonged fasting	Gatorade or Powerade 2 hours prior to surgery
Preoperative	Skin preparation	Chlorhexidine wash night before and morning of surgery
Preoperative	Antibiotic prophylaxis	In accordance with <a href="#">DCMC General Surgery Antimicrobial Selection and Dosing Recommendations</a> policy
Preoperative	Thromboprophylaxis	SCDs for all patients >14 yrs
Pre-operative	Optimization of patient's body temperature	Initiation of convective warming via forced air warmer pre-operatively and maintenance throughout the surgical case
Intraoperative	Initiation of patient-controlled analgesia (PCA)	PCA with short-acting narcotic analgesic
Intraoperative	Avoidance of fluid overload	Restrictive fluid therapy throughout surgical case
Intraoperative	Maintenance of normothermia	Temperature monitoring throughout case, use of warming measures to promote temp >36C
Intraoperative	Intercostal nerve cryoablation	Use of cryoablation to temporarily block nerve transmission of pain signals
Postoperative	Continuation of PCA	PCA with short-acting analgesic
Postoperative	Prevention of nausea & vomiting	Use of multimodal medications (i.e. Zofran®, or dexamethasone) to reduce nausea and vomiting
Postoperative	Avoidance of fluid overload	Balanced salt solution at maintenance rate to maintain urine output of 1.0mL/kg/hr.
Postoperative	Early oral nutrition	Clear fluids as soon as reasonably able to tolerate.

Postoperative	Non-opioid analgesia	Multimodal medications (i.e. ketorolac, acetaminophen, gabapentin, and valium) for analgesia.
Postoperative	Early mobilization	Up to side of bed within 6 hours of surgery POD#0, ambulating in hall POD#1. Activity restrictions include: <ul style="list-style-type: none"> <li><input type="checkbox"/> No bending at chest or waist</li> <li><input type="checkbox"/> No twisting</li> <li><input type="checkbox"/> No log rolling</li> <li><input type="checkbox"/> No raising arms above shoulders</li> <li><input type="checkbox"/> No heavy lifting for two months after surgery</li> <li><input type="checkbox"/> No sports for three months after surgery</li> </ul>
Postoperative	Stimulation of gut motility	Chewing gum on arrival to inpatient bed
Postoperative	Pulmonary toilet	Use of incentive spirometry within 4 hours of surgery POD#0, and hourly when awake thereafter



# Clinical Management: Post-Operative Goals after Surgical Repair of Pectus Excavatum

	Post-Op Day 0	Post Op Day 1	Post Op Day 2
Nursing Assessment	<ul style="list-style-type: none"> <li><input type="checkbox"/> Vital signs as ordered</li> <li><input type="checkbox"/> Pulse oximetry</li> <li><input type="checkbox"/> Braden Q Risk Assessment q shift</li> </ul>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Vital signs as ordered</li> <li><input type="checkbox"/> Pulse oximetry</li> <li><input type="checkbox"/> Braden Q Risk Assessment q shift</li> </ul>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Vital signs as ordered</li> <li><input type="checkbox"/> Pulse oximetry</li> <li><input type="checkbox"/> Braden Q Risk Assessment q shift</li> </ul>
Respiratory	<ul style="list-style-type: none"> <li><input type="checkbox"/> IS instruction</li> <li><input type="checkbox"/> Set volume and hourly while awake goal</li> </ul>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Continue IS hourly while awake</li> <li><input type="checkbox"/> Monitor for decrease in volume or no progression</li> </ul>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Continue IS hourly while awake</li> <li><input type="checkbox"/> Monitor for decrease in volume or no progression</li> </ul>
Diet/Bowel	<ul style="list-style-type: none"> <li><input type="checkbox"/> Encourage p.o. fluids</li> <li><input type="checkbox"/> Advance diet as tolerated</li> <li><input type="checkbox"/> Supplement nutrition with protein shakes</li> <li><input type="checkbox"/> Chewing gum TID for 30 min daily</li> <li><input type="checkbox"/> Stool softeners as ordered</li> </ul>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Encourage p.o. fluids</li> <li><input type="checkbox"/> Advance diet as tolerated</li> <li><input type="checkbox"/> Supplement nutrition with protein shakes</li> <li><input type="checkbox"/> Chewing gum TID for 30 min daily</li> <li><input type="checkbox"/> Stool softeners as ordered</li> </ul>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Encourage p.o. fluids</li> <li><input type="checkbox"/> Advance diet as tolerated</li> <li><input type="checkbox"/> Supplement nutrition with protein shakes</li> <li><input type="checkbox"/> Chewing gum TID for 30 min daily</li> <li><input type="checkbox"/> Stool softeners as ordered</li> </ul>
Pain	<ul style="list-style-type: none"> <li><input type="checkbox"/> PCA</li> <li><input type="checkbox"/> Comfort care orders</li> <li><input type="checkbox"/> Expect scheduled gabapentin, acetaminophen, ketorolac, and valium</li> </ul>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Expect weaning of PCA</li> <li><input type="checkbox"/> Expect scheduled oxycontin</li> <li><input type="checkbox"/> Continue scheduled gabapentin, acetaminophen, ketorolac, and valium</li> </ul>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Continue scheduled oxycontin, gabapentin, acetaminophen, and valium</li> <li><input type="checkbox"/> Expect transition from ketorolac to ibuprofen</li> <li><input type="checkbox"/> Expect scheduled robaxin</li> </ul>
Activity	<ul style="list-style-type: none"> <li><input type="checkbox"/> Out of bed within 4 hours of admission</li> <li><input type="checkbox"/> Out of bed with meals</li> <li><input type="checkbox"/> Educate activity restrictions</li> <li><input type="checkbox"/> PT &amp; OT consult before end of day</li> </ul>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Out of bed with meals</li> <li><input type="checkbox"/> Ambulate a minimum of four times</li> <li><input type="checkbox"/> Educate activity restrictions</li> <li><input type="checkbox"/> PT &amp; OT evaluation and treatment</li> </ul>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Out of bed with meals</li> <li><input type="checkbox"/> Ambulate a minimum of four times</li> <li><input type="checkbox"/> Educate activity restrictions</li> <li><input type="checkbox"/> PT &amp; OT evaluation and treatment</li> </ul>

# Executive Summary

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## **Revision History**

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Revision Dates:

Next Revision Date: 8/01/2022

## **ERAS for Surgical Repair of Pectus Excavatum Team:**

Erich Grethel, MD

Matt Roberts, MD

Mary Lauden, RN

Tammie Warren, APRN

Jason Kearns, RN

Dave Golder, RN

Tara Monde, RN

Tania Cheng, RN

Vicki Suefferlein, RN

Lilian Juneau, RN

Jordan Ruch, CCLS

Cleofas Arenas, RN

Katie Bookout, RN

Kristine Crump, RN

Danielle Casper, RN

Komal Arce, PT

## **Recommendations**

Practice recommendations were directed by the existing evidence and consensus amongst the content experts. Patient and family preferences were included when possible.

## **Approval Process**

EBOC guidelines are reviewed by DCMC content experts, the EBOC committee, and are subject to a hospital wide review prior to implementation. Recommendations are reviewed and adjusted based on local expertise.

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