



Implementation of Enhanced Recovery After Surgery (ERAS) Protocols in Pediatric Cardiac Surgery: A Comprehensive Review

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ABSTRACT

Background: *Enhanced Recovery After Surgery* (ERAS) represents an evidence-based, multidisciplinary approach that optimizes perioperative care, reduces surgical stress, and accelerates postoperative recovery. While ERAS protocols have been widely implemented in adult cardiac surgery, their adaptation to pediatric congenital heart disease (CHD) remains emerging and underexplored. Pediatric populations pose unique challenges due to differences in physiology, surgical complexity, and developmental status. **Objectives:** This review aims to provide a comprehensive overview of ERAS implementation in pediatric cardiac surgery, focusing on its key components, outcomes, and research gaps to guide future practice and investigation. **Methods:** A narrative literature review was conducted using PubMed and Google Scholar, targeting publications from 2010 to 2025. The search utilized the keywords “Enhanced Recovery After Surgery,” “ERAS,” “Pediatric Cardiac Surgery,” and “Congenital Heart Disease.” Relevant randomized controlled trials, cohort studies, reviews, and clinical guidelines were critically analyzed to identify core ERAS elements, perioperative strategies, and reported outcomes. **Discussion:** The reviewed evidence supports that ERAS protocols in pediatric cardiac surgery are feasible and associated with reduced mechanical ventilation duration, ICU stay, and hospital length of stay, without increasing complications or readmissions. However, most available studies are observational, highlighting the scarcity of randomized controlled trials specifically addressing pediatric CHD. **Conclusion:** ERAS offers a promising framework to enhance recovery and safety in pediatric cardiac surgery. Standardized, multicenter trials are required to establish evidence-based pediatric ERAS models and determine their long-term impact on recovery and quality of life.

Keyword: cardiac surgery, congenital heart disease, ERAS, pediatric, recovery

ABSTRAK

Latar Belakang: *Enhanced Recovery After Surgery* (ERAS) merupakan pendekatan multidisiplin berbasis bukti yang bertujuan mengoptimalkan perawatan perioperatif, mengurangi stres pembedahan, dan mempercepat pemulihan pascaoperasi. Meskipun protokol ERAS telah banyak diterapkan pada pembedahan jantung dewasa, adaptasinya pada kasus *Congenital Heart Disease* (CHD) pediatrik masih tergolong baru dan belum banyak diteliti. Populasi pediatrik memiliki tantangan tersendiri karena perbedaan fisiologi, kompleksitas pembedahan, serta status perkembangan. **Tujuan:** Tinjauan ini bertujuan untuk memberikan gambaran komprehensif mengenai penerapan ERAS pada pembedahan jantung pediatrik, dengan menyoroti komponen utama, luaran klinis, serta kesenjangan penelitian untuk panduan praktik dan penelitian selanjutnya. **Metode:** Tinjauan literatur naratif dilakukan dengan menggunakan basis data PubMed dan Google Scholar untuk publikasi tahun 2010 hingga 2025. Pencarian dilakukan dengan kata kunci “*Enhanced Recovery After Surgery*,” “ERAS,” “*Pediatric Cardiac Surgery*,” dan “*Congenital Heart Disease*.” Artikel yang relevan, termasuk *randomized controlled trials*, studi kohort, tinjauan pustaka, dan pedoman klinis dianalisis secara kritis untuk mengidentifikasi elemen utama ERAS, strategi perioperatif, serta luaran yang dilaporkan. **Pembahasan:** Bukti yang ditinjau menunjukkan bahwa penerapan protokol ERAS pada pembedahan jantung pediatrik bersifat layak dan berhubungan dengan penurunan durasi ventilasi mekanik, lama perawatan di ICU, serta lama rawat inap, tanpa meningkatkan komplikasi maupun angka readmisi. Namun, sebagian besar studi yang tersedia bersifat observasional, menyoroti keterbatasan uji acak terkontrol yang secara khusus meneliti CHD pediatrik. **Kesimpulan:** ERAS menawarkan kerangka kerja yang menjanjikan untuk meningkatkan pemulihan dan keamanan pada pembedahan jantung pediatrik. Diperlukan uji multicenter terstandar untuk membangun model ERAS berbasis bukti pada populasi pediatrik serta menilai dampak jangka panjangnya terhadap pemulihan dan kualitas hidup. **Keyword:** bedah jantung, ERAS, pediatrik, pemulihan, penyakit jantung bawaan



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1. Introduction

Congenital heart disease (CHD) is the leading cause of death among congenital birth defects in OECD countries, significantly impacting healthcare systems and society. In the United States, the prevalence of congenital heart anomalies increased from 441,000 in 1990 to 527,452 in 2021, while mortality decreased by 56% over the same period^[1]. In Asia, significant reductions in mortality and disability-adjusted life years (DALYs) have been observed, although Central Asia faces ongoing challenges in managing CHD^[2]. Socioeconomic factors significantly influence CHD outcomes. In the United States, states with lower median household incomes and higher uninsured rates have higher mortality and disability rates among adults with CHD^[3]. In resource-limited settings, undiagnosed CHD remains a critical issue, with diagnostic delays leading to severe complications. Barriers include infrastructural deficiencies and a shortage of specialized healthcare professionals. The prevalence of CHD is projected to rise, particularly among young children, while mortality rates are expected to continue declining. This trend underscores the need for enhanced public health strategies to address the growing disability burden^[4].

Enhanced Recovery After Surgery (ERAS) is a comprehensive, evidence-based approach designed to optimize perioperative care, minimize surgical stress, and improve patient outcomes across various surgical disciplines. ERAS protocols have been shown to significantly enhance recovery, reduce postoperative complications, and decrease healthcare costs. ERAS protocols emphasize preadmission counseling, minimized preoperative fasting, and carbohydrate loading to reduce surgical stress and improve metabolic responses^{[5][6]}. Techniques such as goal-directed fluid therapy, opioid-sparing anesthesia, and maintenance of normothermia are crucial for minimizing surgical stress and enhancing recovery^{[6][7]}. Early mobilization, structured nutritional support, and multimodal pain management are integral to ERAS, facilitating faster recovery and reducing

complications^{[8][9]}. The integration of technologies such as robotic-assisted surgery, AI-driven monitoring, and automated nutrition management has further refined ERAS protocols, enhancing precision and personalized care^[7]. Enhanced Recovery After Surgery (ERAS) protocols in adult cardiac surgery aim to optimize patient outcomes by integrating evidence-based practices across the perioperative period. These protocols have been shown to reduce postoperative complications, shorten hospital stays, and improve overall recovery times. The implementation of ERAS in cardiac surgery, although relatively recent compared to other surgical fields, has demonstrated promising results in various studies. Enhanced Recovery After Surgery (ERAS) programs have been increasingly implemented in pediatric populations, including those with congenital heart disease (CHD). These programs aim to optimize recovery through a multidisciplinary approach, reducing postoperative complications and hospital length of stay (LOS) without increasing risks^[10]. While ERAS protocols are well established in adult cardiac surgery, their application in the pediatric population is relatively recent and still evolving. Differences in physiology, surgical complexity, and developmental considerations require tailored adaptations of ERAS pathways for children. Understanding the implementation, outcomes, and barriers of ERAS in pediatric cardiac surgery is therefore crucial to improve recovery trajectories and long-term outcomes in this vulnerable population.

In conducting this narrative literature review, the search for relevant literature was focused on two major databases: PubMed and Google Scholar. The search strategy employed a combination of keywords such as “*Enhanced Recovery After Surgery*”, “*ERAS*”, “*Pediatric Cardiac Surgery*”, and “*Congenital Heart Disease*”. Boolean operators AND and OR were used to refine and expand the search results appropriately. The inclusion criteria consisted of journal articles published between 2015 and 2025, written in English, and addressing the implementation, outcomes, or challenges of ERAS in pediatric cardiac surgery. Review articles, randomized controlled trials (RCTs), cohort studies, and clinical guidelines were all considered relevant sources. Studies focusing solely on adult populations or unrelated surgical specialties were excluded. From the retrieved articles, those most relevant to the review objectives were selected and critically analyzed to identify key components of ERAS, perioperative strategies, clinical outcomes, and barriers to implementation. The synthesis of these findings aimed to provide a comprehensive understanding of how ERAS protocols can optimize perioperative recovery and improve outcomes among children undergoing cardiac surgery.

2. Methods

In conducting this narrative literature review, the search for relevant literature was focused on two major databases: PubMed and Google Scholar. The search strategy employed a combination of keywords such as “*Enhanced Recovery After Surgery*”, “*ERAS*”, “*Pediatric Cardiac Surgery*”, and “*Congenital Heart Disease*”. Boolean operators AND and OR were used to refine and expand the search results appropriately. The inclusion criteria consisted of journal articles published between 2010 and 2025, written in English, and addressing the implementation, outcomes, or challenges of ERAS in pediatric cardiac surgery. Review articles, randomized controlled trials (RCTs), cohort studies, and clinical guidelines were all considered relevant sources. Studies focusing solely on adult populations or unrelated surgical specialties were excluded. From the retrieved articles, those most relevant to the review objectives were selected and critically analyzed to identify key components of ERAS, perioperative strategies, clinical outcomes, and barriers to implementation. The synthesis of these findings aimed to provide a comprehensive understanding of how ERAS protocols can optimize perioperative recovery and improve outcomes among children undergoing cardiac surgery.

3. Discussion

Enhanced Recovery After Surgery (ERAS) represents a paradigm shift in perioperative medicine from traditional, complication-focused care toward proactive, physiology-preserving management. It is a structured, multidisciplinary, and evidence-based pathway encompassing preoperative optimization, intraoperative anesthesia refinement, and postoperative rehabilitation. The fundamental objective is to attenuate the surgical stress response, maintain homeostatic function, and accelerate postoperative recovery without compromising safety^{[11][12]}. As shown in Figure 1, the conceptual framework of ERAS in pediatric cardiac surgery integrates three main perioperative phases preoperative, intraoperative, and postoperative linked through a

multidisciplinary team and a continuous quality improvement feedback loop leading to improved clinical outcomes.

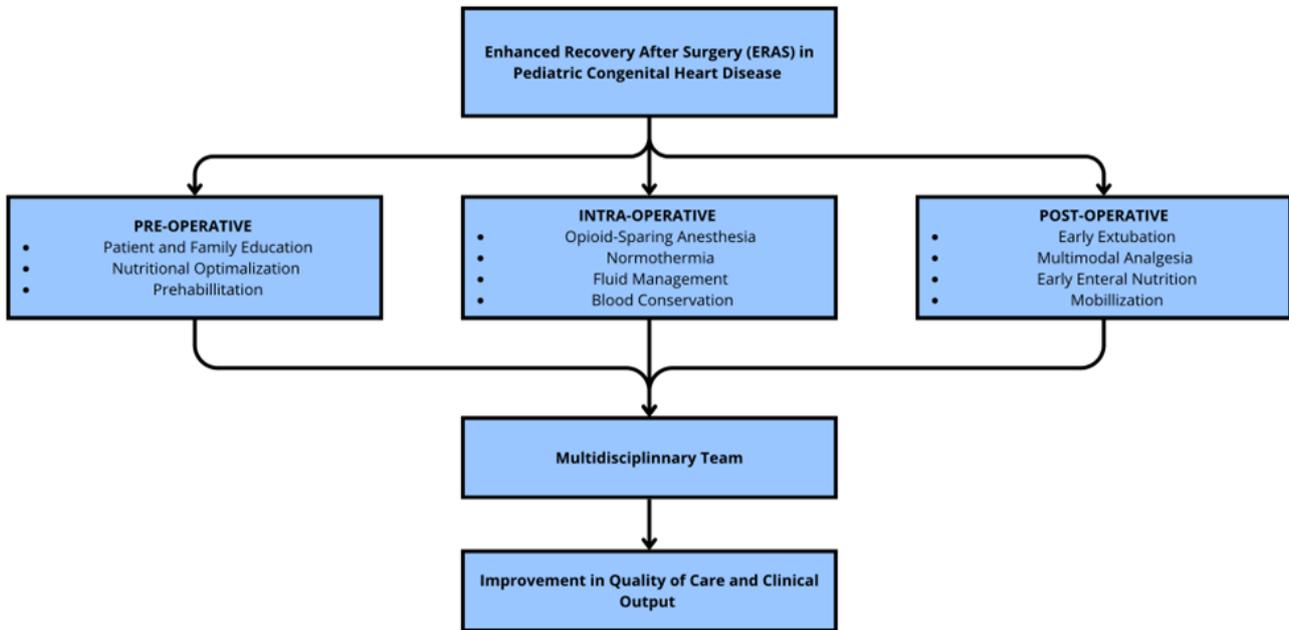


Figure 1. Conceptual Framework ERAS Protocol in Pediatric CHD.

3.1 Key Component of ERAS

Preoperative components

1. Patient education and prehabilitation

Educating patients about the surgical procedure, expected outcomes, and recovery process is crucial. A comprehensive prehabilitation program includes physical conditioning, nutritional and glucose management, advice on quitting smoking and moderating alcohol intake, and psychosocial support. Additionally, patients receive guidance on setting realistic pain management expectations, focusing on opioid-sparing techniques, encouraging early and regular postoperative walking, and adhering to strict discharge criteria. The prehabilitation program begins with an interdisciplinary consultation two to three weeks prior to surgery. During this session, patients undergo a comprehensive evaluation of their physical condition, including frailty and functional capacity, to determine their readiness and willingness to engage in the program. A key focus is placed on physiotherapeutic exercises, urging patients to increase daily physical activities and enhance their nutritional status before surgery to optimize their overall readiness and outcomes^[13]

2. Preoperative Counseling

Preoperative counseling is a crucial component of the Enhanced Recovery After Surgery (ERAS) programs, forming part of the meticulous patient preparation in the preoperative phase. Preoperative counseling is a strategy encompassed within the ERAS framework to prepare patients for surgery. It plays a vital role in reducing preoperative anxiety, which can significantly impact a patient's experience and recovery. By providing patients with comprehensive information and support before surgery, counseling helps them feel

more prepared and less anxious, contributing to a smoother transition into the surgical process and ultimately better outcomes^[14].

3. Nutritional optimization

Perioperative malnutrition exacerbates metabolic issues caused by surgical stress, leading to slower wound healing, heightened infection risk, prolonged hospital stays, and increased mortality. Addressing this, the Perioperative Quality Initiative and the American Society for Enhanced Recovery recommended preoperative nutritional screening for all major surgery patients in 2018. Those at risk should receive oral nutritional supplements at least seven days before surgery to mitigate malnutrition's adverse effects and enhance surgical outcomes.

Intraoperative components

1. Opioid Sparing Anesthesia in ERAS

Enhanced Recovery After Surgery (ERAS) protocols aim to improve patients' perioperative experiences by implementing multimodal pain regimens that often incorporate opioid-sparing strategies. The goal is to balance effective pain control with minimizing the risks and side effects associated with opioid use. ERAS protocols typically include multimodal pain regimens. These regimens involve the use of various analgesic agents and techniques to manage pain effectively, thereby reducing reliance on opioids. In the perioperative setting, a range of nonopioid analgesics may be utilized to reduce opioid consumption. These include :

- a. Acetaminophen
- b. NSAIDs (Nonsteroidal Anti-inflammatory Drugs)
- c. Dexamethasone
- d. Gabapentinoids
- e. Ketamine
- f. Antidepressants

Local anesthesia For some patients, it may be possible to achieve effective pain control primarily through opioid-sparing analgesia, meaning a significant reduction or complete avoidance of opioids (15).

2. Fluid Therapy in ERAS Protocol

Enhanced Recovery After Surgery (ERAS) protocols are designed to reduce variability in patient care and improve outcomes by focusing on various aspects of perioperative management, including fluid therapy. Fluid management is considered a crucial component of ERAS protocols, spanning the entire perioperative period. Fluid therapy within ERAS protocols is structured across three key phases:

- Preoperative Phase

During the preoperative period, the primary emphasis is on limiting prolonged fasting. This approach helps to optimize the patient's fluid status before surgery.

- Intraoperative Phase

Intraoperatively, the goal for fluid management is a goal-directed approach. The objective is to maintain adequate organ perfusion throughout the surgical procedure. This often involves careful monitoring and adjustment of fluid administration based on physiological parameters.

- Postoperative Phase

Postoperatively, patients are encouraged to have early oral intake. This promotes natural rehydration and nutrition, reducing the need for intravenous fluids and supporting recovery.

3. Normothermia

Maintaining normothermia is a crucial element within the Enhanced Recovery after Surgery (ERAS) program, playing a significant role in accelerating patient recovery. The Enhanced Recovery after Surgery (ERAS) program identifies patient warming as a vital strategy to ensure perioperative normothermia. This is considered a fundamental aspect for expediting patient recovery. The ERAS program and the National Institute for Health and Clinical Excellence (NICE) guidelines on inadvertent perioperative hypothermia are designed to complement each other. Their combined application aims to significantly enhance patient recovery outcomes (16).

PostOperative Component

1. Early extubation

Safely achieving early extubation (<6 h after the operation) can reduce ICU and hospital stays, facilitate earlier oral feeding and ambulation, and improve patient satisfaction. The ERAS Cardiac protocols emphasize minimizing intraoperative opioids and using shorter-acting anesthetics, making early extubation feasible for many patients.[36] Early and frequent mobilization are critical components of these protocols and should be communicated to patients before hospital admission to ensure compliance. Early postoperative movement helps reduce pain, fatigue, deep vein thrombosis, cognitive dysfunction, and anxiety. Patients begin their first postoperative physiotherapy session two to three hours after surgery, which includes breathing exercises/active mobilization while seated and upright. These exercises continue until the third to fourth postoperative day, with pain medication managed according to a standardized protocol. As a result of intensive physiotherapy, patients are typically discharged by the fourth or fifth postoperative day (13).

2. Early Enteral Nutrition

Early enteral nutrition (EEN) is a critical component of the Enhanced Recovery After Surgery (ERAS) protocol, which aims to improve postoperative recovery by minimizing surgical stress and promoting early rehabilitation. EEN has been shown to enhance gastrointestinal and immune function recovery, reduce complications, and shorten hospital stays across various surgical procedures. This approach is particularly beneficial in surgeries involving the gastrointestinal tract, where maintaining gut integrity and function is crucial. The following sections detail the impact and considerations of EEN within the ERAS framework (17).

The major perioperative interventions and their expected benefits are summarized in Table 1.

Phase	Component	Description	Expected Benefit / Rationale
Preoperative	Patient and Family Education	Comprehensive counseling about surgical procedures, recovery expectations, pain management, and feeding plan. Parents are treated as active team members.	Reduces anxiety, improves adherence to ERAS elements, and enhances family satisfaction.

	Nutritional Optimization	Screening for malnutrition and initiating preoperative nutritional support; carbohydrate (CHO) loading or shortened fasting protocols (clear fluids up to 2 h pre-anesthesia).	Prevents catabolism, stabilizes glucose levels, reduces postoperative insulin resistance.
	Prehabilitation	Age-appropriate physical and respiratory conditioning, especially in cyanotic or low-weight infants.	Improves cardiorespiratory reserve and reduces postoperative pulmonary complications.
	Risk Stratification & Pre-op Optimization	Identification of comorbidities (anemia, infection, electrolyte imbalance) and correction prior to surgery.	Reduces perioperative morbidity and facilitates early extubation.
Intraoperative	Opioid-Sparing Anesthesia	Use of multimodal analgesia (dexmedetomidine, acetaminophen, regional blocks) to minimize opioids.	Enables faster awakening, stable hemodynamics, and early extubation.
	Normothermia Maintenance	Active warming devices and warmed IV fluids to prevent hypothermia.	Reduces coagulopathy, metabolic stress, and recovery delay.
	Goal-Directed Fluid and Hemodynamic Management	Continuous monitoring (TEE, arterial line) to maintain optimal preload and perfusion; avoid fluid overload.	Minimizes edema, supports cardiac output, and prevents AKI.
	Blood Conservation & Antifibrinolytic Therapy	Cell-saver use, tranexamic acid administration, minimal circuit priming in CPB.	Decreases transfusion needs and inflammatory response.
	Early Extubation Strategy (“Fast-Track” Surgery)	Selection of suitable patients for on-table or early ICU extubation.	Shortens ICU stay and reduces ventilator-associated complications.
Postoperative	Multimodal Analgesia	Combination of	Provides effective pain

		acetaminophen, NSAIDs, and regional techniques to minimize opioids.	relief and reduces sedation duration.
	Early Enteral Nutrition	Initiation of feeding within 6–12 hours post-surgery as tolerated.	Promotes gut integrity, enhances metabolic recovery, reduces infection risk.
	Early Mobilization	Assisted movement and physiotherapy within 24–48 hours post-operation.	Improves pulmonary function, reduces muscle wasting, accelerates discharge.
	Delirium and Stress Prevention	Family presence, minimal environmental stress, adequate sleep cycles.	Prevents postoperative delirium and facilitates cognitive recovery.
	Continuous Quality Monitoring	Ongoing evaluation of adherence to ERAS components and outcome tracking.	Enables protocol refinement and sustainable improvement in outcomes.

Table 1. Key Component Enhanced Recovery After Surgery (ERAS) Protocol

3.2 Evidence Summary and Comparative Findings of ERAS Protocols in Pediatric Congenital Heart Surgery

The collective evidence from recent studies in table 2. underscores the growing feasibility, safety, and clinical benefits of implementing Enhanced Recovery After Surgery (ERAS) protocols in pediatric congenital cardiac surgery. The large cohort study by Andugala et al. (2024) demonstrated that ERAS implementation was associated with significantly reduced durations of postoperative mechanical ventilation, intensive care unit (ICU) stay, and total hospital length of stay compared with conventional care. Importantly, these improvements were achieved without an increase in postoperative complications, cardiac reinterventions, or readmission rates, suggesting that ERAS protocols are both effective and safe in carefully selected pediatric patients with low preoperative risk. This finding aligns with the core objective of ERAS to minimize surgical stress while maintaining patient safety and optimizing recovery trajectories. Conversely, Buchanan et al. (2022) observed no statistically significant differences in perioperative outcomes or complications when stratified across racial and demographic groups. Although this study did not show outcome disparities, its findings highlight the importance of ensuring equitable implementation of ERAS principles across diverse patient populations. It also emphasizes that ERAS benefits may be influenced by institutional resources, case complexity, and adherence consistency rather than patient demographics alone. Complementing these cohort data, the narrative synthesis by Rafeeqi et al. (2021) reinforced the broader advantages of ERAS protocols across pediatric surgical subspecialties, including congenital cardiac procedures. Collectively, these findings underscore that ERAS protocols offer measurable clinical and recovery advantages in pediatric cardiac surgery without compromising patient safety. However, the current body of evidence is primarily derived from retrospective or observational studies, with a notable paucity of randomized controlled trials (RCTs) specifically evaluating ERAS implementation in pediatric congenital heart disease. This gap limits the ability to establish causality and to identify which ERAS components yield the most significant benefits. Therefore, future research should focus on designing prospective, multicenter RCTs to validate standardized pediatric ERAS protocols, assess

long-term outcomes, and refine evidence-based recommendations tailored to the unique physiological and developmental needs of children with congenital heart disease.

Author (Year)	Study Design	Sample	Intervention	Main Finding
Andugala et al. (2024) (18)	Cohort	1084 Children	ERAS Protocol	<ul style="list-style-type: none"> · The implementation of the Enhanced Recovery After Surgery (ERAS) pathway in paediatric cardiac surgery resulted in significantly lower durations of postoperative mechanical ventilation, intensive care unit (ICU) length of stay (LOS), and hospital LOS compared to a control group of patients who did not follow the ERAS pathway. Specifically, the median ICU LOS for ERAS patients was 4.5 hours, and the median hospital LOS was 4 days. · The study found that none of the patients in the ERAS group required readmission to the ICU within 24 hours of discharge, and the rates of cardiac reintervention (2.5%), postoperative complications, and 30-day readmissions were not significantly different when compared to the non-ERAS group, indicating that ERAS is both feasible and safe for select patients with low preoperative risk.

<p>Buchanan et al. (2022) (19)</p>	<p>Cohort</p>	<p>872 Patient</p>	<p>ERAS Protocol</p>	<ul style="list-style-type: none"> · No Significant Differences in Outcomes: The study found no statistically significant differences in perioperative outcomes across racial groups, including postoperative vomiting, extubation in the operating room, median length of postoperative mechanical ventilation, median length of Cardiac Intensive Care Unit (CICU) stay, median length of postoperative hospital stay, and median total length of stay. · Complications and Mortality: There were also no statistically significant differences in overall complications, major complications, arrhythmias, infections, unplanned cardiac reoperation, unplanned readmission within 30 days, or 30-day mortality across all races.
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<p>Rafeeqi et al. (2021)(20)</p>	<p>Review</p>	<p>27 Studies</p>	<p>ERAS Protocol</p>	<p>General Benefits of ERAS</p> <ul style="list-style-type: none"> · Improved Clinical Outcomes and Patient Satisfaction: ERAS is a systematic approach designed to optimize a patient's health, improve clinical outcomes, increase patient satisfaction, and decrease healthcare costs. · Reduced Hospital Stay and Complications: Implementation of ERAS systems leads to a shortened length of stay and reduced complications without increasing patient returns to the healthcare system. · Better Pain Management and Recovery: Patients undergoing surgery within an ERAS program experience less pain, reduced opioid utilization, quicker recovery, and increased satisfaction. · Evolution of Quality and Safety: The evolution of ERAS represents a paradigm of quality and safety in surgical care. <p>Specific Outcomes in Pediatric ERAS Programs</p> <ul style="list-style-type: none"> · Significant Benefits in Pediatric Surgery: Enhanced recovery pathways in the pediatric population have shown significant benefits in clinical outcomes, improved patient and family satisfaction, and decreased healthcare costs. · Reduced Length of Stay and Opioid Use: Implementation of ERAS elements has demonstrated reduced length of stay, shortened time to oral intake, and reduced opioid utilization. · Successful Across Specialties: ERAS has been successfully employed across most pediatric surgical disciplines, from congenital cardiac surgery to colorectal surgery.
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Table 2. Summary Main Finding ERAS Protocols in Pediatric Congenital Heart Surgery

4. Conclusion

Enhanced Recovery After Surgery (ERAS) protocols represent a paradigm shift in the perioperative management of pediatric congenital heart disease, transitioning from traditional, complication-focused models toward proactive, physiology-preserving care. By integrating evidence-based interventions across preoperative, intraoperative, and postoperative phases, ERAS promotes reduced surgical stress, optimized homeostatic function, and accelerated recovery without compromising patient safety. Recent evidence indicates that ERAS implementation in pediatric cardiac surgery is both feasible and beneficial. Cohort studies have demonstrated significant reductions in postoperative mechanical ventilation duration, intensive care unit (ICU) stay, and hospital length of stay, with no associated increase in complications or readmissions. These findings underscore the safety and clinical value of adopting ERAS principles in children undergoing congenital heart surgery. Nevertheless, the existing literature is predominantly composed of observational or single-center studies, and there remains a critical paucity of randomized controlled trials (RCTs) evaluating ERAS protocols specifically in pediatric congenital cardiac populations. This limitation hinders causal inference and the identification of the most effective perioperative components driving improved outcomes. Future research should therefore prioritize prospective, multicenter RCTs aimed at standardizing pediatric ERAS frameworks, defining evidence-based perioperative bundles, and exploring long-term outcomes such as neurodevelopmental recovery, quality of life, and cost-effectiveness. With further validation and refinement, ERAS has the potential to become a global benchmark for optimizing recovery, enhancing safety, and improving holistic care in pediatric cardiac surgery.

References

- [1] Bhalodia P, Suppala P, Patel L, Patel V, Rathod U, Vala L, et al. Abstract 4146082: Evolving Burden of Congenital Heart Anomalies in the United States and its Trend in the last three Decade: A Benchmarking Analysis. *Circulation* [Internet]. 2024 Nov 12 [cited 2025 Oct 12];150(Suppl_1). Available from: https://www.ahajournals.org/doi/10.1161/circ.150.suppl_1.4146082
- [2] Zhang H, Cao S, Que Y, Dai Y, Cai M, Lin N. The Burden of Congenital Heart Disease in Asia and 34 Countries and Territories from 1990 to 2021: A Systematic Analysis Based on the Global Burden of Disease Study 2021 [Internet]. 2025 [cited 2025 Oct 12]. Available from: <https://www.researchsquare.com/article/rs-7026873/v1>
- [3] Suresh Kumar V, Sable C, Nakiwala D, Kassebaum N. Abstract 4142897: The Burden of Adult Congenital Heart Disease in the United States. *Circulation* [Internet]. 2024 Nov 12 [cited 2025 Oct 12];150(Suppl_1). Available from: https://www.ahajournals.org/doi/10.1161/circ.150.suppl_1.4142897
- [4] Ye E, Wu E, Tang T, La X. Global, regional, and national burdens of congenital heart anomalies from 1990 to 2021, and projections to 2050. *Front Pediatr*. 2025 Aug 18;13:1601620.
- [5] Torres P, Ghabra H. Enhanced Recovery after Colorectal Surgery. In: Abd-Elsayed A, editor. *Basic Anesthesia Review* [Internet]. 1st ed. Oxford University Press; New York; 2024 [cited 2025 Oct 12]. p. 709–10. Available from: <https://academic.oup.com/book/57303/chapter/461790386>
- [6] Karol Bednarz, Anita Warzocha, Magdalena Kowalczyk, Piotr Pitrus, Anita Krowiak, Gabriela Majka, et al. ENHANCED RECOVERY AFTER SURGERY IN BARIATRIC SURGERY - REVIEW. *IJITSS* [Internet]. 2025 Sep 10 [cited 2025 Oct 12];2(3(47)). Available from: <https://rsglobal.pl/index.php/ijitss/article/view/3707>
- [7] Rusnell L, Nelson G. Future Directions in Enhanced Recovery After Surgery (ERAS) for Gynecologic Surgery. *Clinical Obstetrics & Gynecology* [Internet]. 2025 Aug 28 [cited 2025 Oct 12]; Available from: <https://journals.lww.com/10.1097/GRF.0000000000000967>
- [8] Wu D, Wang J. Impact of enhanced recovery after surgery on postoperative pain management and functional recovery in patients with colorectal cancer. *World J Gastrointest Surg* [Internet]. 2025 Sep 27 [cited 2025 Oct 12];17(9). Available from: <https://www.wjgnet.com/1948-9366/full/v17/i9/107356.htm>
- [9] Anisah Nazrah Siregar, Anna Millizia. Implementation of Enhanced Recovery After Surgery (ERAS) Protocols in Abdominal Surgery. *JURRIKES*. 2025 Sep 23;4(3):555–70.

- [10] Murphy T, Brown M, Sale S, Nasr V. Challenges to the Wider Implementation of Pediatric Cardiac Surgical Enhanced Recovery Programs: ‘What’s in a Name?’ *Journal of Cardiothoracic and Vascular Anesthesia*. 2023 Nov;37(11):2191–3.
- [11] Parks, Ms, Rn, Cnp L, Routt, Msn, Anp/Gnp-Bc, Aocnp M, De Villiers, Msn, Rn, Ocn, Acns-Bc A. Enhanced Recovery After Surgery. *JADPRO* [Internet]. 2018 Aug 1 [cited 2025 Oct 12];8(5). Available from:[https://www.advancedpractitioner.com/issues/volume-9,-number-5-\(julaug-2018\)/enhanced-recovery-after-surgery.aspx](https://www.advancedpractitioner.com/issues/volume-9,-number-5-(julaug-2018)/enhanced-recovery-after-surgery.aspx)
- [12] Slavchev S, Yordanov A. Basic principles of anesthesia and postoperative analgesia in patients operated within an enhanced recovery after surgery (ERAS) protocol. *JMPAS*. 2022 Mar 30;11(2):4752–6.
- [13] Gunaydin S, Simsek E, Engelman D. Enhanced recovery after cardiac surgery and developments in perioperative care: A comprehensive review. *Turk Gogus Kalp Dama*. 2025 Jan 1;33(1):121–31.
- [14] Hekal M, Eskandar K. Revolutionizing Surgical Care: Exploring the Key Components of ERAS for Enhanced Recovery. *Rev salud bosque*. 2024 Mar 25;13(1):1–17.
- [15] Seitz V, Tighe K, Davidson ERW. Opioid Management in the Setting of Enhanced Recovery After Surgery (ERAS) Protocols. *Clinical Obstetrics & Gynecology* [Internet]. 2025 Sep 4 [cited 2025 Oct 12]; Available from: <https://journals.lww.com/10.1097/GRF.0000000000000965>
- [16] Bernard H. Patient warming in surgery and the enhanced recovery. *Br J Nurs*. 2013 Mar 28;22(6):319–25.
- [17] Wang Z, Peng W, Zhang J. The Effect of Early Enteral Nutrition under the ERAS Model on Gastrointestinal and Immune Function Recovery in Patients Undergoing Gastric Tumor Surgery. *Ann Ital Chir*. 2024 Dec 20;95(6):1147–54.
- [18] Andugala S, McIntosh A, Orchard J, Rahiman S, Miedecke A, Keyser J, et al. Successful Implementation of Enhanced Recovery After Surgery (ERAS) in Paediatric Cardiac Surgery in Australia. *Heart, Lung and Circulation*. 2024 Aug;33(8):1201–8.
- [19] Buchanan R, Roy N, Parra MF, Staffa SJ, Brown ML, Nasr VG. Race and Outcomes in Patients with Congenital Cardiac Disease in an Enhanced Recovery Program. *Journal of Cardiothoracic and Vascular Anesthesia*. 2022 Sep;36(9):3603–9.
- [20] Rafeeqi T, Pearson EG. Enhanced recovery after surgery in children. *Transl Gastroenterol Hepatol*. 2021 Jul;6:46–46.