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ERAS: A New Era in Paediatric Surgical Care

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Introduction

The Institute of Medicine's landmark report, "To Err Is Human", sparked a major transformation in clinical and surgical care. It inspired a renewed commitment to safety, quality, and patient-centred care as essential pillars of healthcare.(1) Today, this change in surgical safety and quality is seen in the development and widespread adoption of Enhanced Recovery After Surgery (ERAS) protocols.(2)

ERAS is a multidisciplinary, evidence-based approach aimed at improving clinical outcomes and patient satisfaction, reducing complications, and shortening length of hospital stay. The concept of ERAS was introduced by Henrik Kehlet's pioneering hypothesis, which postulated that postoperative morbidity and recovery time could be significantly reduced by implementing a coordinated, multimodal approach focused on minimizing the body's surgical stress response and maintaining physiological homeostasis. These included eliminating the negative sequelae of pain, cognitive dysfunction, cardiac and pulmonary complications, and nausea and vomiting. (3)

Adult ERAS guidelines have now been published across 15 different surgical specialities. The first was developed for patients undergoing colorectal surgery, and subsequent guidelines have largely been adapted from this foundational work. Over the past two decades, these protocols have shown well-established benefits in the adult population. These include 30–50% reductions in both hospital length of stay and hospital readmissions. (4) However, ERAS principles for paediatric patients have lagged behind. In 2018, the inaugural ERAS Society Paediatric World Congress was held, and the first Paediatric ERAS Society Committee was established to direct protocol development. (3)

Key differences in Paediatric ERAS

ERAS requires adaptation to age-related physiological and psychological differences, as paediatrics includes a more heterogeneous group of patients ranging from neonates to adolescents. There are also unique groups of paediatric surgical populations that lack comparison to adults, such as the repair of congenital malformations.(2)

Phases and Role players in ERAS

For pediatric ERAS principles to be successful, a holistic approach to patient care is essential. A shift from silo-based care to a multidisciplinary, patient-centered approach needs to be adopted with team decision-making, taking into consideration all aspects of a patient's surgical journey.(3) The ERAS team consists of core and ancillary support members. The core members include surgeons, anaesthetists, nursing staff and the patient with their family. Ancillary team members include paediatricians, neonatologists, allied health staff (dietitians, pharmacists, physiotherapists and occupational therapists),

administrative staff, and key hospital stakeholders. Each team member plays an important role in each phase of the ERAS journey, ensuring protocol adoption, implementation, compliance, and monitoring. The phases of ERAS are depicted below with the roles of the core team members described further.



Figure 1: Phases of ERAS

The role of the surgeon (4, 5)

Pre-admission and pre-operative phase:

- Patient selection for ERAS. *Table 1* lists procedures which have been shown to benefit from ERAS protocols.
- Patient and family education and support, including management of expectations.
- Working in conjunction with the anaesthetist in implementing pre-operative orders.

Intraoperative phase:

- Use of minimally invasive surgical techniques.
- Minimising use of peritoneal drains, NGTs and urine catheters unless use is required.

Post-operative phase and follow up:

- Work with the nursing team and allied health staff to ensure that patients are achieving their postoperative goals, assessing for safe discharge home, and scheduling a routine follow-up date.

Table 1: Candidate Paediatric ERAS Conditions (5)

Paediatric Surgery • Colorectal surgery • Enterostomy Closures • Lung Resections • Solid Tumour Resections • Appendectomy • Neonatal Bowel Surgeries	Otorhinolaryngology • Complicated Aspirations • Endoscopic sinus surgery • Tympanoplasty Ophthalmology • Cataract surgery • Strabismus surgery
Neurosurgery • Craniosynostosis surgery • Ventriculo-peritoneal shunts	Urology • Ureteral re-implantation • Pyeloplasty
Orthopaedic Surgery • Scoliosis surgery	Craniofacial • Cleft Palate Repair

The role of the anaesthetist (4, 5)

Pre-admission and pre-operative phase:

- Review of surgical and anaesthetic plan with patient and family.
- Initiation of a multi-modal analgesia plan.
- Implementation of appropriate fasting guidelines.
- Assessing postoperative nausea and vomiting (PONV) risk and need for anxiolysis.

Intraoperative phase:

- Balanced anaesthetic technique, ensuring haemodynamic stability and minimising side-effects that delay recovery.
- Use of multimodal analgesic techniques, limiting the use of opioids and creating regional anaesthesia protocols.
- Maintaining zero-status fluid balance.

Post-operative phase and follow up:

- Offering acute pain services and ensuring an adequate post-operative pain management plan is in place.
- Continued prevention of PONV.
- Monitoring for and treating chronic pain.

The role of the nursing team and allied health staff

The nursing team and allied health staff are an important part of the ERAS programme's "implementation team". They play a key role in reinforcing the ERAS care plan with the patient and family, ensuring that pre- and post-operative orders are implemented, and that post-operative goals are met. (4, 5)

The role of the patient and family

ERAS protocols are developed with the principle **"nothing about us, without us."** This means the patient is at the centre of every decision and should always be included in the process. In paediatrics, the patient-family core is unique, therefore the family's viewpoint matters, and ERAS protocols should not add extra burden to them. Cooperation and effort from both the patient and the family are essential for successful ERAS implementation from pre-admission through follow-up. (4, 5)

Principles of ERAS

For ERAS to be effective, its principles must be consistently applied. A common shortfall is applying only a portion of the elements, thereby losing their full clinical advantage. While each surgical procedure has its own tailored pathway, there are several general core principles that consistently underpin improved outcomes, these are discussed further below.

Preoperative Phase

The theme of the pre-operative phase is **patient and family education and patient optimisation**. (4, 6-8)

The following goals and principles apply to the pre-operative phase:

- **ERAS Principle: Patient and Family preparation: Biopsychosocial**

Goal: *Set expectations and offer information in the form of counselling and an information package.*

Patient and parental involvement, education, expectation management, and counselling have been shown to be central to adhering to the ERAS guidelines. Use of ERAS information leaflets in the patient's native language can help them understand the process and goals. Education provided to the child should be age-appropriate. This helps alleviate anxiety and improve overall satisfaction.

- **ERAS Principle: Prehabilitation and optimisation of chronic conditions**

Goal: *Optimize co-morbidities to stable physiology.*

Patients with chronic illnesses should be well controlled and on best medical therapy prior to surgery. Malnourished patients should receive nutritional support and those with chronic lung disease should receive pre-operative physiotherapy or respiratory muscle training.

Identification of high-risk patients with ASA scores >2, syndromic manifestations, complicated comorbidities, and severe obstructive sleep apnoea should be conducted, and these patients should be omitted from the ERAS programme.

- **ERAS Principle: Fasting guidelines and Carbohydrate Loading**

Goal: *Complex carbohydrate drinks between 1 and 2hr pre-operatively.*

All non-diabetic patients should receive oral preoperative carbohydrate loading with a clear liquid complex carbohydrate drink. If not available, apple juice or electrolyte drinks are alternatives.

There are several recommendations regarding the volume and timing of preoperative clear fluid intake. While the ERAS guidelines suggest 10ml/kg, with a maximum of 350mls 1-2 hours preoperatively; in our setting, the 2019 PACSA *Consensus Statement on Clear Fluids Fasting for Elective Paediatric General Anaesthesia* is followed, allowing up to 3 mL/kg of clear fluid up to 1 hour before induction. Gastric emptying of water occurs within approximately 30 minutes and is even faster for glucose-containing fluids. MRI studies support this, showing that residual gastric volumes return to baseline within 1 hour.

In children who have not been weighed, age-based volume banding may be used, although supporting evidence is limited. Suggested maximum volumes are 55 mL for ages 1–5 years, 140 mL for 6–12 years, and up to 250 mL for those older than 12 years.(9)

This aims to avoid the negative effects of prolonged fasting. These include insulin resistance, depletion of glycogen reserves, depletion of intravascular volume and protein breakdown leading to a catabolic state with decreased overall muscle strength.

- **ERAS Principle: Pre-medication and Anxiety Management**

Goal: *Minimise the stress response, improve co-operation and reduce emergence delirium.*

Non-pharmacological methods such as parental presence, play therapy and education videos assist in anxiety reduction.

Pharmacological agents should be used where indicated. Long-acting sedatives should be avoided with clonidine and dexmedetomidine becoming more popular as a premedication. Ensure the correct dose and timing of pre-medication to ensure it is efficacy.

- **ERAS Principle: Avoidance of oral mechanical bowel preparation (MBP)**

Goal: *Reduce risk of dehydration and electrolyte abnormalities.*

Patients should not receive routine oral laxatives, suppositories or other bowel prep agents. This requires an additional day of hospitalisation for preparation and invasive procedures such as; insertion of an NGT for administration, an IV line for fluid administration, and additional laboratory tests to ensure electrolyte balance, with little associated benefit.

The aim of MBP is to reduce complications associated with faecal bacterial contamination and wound sepsis. In a retrospective review of 272 children where MBP was administered for reversal of colostomy, an increased risk of wound sepsis and length of hospital stay was found.

- **ERAS Principle: Thrombosis prophylaxis**

Goal: *Reduce the risk of peri-operative DVT and PE.*

Thromboprophylaxis in paediatric patients remains controversial, as the overall risk of VTE is relatively low, and there is currently no validated paediatric surgical risk stratification tool equivalent to the adult Caprini score. Risk factor-based assessment is therefore commonly used in clinical practice. Common risk factors are listed in the table below. (10) Patients with one or more risk factors for developing DVT should have compression stockings prior to induction of anaesthesia and receive pharmacological prophylaxis with low molecular weight heparin postoperatively. Use of sequential compression devices prior to induction in patients aged 10 years or older is recommended.

Table 2 showing risk factors for VTE in Paediatrics	
Age	Incidence of VTE highest age <1 or >13 yrs
Central venous catheter	Present in >90% of neonatal VTE and >33% of other cases Highest risk if CVC in lower limb > subclavian > jugular, Risk may be higher in PICC lines
Surgery	Present in 10–15% of cases
Malignancy	Doubles risk of VTE, High risk with acute lymphoblastic leukaemia
Infection/sepsis	Present in >33% cases
Major trauma/burns	Present in approximately 10% of cases
Drugs	Chemotherapy, Oestrogen contraceptive pill (3-fold increase), Parental nutrition
Immobility	Present in 25% of cases of prolonged bed rest
Congenital thrombophilia	Factor V Leiden, Antithrombin III deficiency, Protein C/S deficiency, Increased factor VIII
Acquired thrombophilia	Nephrotic syndrome, Antiphospholipid syndrome, Connective tissue disease
Obesity	Increased incidence of VTE
Cardiac disease	Congenital heart disease and its surgery
Inflammatory bowel disease	Ulcerative colitis greater than Crohn's disease
Sickle cell disease	
Venous anomalies	IVC atresia, May–Thurner syndrome

Intraoperative Phase

This phase emphasises **prevention** and incorporates multiple intraoperative interventions to prevent anaesthetic and surgical complications. (4, 6-8)

- **ERAS Principle: Anaesthetic Technique**

Goal: *Rapid emergence with reduction in post-operative neurocognitive dysfunction.*

To ensure adequate control of the surgical stress response, adequate depth of anaesthesia and multimodal analgesia should be administered. Other factors include hemodynamic control, adequate oxygenation, and lung-protective ventilation strategies, with prevention of atelectasis.

Appropriate management of neuromuscular blockade, including train-of-four monitoring and adequate reversal of blockade is recommended to reduced postoperative respiratory complications.

The benefit of total intravenous anaesthesia vs volatile anaesthesia remains a debated topic, and consideration of patient factors and anaesthetist expertise should guide this decision. The table below outlines the pros and cons of the use of TIVA. (11)

Table 3: Pros and Cons of TIVA use in paediatrics		
	Pros	Cons
Clinical	• Reduction in airway reactivity • Hypoxic pulmonary vasoconstriction intact • Enhanced ciliary function • Reduced emergence delirium • Reduced PONV • Safe in malignant hyperthermia	• Risk of bacterial contamination • Pain on injection • Risk of associated metabolic phenomena; PRIS, lactic/metabolic acidosis
Practical	• Less interference with neuromonitoring • Titratable, easy delivery via pump • Maintenance of SV for remote site anaesthesia • Use in airway surgery or shared airway procedures	• Requires I.V. access and infusion pumps • Potential for disconnection, risk of awareness • Lack of EEG monitoring availability or reliable depth of anaesthesia monitor
Other	• No atmospheric pollution of vapours • Associated with overall reduced costs • Patients with a fear of facemasks	• Accumulation in prolonged procedures or obese patients • Environmental effect: plastic and propofol waste • Disposables may be costly

ERAS Principle: Pre-emptive Analgesia

Goal: *Reduction of chronic pain and opioid related side effects.*

Multimodal analgesia principles should be used, minimising the use of opioids to less than 0.3mg/kg intravenously of morphine or equivalent. Intravenous paracetamol has been shown to reduce total opioid consumption, oversedation and duration of monitoring in the PACU.

Regional anaesthesia, such as epidural, caudal, catheter-based regional blocks (transversus abdominis plane catheters, quadratus lumborum catheters, erector spinae plane catheters), and wound catheters are superior to systemic analgesia and should be performed when indicated, with the caregiver's consent. Regional anaesthesia has been shown to attenuate the pro-inflammatory and metabolic responses associated with surgical stress. It may also decrease the intraoperative requirements of volatile and intravenous anaesthetic agents.

Local anaesthetic dosing should not exceed the maximum dose in order to avoid local anaesthetic systemic toxicity.

- **ERAS Principle: Antimicrobial prophylaxis and surgical site preparation**

Goal: *Antimicrobial prophylaxis should be administered within 60 minutes prior to skin incision.*

Surgical site prepared with chlorhexidine-alcohol to prevent wound sepsis.

- **ERAS Principle: Fluid and Blood Management**

Goal: *Maintain euvoemia.*

The recommended initial fluid rate is between 2-5mls/kg/hour, this can be decreased for laparoscopic surgery and increased for open procedures with greater losses. Fluid management should be goal-directed, using dynamic monitors of fluid responsiveness if available, avoiding fluid overload and glucose imbalance. Decisions should be made clinically based on the fluid status of the patient.

- **ERAS Principle: Temperature Management**

Goal: *Keep core temperature between 36°C-38°C intraoperatively.*

Normothermia should be maintained with active warming. This avoids the negative effects of perioperative hypothermia, such as increased oxygen consumption and metabolic demand, delayed drug metabolism and prolonged recovery from anaesthesia, arrhythmias, coagulopathy with increased perioperative blood loss, increased risk of surgical site infection and impaired wound healing

- **ERAS Principle: Post-operative Nausea and Vomiting (PONV) Prevention**

Goal: *Offer PONV prophylaxis according to risk stratification.*

Risk stratification for PONV should be done; the 4-point paediatric-specific Eberhart scale can be used. All patients with ≥ 2 risk factors (surgery ≥ 30 mins, age ≥ 3 , strabismus surgery and history of PONV) should be offered multimodal PONV prophylaxis, involving adequate preoperative hydration, minimal use of opioids and anaesthetic gases.

A more comprehensive perioperative risk stratification tool developed by the American Society for Enhanced Recovery and Perioperative Medicine is depicted below. This tool incorporates pre, intra and postoperative risk factors, as well as recommendations for prophylaxis and rescue therapy.(12)

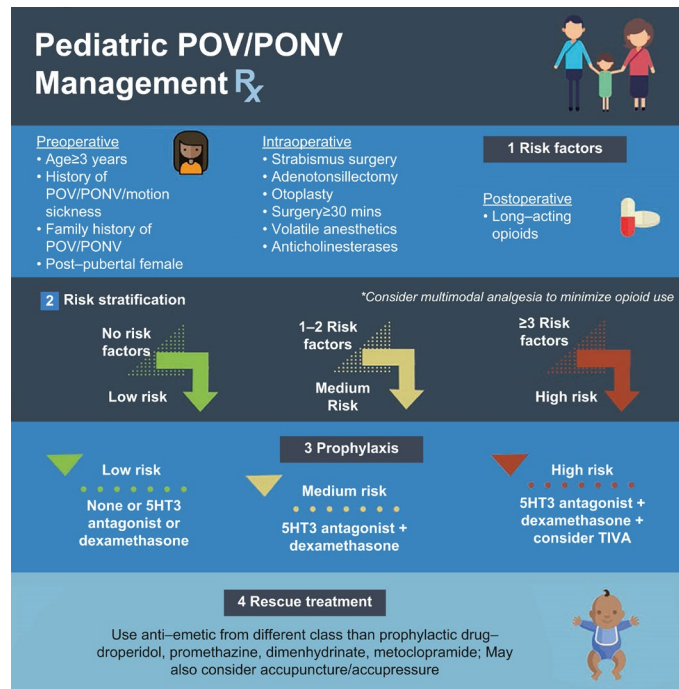


Figure 2: PONV prophylaxis- American Society for Enhanced Recovery and Perioperative Medicine

- **ERAS Principle: Minimally invasive surgical approach**

Goal: Reduce tissue trauma and scarring to expedite recovery.

Laparoscopic or robotic surgery should be performed whenever possible and if technical skill is available.

- **ERAS Principle: Avoidance of unnecessary drains and catheters**

Goal: Reduction of sepsis and postoperative pain.

Perianastomotic and/or pelvic drains can be safely omitted. Early removal of drains was required by day 4 postoperatively. Transurethral catheters should be removed on day 1 postoperatively if there is a low risk of urinary retention.

- **ERAS Principle: Avoidance of nasal and/or orogastric tubes (NGT)**

Goal: Remove prior to leaving theatre if used.

Orogastric tubes can be placed to drain gastric contents if required, but should be kept in situ temporarily.

Postoperative Phase

The theme of this phase evolves around **rapid recovery**. This begins in the post-anaesthetic care unit (PACU) and continues until discharge, with the majority of the focus on the first post-operative day. (4, 6-8)

- **ERAS Principle: Optimise physiological parameters prior to discharge from PACU**

***Goal:** Minimal sedation, control of PONV.*

Standardised handover and PACU discharge criteria ensuring adequate control of pain and PONV. These factors should be assessed and optimised on every post-operative day.

- **ERAS Principle: Postoperative Analgesia**

***Goal:** Scheduled paracetamol and NSAID prescribed if no contraindication. Opioid use minimised to $\leq 0.15\text{mg/kg/day}$ of intravenous Morphine or equivalent.*

Use of multimodal analgesia and adjuvants as required, such as dexmedetomidine, ketamine and clonidine, with continuous infusion of peripheral nerve catheters and epidurals. The focus should be on using non-opioid analgesia in order to avoid the negative side effects associated with its use (such as nausea, vomiting, sedation, constipation and pruritis). Opioids should be reserved for rescue.

- **ERAS Principle: Early Feeding and Mobilization**

***Goal:** Clear fluid on Postop day 0 and regular diet on Postop day 1. Mobilise by post-op day 1.*

Nutrition is important for supporting growth and development and promoting wound healing. Early oral intake protocols- Clear liquids should be started in the evening of the day of surgery, and a regular diet should be commenced on day 1 post-operatively.

Patients should be mobilised out of bed on day 1 post-operatively using a multidisciplinary approach that incorporates pain management, encouragement, and physical therapy. There is little data on how to implement this intervention; a few strategies have shown some success, such as eliminating in-room entertainment, using hallway posters, and using patient diaries and pedometers in older children.

- **ERAS Principle: Early removal of drains and IV catheters**

Goal: *Removal as early as possible. Urine catheters are removed on the day of epidural removal. Remove IV by post-op day 1.*

Routine use of NGTs in paediatrics is not recommended. Current evidence shows substantial decreases in time to first oral intake and time to first stool passage, and earlier discharge, in patients undergoing laparotomy without an NGT. However, there was an increase in post-operative vomiting.

The use of peritoneal drains in children should be avoided, as they are often a source of infection and pain. In a randomised study of 100 children undergoing laparoscopic Roux-en-Y hepatojejunostomy for excision of choledochal cysts, the group without post-operative drain placement had lower pain scores, a quicker time to resumption of normal activity, and earlier discharge. In the 12-month postoperative follow-up, neither group were found to have complications of biliary, pancreatic or intestinal leaks. When a drain is warranted, removal at the earliest time is recommended.

An effective way to ensure that the complete set of principles is applied is to use an ERAS checklist from the pre-operative period through to discharge. This should be included with the patient's theatre records and checked off as performed to ensure all elements are met. An alternative is to incorporate the ERAS guidelines into the WHO Surgical Safety Checklist. ([See appendix for example of the WHO/ERAS combined checklist](#)).

Perioperative ERAS checklist		
Pre-Operative	Intraoperative	Postoperative
☐ Patient and family education and engagement	☐ Antimicrobial prophylaxis given within 60min prior to skin incision and surgical site preparation	☐ Immediate Recovery Period: Pain and PONV management
☐ Optimisation of medical co-morbidities	☐ Standardized anaesthetic protocols used ☐ Multi-modal Analgesia and Regional Anaesthesia used where indicated	☐ Early removal of intraperitoneal/ peri-anastomic drains`
☐ Prolonged fasting avoided ☐ Carbohydrate Loading if indicated	☐ Surgical procedure (minimally invasive techniques)	☐ Early removal of urinary catheters
☐ Non-opioid analgesic administered	☐ Appropriate Fluid and Blood Management	☐ Goal directed fluid therapy continued
☐ Pre-medication and Anxiety Management if required	☐ PONV prophylaxis for patients at risk	☐ Opioid sparing pain regime
☐ Avoidance of oral mechanical bowel preparation	☐ Avoiding nasogastric tubes, Urinary catheters and routine drain insertion unless indicated	☐ Early oral nutrition initiated
☐ Venous thrombo-embolism prophylaxis	☐ Standardized hypothermia prevention	☐ Early mobilization initiated

Figure 3: Perioperative ERAS checklist

Post operative Goals

The aim of ERAS is to allow for early and safe discharge home. Patients achieving their post-operative goals is key in this regard. A way to motivate patients and caregivers to do this is to have a daily checklist of goals achieved as part of the ERAS protocol, defined safe discharge criteria agreed upon by caregivers, a scheduled follow-up date, and contact information in case of emergencies or further information required by the caregiver. (13) [\(See appendix for example of ERAS Goals and accomplishments and Discharge Checklist used at the Sunrise Children's Hospital in USA\).](#)

Special Populations in ERAS

Neonates and Congenital Heart Disease

In addition to the above general recommendations, these two populations have specific recognised ERAS recommendations.

Neonates

This group of patients with their unique physiology are noted to have a high variability in their perioperative management, leading to serious and avoidable complications. Neonates undergoing intestinal surgery have been identified as a population that can greatly benefit from ERAS protocols. A major concern in neonates requiring surgery is anaesthesia-induced neuronal apoptosis. The use of regional anaesthesia as an adjunct to general anaesthesia in patients undergoing major abdominal surgery (gastroschisis, omphalocele, and congenital diaphragm repair) helps reduce this risk.

The ERAS Society therefore developed consensus guidelines for Perioperative Care in Neonatal Intestinal Surgery.

These guidelines were developed for term neonates (≥ 37 weeks of gestation) requiring intestinal surgery in the first 4 weeks of life with no other major comorbidities. Neonates with complicated surgical conditions were excluded.

One key component is implementing multidisciplinary team communication. This entails a pre-intra and postoperative “team huddle” using a structured process to discuss concerns. The guidelines are summarised below. (14) The Quality and Strength of recommendations are recorded in brackets as (Quality/Strength).

Pre-Operative

Optimal Haemoglobin:

Restrictive transfusion strategies should guide care:

- Hb > 9 g/dL for term neonates without oxygen support.
- Hb > 11 g/dL for term neonates in the first week, requiring oxygen or intubation.
- Decisions should integrate Hb targets, the neonate’s clinical condition, and local protocols. (Low/Weak)

Antimicrobial prophylaxis:

- Administration of appropriate preoperative antibiotic prophylaxis within 60 min prior to skin incision. (Low/Weak)
- Antibiotic therapy should be discontinued within 24 hours postoperatively, except where ongoing treatment is clinically necessary. (Low/Weak)

Intraoperative

Perioperative analgesia

- Administer paracetamol regularly during the early postoperative period to minimise opioid use, unless contraindicated. (High/Strong)
- An opioid-limiting strategy is advised postoperatively, with breakthrough pain treated using minimal effective opioid dosing and continuous patient monitoring. (Moderate/Strong)
- Perioperative analgesia should combine regional anaesthesia and paracetamol with general anaesthesia, and continuation of multimodal strategies post-operatively. (High/Strong)

Perioperative fluid management

- Manage perioperative fluids to ensure tissue perfusion and avoid hypovolemia, fluid overload, hyponatremia, or hyperglycemia. (Moderate/Weak)

Preventing intraoperative hypothermia

- Maintain normothermia by continuous intraoperative temperature monitoring and pre-emptive measures to prevent hypothermia (<36.5 °C). (Low/Strong)

Surgical practices

- In patients with uncomplicated intestinal atresia, primary anastomosis should be the first choice. (Very Low/Weak)

Post-Operative

Postoperative nutritional care

- Start enteral feeds early (within 24–48 h) after surgery whenever possible, without delaying for bowel function to return. (High/Weak)
- Use breast milk as the first choice for nutrition (High/Strong)
- In neonates with a stoma, monitor urinary sodium, aiming for >30 mmol/L and greater (Low/Weak)

Parental involvement

- Support early, individualized hands-on care by parents, with structured practice to strengthen their skills, uphold their primary caregiver role, and facilitate discharge readiness. (High/Strong)

Mucous fistula re-feeding

- Mucous fistula re-feeding should be employed in neonates with enterostomy to support growth. (Moderate/Weak)

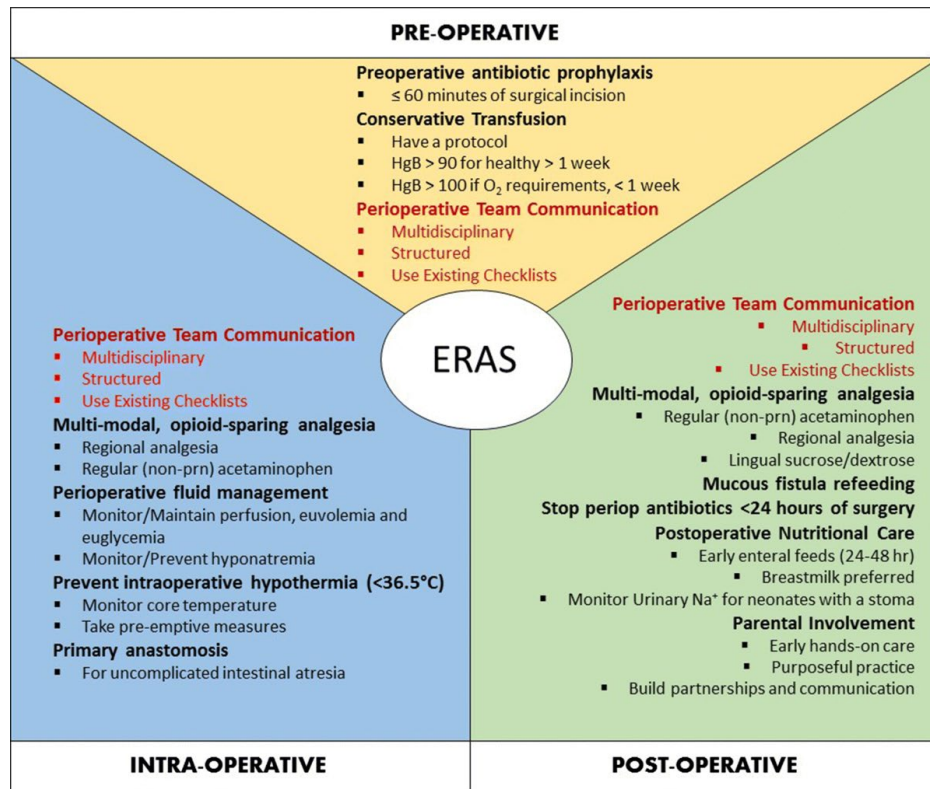


Figure 4 Elements of the ERAS for neonatal intestinal resection surgery.

In the above consensus guidelines for neonatal care, it was noted that peri-operative analgesia was not addressed for minor procedural pain. ERAS consensus guidelines for non-pharmacological pain management were formed in order to minimise the use of opioids.

Four non-pharmacological strategies are recommended to reduce pain during minor procedures (such as during heel lance, venipuncture, NG/OG tube insertion, nasopharyngeal suctioning), they may be used alone or alongside pharmacological measures, unless contraindicated.(15)

- Use of oral sucrose, dextrose, or glucose (High/Strong)
- Feeding or non-nutritive suckling either alone or combined with swaddling or holding. (High/Strong)
- Skin-to-skin care (Moderate/Strong)
- Music therapy (Low/Weak)

Cardiac surgery

Patients undergoing repair of congenital heart lesions are considered suitable for ERAS based on two risk stratification tools: the Risk Adjustment for Congenital Heart Surgery (RACHS), which classifies procedures into six categories according to operative risk, and the Partial Risk Adjustment in Surgery (PRAiS), a predictive model for 30-day mortality following paediatric cardiac surgery that incorporates procedure type, underlying diagnosis, age, weight, and comorbidities.

Patients with a RACHS score of 1–3 and a PRAiS score of 10–15 are typically selected for ERAS. Conditions within this group commonly include ASD and VSD repair, RV–PA conduit procedures, subaortic stenosis resection, coarctation of the aorta repair, and partial or total cavopulmonary shunt operations.

While the core ERAS principles remain consistent, several procedure-specific recommendations are outlined below.

The preoperative phase

- A pre-admission visit is required to perform investigations such as haematological tests, ECHO, ECG, CXR and admission swabs. This eliminates the need for an additional day of hospital admission prior to surgery.

The Intraoperative phase

- Avoidance of long-acting anaesthetic agents with a shift towards the use of TIVA with dexmedetomidine.
- Use of transoesophageal echo to confirm diagnosis and exclude new pathology, to guide fluid management and assess the results of surgical repair.
- The use of blood conserving strategies in order to minimise allogenic blood transfusion. This includes meticulous surgical technique, reducing physiological factors that worsen coagulopathy (acidosis, hypocalcaemia and hypothermia), use of cell salvage, regular dosing of antifibrinolytic agents, reversal of heparin with protamine guided by point of care testing, reducing haemodilution by using low volume priming circuits and use of haemofiltration during bypass and ultrafiltration after surgery.

The post-operative phase

- Aim to extubate in theatre or on the same day in ICU.
- Chest drains, invasive lines and pacing wires are removed on postoperative day 1, with pre-discharge ECHO performed.
- Patients and parents are educated on red flags and the patient is discharged on postoperative day 2 with virtual follow-up in 48 hours post discharge.(16)

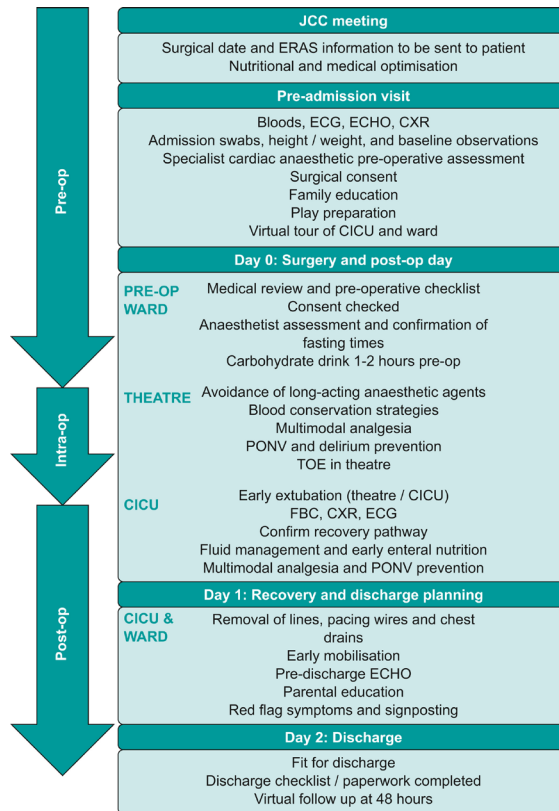


Figure 5 Paediatric ERAS pathway for cardiac surgery

Implementation and Quality Improvement

The final piece required for an ERAS protocol to be successful is regular auditing of compliance, with outcomes measured. This is an often-overlooked but crucial step to understanding real-time clinical data and the ERAS performance, benefits, and challenges encountered.

Protocol compliance can be split into two categories: low-compliance items (40-50% achieved) and high-compliance items (>80% achieved). Using the Plan-Do-Study-Act (PDSA) pathway, the challenges in achieving compliance with the low-compliance items can be targeted to achieve >80% compliance at steady state. This requires ongoing staff training and stakeholder engagement.(1)



Figure 6: PDSA Cycle for quality improvement

Rationale for ERAS in children: Assessing outcomes:

The paediatric population can be divided into two different populations. The first being healthy children that require elective outpatient procedures and the second being hospitalised children requiring major surgery (e.g. colorectal, urological and craniofacial surgery); therefore, the objectives and assessment of outcomes are different.

In the outpatient setting, the focus should be on preventing PONV, assessing and managing pain, and ensuring patient, family, and staff satisfaction. In hospitalised patients, the primary outcomes measured are surgical-related morbidity (wound sepsis), length of stay (LOS), re-admission rate, reduction in postoperative pain and opioid use, and patient and family satisfaction. Mortality is not always included, as this is a fortunately rare complication in children. (17, 18)

In 2018, *Short et al* implemented the first 19-element ERAS protocol. This study focused on adolescents undergoing elective intestinal surgery. This study yielded substantial results, including a decrease in average length of stay, a shorter time to commencement of a regular diet, and reduced mean opioid and intraoperative fluid doses. There was also no difference shown in re-admission or complication rate. (1)

Further studies across multiple paediatric surgical populations have shown similar benefits, including:

Gastro-intestinal Surgery:

- Appendectomy, Pyloromyotomy, Meckel's diverticulum, and Reduction of Intussusception surgery conducted by Gao *et al* in 2019. (14)
- Stoma Reversal Surgery conducted by Modrzyk *et al* in 2020. (16)
- Oesophageal Replacement surgery for Oesophageal Atresia conducted by Saoji *et al* in 2024. (20)

- Bariatric Surgery conducted by Svetanoff *et al* in 2022. (19)

Urological surgery:

- Lower Urinary Tract Reconstruction conducted by Rove *et al* in 2020. (14)
- Bladder Augmentation (Cystoplasty) was conducted by Hecht *et al* in 2020. (15)

Orthopaedic surgery

- Periacetabular Osteotomy (Developmental Dysplasia of the Hip) was conducted by Li *et al* in 2020. (17)
- Distal Humerus Fracture Repair (Open reduction) conducted by Lu *et al* in 2022. (18)

These studies used ERAS protocols, which consistently incorporated preoperative parent education, carbohydrate loading, multimodal analgesia, and early postoperative feeding and mobilisation. These interventions were associated with improved outcomes, including reduced length of hospital stay (typically by 2–3 days), faster return of bowel function and oral intake, decreased reliance on opioids, lower complication rates, and reduced healthcare costs. Demonstrating significant benefits in enhancing recovery and improving perioperative outcomes in children. For more information, please refer to the referenced article.

Currently, two large, multicentre trials are underway that could consolidate paediatric ERAS. The first is the ENRICH-US (ENhanced Recovery In CHildren Undergoing Surgery) trial, a prospective randomised controlled trial conducted at 18 sites in the United States that examines the implementation of ERAS gastrointestinal surgery, and the other is the PURSUE trial, which examines patients undergoing urological surgery. (Paediatric Urology Recovery after Surgery Endeavour). (3, 6)

Medico-social-economic impact

A key driver of implementing ERAS protocols is their potential to maximise the quality of care while minimising costs. A major portion of this is achieved through reduced hospital stay and reduced morbidity. This has been evident in adult ERAS programs, with the same holding true for paediatric colorectal surgery.(19) The additional social benefit is that shorter hospital stays for a given procedure free up inpatient capacity, allowing higher admission volumes and increased bed occupancy rates without additional overhead expenditure.(20)

It is also important to recognise that in-hospital economic evaluations fail to fully reflect indirect societal costs, particularly those related to postoperative in-home care for children and the associated impact on caregiver earnings, which should be considered to provide a more complete depiction of the true cost impacts of ERAS.(19)

Future Development in ERAS

Artificial intelligence (AI) is increasingly recognised as the future of healthcare and, when used to complement clinical judgement, can serve as a powerful force multiplier in paediatric ERAS in a number of ways, a few of them are listed below. (21, 22)

- **Technology-assisted prehabilitation:** Use of smartphone apps, wearable technology, and virtual reality, among other technologies, has shown enhanced adherence to prehabilitation programs, improved physical function, improved 6-minute walk test, reduced fatigue and nausea, enhanced appetite, and improved global health status. These can be especially of use in the older paediatric and adolescent population.
- **Technological advancements in nutrition:** Smartphone-assisted calorie-tracking apps and surveillance video methods enable objective assessment of nutritional intake, potentially improving compliance with nutritional support protocols and benefiting both overweight and malnourished patients.
- **Pre-operative planning and diagnosis:** AI algorithms can process patient data to deliver comprehensive insights and develop personalised preoperative plans tailored to each individual, thereby improving surgical outcomes and reducing side effects.
- **Patient education:** Large Language Models are a valuable resource, but clear, age-appropriate communication is essential. Before surgery, they can help explain procedures to young patients and their families in simple, understandable terms, reducing anxiety and encouraging better patient cooperation.
- **Intraoperative assistance:** AI enables precision anaesthesia via closed-loop systems, leading to fewer side effects, reduced anaesthesia overdosing, and faster emergence. During surgery, AI-driven tools can improve surgeons' ability to perform complex procedures with greater accuracy, increased stability, and greater control (Robotic surgery).
- **Postoperative:** Through continuous postoperative monitoring, AI can recognise early physiological or recovery changes suggestive of complications, enabling prompt intervention. By analysing extensive, individualised patient data, AI supports the development of personalised postoperative care plans tailored to each patient's unique needs, significantly enhancing the precision and effectiveness of postoperative care.

Arguments against and challenges in adopting ERAS in Paediatrics

- Difficulty in extrapolating data from adult protocols, and there is heterogeneity in age and in physiological and neurological development in paediatrics.
- Paediatric patients have better baseline physiology with decreased morbidity and mortality after surgery; therefore, there may be little benefit in adopting protocolized ERAS programs.
- Clinical acumen and the “Art of Medicine” are being lost through continual protocolization.
- Certain elements of ERAS lack high-quality evidence in the paediatric population, e.g., venous thromboembolism prophylaxis.
- Fears that earlier discharge from hospital care may lead to an increased readmission rate.
- Poor access to healthcare in low- and middle-income countries may lead to an increased risk of morbidity and mortality.
- Staff shortages and high turnover can lead to variability in the implementation of ERAS principles and in ongoing staff education. (3, 6)

Conclusion

Paediatric Enhanced Recovery After Surgery represents a collaborative, evidence-based approach to improving surgical outcomes and the overall experience of children and their families. By integrating standardised practices across the preoperative, intraoperative, and postoperative phases of care, ERAS aims to reduce surgical stress, minimise complications, promote faster recovery, and support safe, timely discharge. **This is crucial as a child’s recovery is a family’s recovery.**

Central to paediatric ERAS is the involvement of multidisciplinary teams and families, recognising parents and caregivers as essential partners in care. Through consistent communication, education, and individualised support, ERAS pathways empower families, enhance continuity of care, and promote confidence in managing recovery at home.

Successful implementation of paediatric ERAS requires ongoing evaluation, staff engagement, and adaptation to local contexts. By embedding ERAS principles into routine practice, healthcare teams can deliver high-quality, child-centred care that improves outcomes while prioritising safety. The development of standardised, surgery-specific paediatric ERAS protocols is the way forward, with larger studies to demonstrate the long-term benefits.

Appendix

ERAS checklists

Incorporation of ERAS principles into the WHO surgical safety checklist (23)

ERAS Surgical Safety Checklist

Before induction of anaesthesia	Before skin incision	Before patient leaves operating room
Has the patient confirmed his/her identity, site, procedure, and consent? ☐ Yes	☐ Confirm all team members have introduced themselves by name and role	Nurse verbally confirms: ☐ The name of the procedure ☐ Completion of instrument, sponge and needle counts ☐ Specimen labeling (read specimen labels aloud, including patient name) ☐ Whether there are any equipment problems to be addressed
Is the site marked? ☐ Yes ☐ Not applicable	☐ Confirm the patient's name, procedure, and where the incision will be made	
Is anesthesia machine and medication check complete? ☐ Yes	Has appropriate antibiotic prophylaxis been given within the last 60 minutes? ☐ Yes ☐ Not applicable	
What is the patient's NPO status?	Anticipated Critical Events	To Surgeon, Anesthetist, and Nurse:
Does the patient have a:	To surgeon: ☐ What are the critical or non-routine steps? ☐ How long will the case take? ☐ What is the anticipated blood loss?	What are the key concerns for recovery and management of this patient? ☐ What is the postoperative analgesia plan? Any contraindications to NSAIDs? ☐ What is the postoperative nausea prevention plan? Any contraindications to early feeds? ☐ What is the postoperative DVT prophylaxis plan? ☐ What are expected ongoing maintenance fluid requirements? ☐ Have all unnecessary drains, NGs, foleys been removed?
Known allergy? ☐ No ☐ Yes	To anesthetist: ☐ Are there any patient-specific concerns? ☐ What is the plan for intraoperative fluid management?	
Difficult airway or aspiration risk? ☐ No ☐ Yes, and equipment/assistance available	To nursing team: ☐ Are there equipment issues or any concerns?	
Risk of >50mL blood loss? ☐ No ☐ Yes, two IVs/central access and fluids planned?	Is essential imaging displayed? ☐ Yes ☐ Not applicable	
What is the opioid-sparing analgesia plan?		
What is the warming and temperature monitoring plan?		
What DVT prophylaxis is planned or in place?		
What antibiotics and skin prep have been requested?		
Is the appropriate surgical equipment available? ☐ Yes		
Does the patient need to void or foley required?		

ERAS Goals Accomplishment Checklist and Discharge Criteria

Enhanced Recovery After Surgery Goals and Accomplishments		Patient Name / Surgery Date: _____	
		Surgery Type / Surgeon: _____	
Day Prior to Surgery	Day of Surgery	Day 1	Day 2
☐ I have reviewed the educational videos and materials	☐ I have tolerated drinking liquids as instructed by the surgery team	☐ I have walked out of the room at least 5 times today ☐ ☐ ☐ ☐ ☐	☐ I have walked out of the room at least 5 times today ☐ ☐ ☐ ☐ ☐
☐ I have filled my prescriptions and will begin taking them as instructed	☐ I have made sure to tell my nurse if I'm feeling sick or am in pain	☐ I am comfortable and my pain is controlled with oral medications	☐ I am comfortable and my pain is controlled with oral medications
☐ I will not have any food except clear liquid after midnight	☐ I have tried solid food (if offered to me)	☐ I am not nauseated or have told the nurse I'm sick	☐ I am not nauseated or have told the nurse I'm sick
☐ I will drink clear liquids as instructed by the surgery team	☐ I have walked out of my room this many times ☐ ☐ ☐ ☐ ☐	☐ If I have a foley catheter or nasogastric tube it has been removed	☐ I have asked the surgical team my questions
☐ I have asked all of my questions about surgery and recovery	☐ I have asked the surgical team my questions	☐ I have asked the surgical team my questions	☐ I am comfortable with my discharge and recovery plan

Enhanced Recovery After Surgery Discharge Checklist
☐ I feel safe going home and understand my recovery plan
☐ My pain is controlled on oral medications
☐ I have all of my prescriptions and understand how to take them
☐ I am tolerating clear liquids
☐ I am able to walk independently or as before surgery
☐ I am able to dress myself (or as before surgery)
☐ I am comfortable with wound care and/or stoma care if applicable
☐ My outpatient follow up appointment is arranged and I have the clinic phone number
☐ All of my questions have been answered

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