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REVIEW / DERLEME

Enhanced recovery after cardiac surgery and developments in perioperative care: A comprehensive review

Kalp cerrahisi sonrası hızlandırılmış iyileşme ve perioperatif bakımda gelişmeler: Kapsamlı derleme

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ABSTRACT

Enhanced Recovery After Cardiac Surgery (ERAS Cardiac) protocols offer a comprehensive, multidisciplinary approach to improve patient outcomes and reduce postoperative complications. By incorporating evidence-based practices, ERAS Cardiac aims to reduce hospital stays, enhance patient satisfaction, and optimize resource utilization. Key components include patient education, prehabilitation, nutritional optimization, and personalized medicine. The protocol's success relies on interdisciplinary collaboration among healthcare professionals, as well as active patient and family engagement. Despite challenges in implementation, such as resource constraints and patient variability, ongoing research and adaptive strategies continue to refine ERAS Cardiac programs, promising significant advancements in cardiac surgical care and recovery.

Keywords: Enhanced recovery after cardiac surgery, perioperative care, prehabilitation.

ÖZ

Kalp Cerrahisi Sonrası Hızlandırılmış İyileşme (ERAS Kardiyak) protokolleri, hasta sonuçlarını iyileştirmek ve ameliyat sonrası komplikasyonları azaltmak için kapsamlı, multidisipliner bir yaklaşım sunar. Kanıta dayalı uygulamaları içeren ERAS Kardiyak, hastanede kalış sürelerini azaltmayı, hasta memnuniyetini artırmayı ve kaynak kullanımını optimize etmeyi amaçlar. Temel bileşenler arasında hasta eğitimi, prehabilitasyon, beslenme optimizasyonu ve kişiye özel tedavi yer alır. Protokolün başarısı, sağlık çalışanları arasındaki disiplinler arası işbirliğine ve aktif hasta ve aile katılımına bağlıdır. Kaynak kısıtlamaları ve hasta değişkenliği gibi uygulama zorluklarına rağmen, devam eden araştırmalar ve uyarlanabilir stratejiler ERAS Kardiyak programlarını sürekli olarak iyileştirir ve kardiyak cerrahi bakım ve derlenmede önemli ilerlemeler vadetmektedir.

Anahtar sözcükler: Kalp cerrahisi sonrası hızlandırılmış iyileşme, perioperatif bakım, prehabilitasyon.

The Enhanced Recovery After Surgery (ERAS) protocols employ a holistic, evidence-driven, multidisciplinary strategy aimed at enhancing patient recuperation and minimizing postoperative complications. Success in this initiative demands a collaborative effort among a diverse team of healthcare professionals, including surgeons, anesthesiologists, nursing staff, perfusionists, physical therapists, nutritionists, and social workers, as well as the involvement and comprehension of patients and their families.[1] The ERAS protocols are prominent in the context of cardiac surgery due to the current high-risk nature of these procedures and the vulnerable patient population. Implementing these protocols can lead to significant improvements in patient outcomes by addressing the specific challenges associated with cardiac surgery. These include reduced morbidity and mortality, shorter hospital stays, and optimized patient satisfaction. Moreover, ERAS can contribute to more efficient use of healthcare resources, reducing overall

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costs and improving the sustainability of cardiac surgical care.[2]

HISTORY

The concept was pioneered in the late 1990s by Kehlet,[3] a Danish surgeon. Kehlet aimed to challenge traditional perioperative care practices, which often involved prolonged fasting, extensive bowel preparations, and delayed mobilization. Kehlet's initial work focused on colorectal surgery, where he demonstrated that a multidisciplinary approach could significantly reduce postoperative complications and hospital stays. This approach integrated various evidence-based practices, including optimal pain management, early mobilization, and nutritional support, into a cohesive protocol. Since then, the principles of ERAS have been adapted to all surgical specialties, including gynecology, orthopedics, urology, and, most recently, cardiac surgery.

The genesis of the ERAS Society can be traced back to the formation of the ERAS Study Group, initiated by pioneering surgeons Fearon et al.[4] in 2001. Officially becoming a nonprofit medical society in 2010, the ERAS Society has grown to encompass a range of subspecialties. It advocates for the implementation of uniform best practices throughout the perioperative process, underscores the significance of empirical self-assessment, and fosters enhancements in patient treatment. Protocols of ERAS were developed to address the specific needs of cardiac surgery patients. These protocols incorporated key principles while considering the unique aspects of cardiac procedures. In 2017, a pioneering collaboration among cardiac surgeons, anesthesiologists, and intensivists marked the formation of the Society for Enhanced Recovery After Cardiac Surgery (ERAS Cardiac). In 2019, they took a significant step forward by releasing their inaugural guidelines. This publication offered a comprehensive review of existing literature and set forth evidence-based recommendations to optimize patient care in cardiac surgery.[5]

GUIDELINES

Initiated with a seminal consensus document for colonic procedures in 2005, the ERAS Society has broadened its impact by adapting the colorectal surgery protocol to a range of surgical fields, achieving noteworthy outcomes. Since its inception, the ERAS Society has released 20 guidelines covering a wide spectrum of surgeries and perioperative care practices.[6] The groundbreaking 2019 publication introduced the first expert consensus on enhanced recovery protocols for cardiac surgery, outlining 22 care bundles grounded in evidence.[5] This pioneering work emphasizes shifting towards a standardized, patient-focused care model, underscored by diligent auditing and benchmarking. The guidelines were formulated based on a comprehensive evaluation of various study types, with evidence quality appraised to establish consensus recommendations, receiving endorsement from the ERAS Society. With evolving clinical insights and the identification of new perioperative approaches, there has been a drive to update these protocols. An international panel of multidisciplinary experts convened to expand upon the ERAS Cardiac framework, rigorously examining the literature to refine clinical practice guidelines for cardiac surgery. Following the addition of many new publications and evidence on various topics related to cardiac surgery, an updated consensus statement by the ERAS Society was published in 2024.[7] The new document has a broader focus on integrating interdisciplinary care and enhancing recovery through various strategies, covers new advancements and updates since the 2019 guidelines, and incorporates new clinical trials and research, including recent findings on patient engagement tools, prehabilitation, and multimodal analgesia. It emphasizes the importance of interdisciplinary collaboration and continuous improvement by providing updated strategies for integrating protocols in diverse healthcare environments. The classes of recommendation and levels of evidence are briefly summarized in Table 1a and b. All tools for education, information, turnkey order sets, and publications are listed in the ERAS Cardiac Society homepage (www.erascardiac.org).

INTERDISCIPLINARY COLLABORATION AND TEAMWORK

The assembly of the multidisciplinary team is pivotal to the ERAS program's success, with composition tailored to available hospital resources. Key stakeholders include nursing staff, surgeons, anesthesiologists, intensivists, pharmacists, perfusionists, advanced practice providers, registered dietitians, respiratory and physical therapists, case managers, and cardiac rehabilitation specialists. Central to this team's effectiveness is a unified commitment to transformative care principles, necessitating a collaborative approach to cultural adaptation, education, and seamless coordination of patient care, ensuring each member contributes to the comprehensive, patient-centered recovery pathway.[8]

Table 1a. Comparative analysis of initial guidelines (2019) with expert recommendations from ERAS Cardiac Society (2024) according to the classification of recommendation and quality of evidence

Intervention	LOE by COR (2019)	QOE Update (2024)
Preoperative		
Patient engagement and access to technology	Class IIa - Level C-LD	Low
Prehabilitation	Class IIa - Level B-NR	Low
Clear liquids up to 2-4 H/carbohydrate loading	Class IIb - Level C-LD	Low
Correction of nutritional deficiency	Class IIa - Level C-LD	
Smoking & alcohol cessation	Class IC - Level LD	
Preoperative measurement of hemoglobin A1c	Class IIa - Level C-LD	
Intraoperative		
Anti-fibrinolytics	Class IA	
Infection reduction bundle	Class IB - Level R	High
Goal-directed fluid therapy	Class IB - Level R	Moderate
Multimodal, opioid-sparing, pain management	Class IB - Level NR	Moderate
Avoidance of hyperthermia	Class III - Level B-R	
Optimization of sternal closure	Class IIa - Level B-R	
Postoperative		
Early extubation	Class IIa - Level B-NR	Moderate
Delirium screening	Class IB - Level NR	High
Chemical/mechanical thromboprophylaxis	Class IIa - Level C-LD	
Chest tube drain management	Class IB - Level NR	
Early detection of kidney stress & related interventions	Class IIa - Level B-R	Moderate
Avoidance of hypothermia	Class IB - Level NR	
Perioperative glycemic control	Class IB - Level R	

Table 1b. Summary of modification/additions in updated consensus statement (2024)

Intervention	QOE by COR Update (2024)
Preoperative	
Multidisciplinary team, including a dedicated coordinator, as an extension of the heart team	Moderate
Routine auditing and evaluation	Moderate
Multifaceted patient screening and risk assessment	Moderate
Intraoperative	
Transesophageal echocardiography	Moderate
Mechanical ventilation with lung-protective strategies	High
Central nervous system monitoring	Moderate
Goal-directed perfusion	Low
Postoperative	
Standardized risk factor assessment to prevent postoperative nausea and vomiting	Moderate
Early postoperative ambulation and upper extremity exercise	Moderate
Comprehensive patient blood management program	Moderate
Atrial fibrillation prevention strategies	Moderate

LOE: Level of evidence; COR: Classification of recommendation; QOE: Quality of evidence; A-level evidence: B-R, B-level evidence; Randomized studies: B-NR, B-level evidence; Non-randomized studies: C-LD, C-level evidence, limited data.

Involving patients and their families in the recovery process can improve compliance and satisfaction. Providing clear information and support can empower patients to take an active role in their recovery.

KEY COMPONENTS OF ERAS CARDIAC PROTOCOLS

The ERAS Cardiac program outlines a structured approach to enhance recovery after

Table 2. Enhanced Recovery After Cardiac Surgery brief protocol

Prehabilitation	Patients/family counseling, medical optimization, smoking/alcohol cessation, nutritional status (NRS 2002)
Preoperative	• Anemia treatment (If Hb <13 g/dL) • Glucose/insulin adjustment (If HbA1c <7%) • Prealbumin/CRP (additional nutrition, if needed)
Operation day	• Fasting 12 h • Premedication: Pregabalin 150-300 Mg PO • Maltodextrin (24 g) 2 h before surgery • Antibiotic/thromboembolic prophylaxis
Operation	• Anesthesia protocol • ESP block • Induction agents (lidocaine, propofol, ketamin, rocuronium) • Maintenance (sevoflurane, remifentanil infusion, rocuronium) • Acute normovolemic hemodilution • Goal-directed fluid therapy • Goal-directed perfusion • Avoidance of hyperthermia • Lung-protective ventilation • Trigger for transfusion (Hb <7 g/dL) • Antifibrinolytics (tranexamic acid infusion) • Multimodal analgesia • Minimally invasive surgery • Topical sealants/hemostatic agents • Cell-saver • Hemofiltration/hemoadsorption • Minimally invasive extracorporeal circuitry • Rigid sternum fixation • Infection reduction bundle
Intensive care unit	• Early extubation (respiratory physiotherapy) • Multimodal analgesia • PONV prophylaxis • Bowel motility • Early mobilization • Chest tube drain management • Detection of kidney stress & function • Avoidance of hypothermia • Perioperative glycemic control • Delirium screening • Prealbumin/CRP follow-up (additional nutrition, if needed) • Compression stockings/thromboembolism prophylaxis
Ward	• Surgical incision care • Respiratory physiotherapy • Prealbumin/CRP follow-up (additional nutrition, if needed) • Remote monitoring
Control (30-days)	• Outpatients

NRS: Nutritional risk scoring; Hb: Hemoglobin; HbA1c: Hemoglobin A1c; PO: Per oral; ESP: Erector spinae plane; PONV: Postoperative nausea and vomiting; CRP: C-reactive protein.

cardiac surgery and encompasses the following principles: *(i)* identification of key care bundles with potential recovery impact, *(ii)* understanding postsurgical event or complication rates within these bundles, *(iii)* formulating strategies to mitigate these issues, *(iv)* establishing uniform care protocols,

and *(v)* gathering and analyzing data to assess intervention outcomes.[9] Our institutional protocol is demonstrated in Table 2. These protocols are structured into three main phases: preoperative, intraoperative, and postoperative.

PREOPERATIVE PHASE

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.[10] 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.[11,12]

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.[13] Those at risk should receive oral nutritional supplements at least seven days before surgery to mitigate malnutrition's adverse effects and enhance surgical outcomes.[14,15]

Identification and treatment of preoperative anemia and a comprehensive patient blood management strategy

Identifying and managing preoperative anemia, prevalent in up to 40% of surgical patients, is critical for minimizing postoperative complications. Addressing anemia before surgery, primarily through the assessment of iron levels, occult blood loss, and other conditions, is vital to enhance patients' physiological resilience and reduce the necessity for blood transfusions. Implementing standardized transfusion protocols within an ERAS Cardiac framework, based on specific triggers including intraoperative hematocrit levels and oxygen delivery metrics, alongside auditing transfusion practices, ensures adherence to best practices and improves patient outcomes.

The benefit of a multidisciplinary patient blood management (PBM) care pathway in cardiac surgery has been established in the literature and is reflected in the numerous guidelines published by major societies. However, despite the importance of PBM, implementation remains variable across institutions. Patient blood management protocols play an important role in ERAS Cardiac by minimizing blood loss, reducing the need for transfusions, and improving overall patient outcomes. By implementing strategies such as preoperative anemia management, meticulous surgical techniques, and the use of antifibrinolytic agents, PBM protocols help maintain optimal hemoglobin levels, reduce the risk of complications, and shorten hospital stays. These measures not only enhance patient safety and recovery but also contribute to more efficient use of healthcare resources, ultimately leading to better long-term health for cardiac surgery patients.[16-18]

Preoperative fasting and carbohydrate loading

The American Society of Anesthesiology's 1999 revision of fasting guidelines encourages preoperative carbohydrate loading, allowing clear liquids up to 2 h before surgery to enhance patient satisfaction and clinical outcomes.[19] This approach reduces glucose variability and postoperative insulin resistance.[20] The ERAS Cardiac guidelines recommend 800 mL of a 12.5% carbohydrate clear drink the night before and 400 mL of the same fluid 2 h prior to surgery, except for patients with severe diabetes due to different insulin dynamics.[21]

Premedication

For premedication, avoiding benzodiazepines and other long-acting drugs is advised due to their association with increased delirium risk. Pregabalin at a dose of 75 mg is effective in reducing postoperative morphine requirements and lowering the chance of chronic postoperative pain with fewer side effects such as somnolence and dizziness compared to gabapentin.[22]

INTRAOPERATIVE PHASE

The intraoperative phase aims to modernize surgical practices by reducing the use of nasogastric

tubes, drains, and catheters. Care is also taken to ensure a proper fluid and hemodynamic balance, as well as employing minimally invasive techniques, along with using opioid-sparing multimodal analgesia. Emphasis is also placed on appropriate use of antimicrobials and nausea prophylaxis.[23] Key goals include meticulous management of fluids and hemodynamics during cardiopulmonary bypass to prevent fluid overload and organ dysfunction, marking a significant departure from traditional approaches.

Multimodal analgesia to mitigate intraoperative and postoperative opioid use

Effective pain management after cardiac surgery is vital to prevent complications such as hemodynamic instability, postoperative delirium, prolonged intubation, chronic pain, and the risk of opioid dependency. To counteract these issues, multimodal analgesia has become a cornerstone of ERAS Cardiac protocols. This approach combines various analgesic medications and anesthetic techniques to address pain by targeting both peripheral and central receptors, reducing the need for opioids while maintaining effective pain relief. Common nonopioid analgesics include acetaminophen, ketamine, dexmedetomidine, gabapentin, and pregabalin. Additionally, neuraxial and regional anesthesia methods are increasingly used within these frameworks. The unique aspect of multimodal analgesia is educating patients before surgery about pain management expectations, understanding the multimodal strategy, and being aware of the risks associated with opioids.[24,25] The ERAS Cardiac program emphasizes advanced pain management techniques and specific intraoperative anesthesia and physiological management goals. This includes lung-protective ventilation strategies using low tidal volumes and positive end-expiratory pressure, alongside lung recruitment maneuvers. Blood conservation techniques such as cell-saving and viscoelastic testing are also integrated to minimize blood loss and the need for transfusions, aligning with the comprehensive strategy to optimize patient outcomes during cardiac surgery.[26]

Detailed monitorization

Transesophageal echocardiography is essential in cardiac surgery for monitoring. It provides a thorough view of the heart's structure and function, including the aorta, cardiac performance, volume status, valve structure/function, and shunt detection. Transesophageal echocardiography is less invasive compared to pulmonary artery catheterization and offers more accurate and reliable information, making it crucial for intraoperative management and decision-making in most cardiac surgeries.[27] Advanced hemodynamic monitoring systems, such as pulse contour analysis and esophageal Doppler monitoring, allow real-time assessment of a patient's cardiovascular status during and after surgery. These technologies provide detailed insights into fluid status and cardiac function, enabling precise management. Additionally, wearable technologies such as continuous glucose monitors and activity trackers offer valuable data on a patient's physiological state and activity levels.

Goal-directed fluid therapy

Cardiac surgery's complexity requires careful fluid management to accommodate changes in myocardial function, significant fluid shifts, and vascular endothelium stress. Precise fluid administration is vital to avoid overload and ensure adequate perfusion. Goal-directed fluid therapy optimizes fluid management by using dynamic parameters to guide fluid administration.[28]

Minimally invasive techniques

Utilizing minimally invasive cardiac surgery (MICS) techniques is crucial to reducing patient trauma and speeding up recovery times. These methods can result in faster recovery, less pain, and decreased infection rates. Research has demonstrated that MICS, particularly when combined with ERAS Cardiac protocols, is extremely effective. Integrating MICS with ERAS Cardiac may further enhance the beneficial outcomes.[29,30]

Reducing surgical site infections

To decrease the incidence of surgical site infections, administering antibiotics intravenously 30 to 60 min before the incision is effective. Moreover, applying antiseptic solutions to the skin can be beneficial. Continuing antibiotic therapy for 48 h after surgery has been shown to significantly reduce the risk of sternal infections.[23]

Minimally invasive extracorporeal circulation

Modern cardiac surgery combines advancements in surgical methods and cardiopulmonary bypass technology to reduce the invasiveness of procedures, specifically for high-risk, elderly patients, who often have multiple comorbidities. This approach reduces the detrimental effects of cardiopulmonary bypass, which include blood contact with artificial surfaces, activation of the coagulation system, hemodilution,

and hypoperfusion leading to microcirculatory disturbances. The concept of more "physiological" intraoperative perfusion has evolved to mitigate these surgical harms, with minimally invasive extracorporeal circulation being a central component.[31,32]

POSTOPERATIVE PHASE

Maintaining the strategies established during the pre- and intraoperative phases is vital in the postoperative period. Key goals include reducing opioid use, ensuring fluid balance, encouraging early mobility, feeding, and promptly removing catheters and drains.

Postoperative Nausea and Vomiting

Postoperative nausea and vomiting can significantly affect patient satisfaction. Major risk factors include the use of perioperative opioids, being a nonsmoker, female sex, and a history of motion sickness or postoperative nausea. Treatment options include 5-HT3 antagonists, dexamethasone, scopolamine, perphenazine, diphenhydramine, propofol, droperidol, neurokinin-1 antagonists, and acupuncture.[33]

Pain control

The ERAS Cardiac programs incorporate regional pain blocks, local analgesics, such as ropivacaine injections at surgical sites, alternative pain medications, and judicious use of opioids in the postoperative phase, demonstrating promising results.[34]

Normothermia

Hypothermia, defined as a core body temperature below 36°C, is associated with higher risks of postoperative complications, including arrhythmias, surgical site infections, coagulation disorders, and mortality. Anesthetics used in cardiac surgery can disrupt body temperature regulation by causing vasodilation, impacting the hypothalamus, and decreasing sympathetic nervous activity. It is essential to rewarm patients after cardiopulmonary bypass and maintain warmth in the intensive care unit (ICU) using methods such as forced-air warming and warming blankets.[35]

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.

Avoiding delays in removal of tubes, drains, and lines

Removing tubes, drains, and lines as soon as they are no longer necessary promotes early mobilization, reduces patient discomfort, and minimizes the risk of associated infections.[37]

Postoperative atrial fibrillation

Postoperative atrial fibrillation is a common complication after cardiac surgery, associated with increased adverse outcomes. Preoperatively, it is recommended to screen patients for paroxysmal or chronic atrial fibrillation and start appropriate treatments based on individual risk assessments for postoperative atrial fibrillation. This may include administering beta-blockers or amiodarone, tailored to the patient's specific risk profile. Intraoperatively, surgical procedures such as posterior pericardiotomy should be considered for select patients. Postoperatively, it is crucial to focus on electrolyte normalization, strategies for rate or rhythm control, and anticoagulation management.[38]

Screening and prevention of perioperative delirium

To combat perioperative delirium, a notable complication after cardiac surgery, routine screening with standardized tools is essential for early identification and management, potentially reducing subsequent morbidity. Essential strategies include encouraging perioperative ambulation, ensuring access to vision and hearing aids, fostering family interactions, maintaining regular sleep/wake cycles, and frequent patient reorientation. Additionally, addressing pain using multimodal analgesics is crucial, as pain significantly contributes to the development of postoperative delirium.[39,40]

AUDIT

Given the complexity of the care process, continuous auditing of patient outcomes and care procedures helps the team maintain a comprehensive perspective. While most healthcare facilities use electronic medical records, creating detailed reports to capture essential data points can be challenging. Real-time data capturing allows stakeholders to review and act on current information. Adjustments to care should be made if compliance or outcomes fall short of goals. Measuring outcomes and compliance together are basics for identifying challenges and improvement opportunities.[41]

Implementation

Implementing the ERAS Cardiac framework goes beyond merely adopting new protocols and requires a fundamental shift in healthcare culture towards patient-centered care, enhancing both the speed and completeness of recovery processes. The initiative's success depends on appointing a dedicated coordinator to oversee educational programs, troubleshoot issues, and gather data. It also involves identifying and leveraging the expertise of specialty champions who may have varying practices and preferences. Achieving consensus on evidence-based standardization, while respecting individual preferences is crucial. This effort includes reviewing guidelines and the literature and consulting with external experts to build agreement among stakeholders. Efficiency gains are achieved through the electronic standardization of order sets. Tailoring adjustments to fit specific health system needs and exploring grant funding opportunities for program components are vital for successful implementation.

Implementing protocols presents several challenges, including variability in protocol adherence, financial resource constraints, and the need for extensive staff training. This can require significant initial investment in training, resources, and infrastructure, which can be a deterrent for many institutions, particularly those with limited budgets. Communication gaps can impede the integration of protocols. Integrating new protocols into existing workflows can be challenging and may require significant adjustments to daily routines and procedures. The diverse health status of patients undergoing cardiac surgery can complicate standardization.[42,43]

Clinical evidence and outcomes

The adoption of ERAS Cardiac protocols is supported by a substantial and growing body of clinical evidence. Research has shown significant benefits, including shorter hospital stays, reduced complication rates, and improved patient satisfaction. Notably, the number of publications on ERAS has increased markedly, with more than 1,600 articles on PubMed since 2000, half of which have been published since 2016. Systematic reviews and meta-analyses have synthesized findings from multiple studies, offering comprehensive insights into the protocols' effectiveness.

Williams et al.[44] conducted a study comparing patients managed with pre-ERAS Cardiac protocols (n=489) and post-ERAS Cardiac protocols (n=443). They found that the median postoperative length of stay decreased from 7 to 6 days ($p<0.01$) and total ICU hours reduced from a mean of 43 to 28 h ($p<0.01$). The incidence of gastrointestinal complications dropped from 6.8 to 3.6% ($p<0.05$). Opioid use decreased by an average of 8±1.2 mg of morphine equivalents per patient in the first 24 h postoperatively ($p<0.01$). Additionally, the rates of reintubation and ICU readmission were reduced by 1.2% and 1.5%, respectively. Patient satisfaction increased from 86.3% with pre-ERAS Cardiac protocols to 91.8% with post-ERAS Cardiac protocols, with improvements across all measured indices, including patient focus, culture, and engagement.

In another propensity-matched analysis (n=76), patients managed based on ERAS Cardiac protocols experienced significantly shorter median ventilation times (3.5 *vs*. 5.3 h, p=0.01), median ICU stays (28 *vs*. 48 h, p=0.005), and median hospital stays (5 *vs*. 6 days, p=0.03).[45]

A recent meta-analysis covering 13 single-center randomized controlled trials (a total of 1,704 patients; 850 managed with ERAS Cardiac-like protocols and 854 in the standard care group) found no significant difference in in-hospital mortality between the ERAS Cardiac and standard treatment groups.[46] However, ERAS Cardiac was associated with reduced ICU stays (standardized mean difference [SMD]=–0.57, $p<0.01$), shorter hospital stays (SMD= –0.23, $p<0.01$), and lower overall complication rates compared to the standard protocol (relative risk [RR]=0.60, $p<0.01$), primarily due to a reduction in stroke incidence (RR=0.29 [0.13; 0.62], $p<0.01$).

Another meta-analysis evaluating 15 studies (a total of 5,059 patients; 1,706 in the study group and 3,353 in the control group) demonstrated that improved recovery protocols in cardiac surgery decreased perioperative complications (RR=0.73, 95% confidence interval [CI]: 0.52-0.98) and reduced

hospital readmissions within 30 days after surgery (RR=0.51, 95% CI: 0.31-0.86).[47] Differences in extubation time, hospital stay, and ICU length of stay were less pronounced but still favored the ERAS Cardiac group.

In a systematic review, Zhang et al.[48] evaluated one randomized controlled trial, one quasi-experiment, and seven retrospective/prospective studies. They found significant improvements in hospital and ICU lengths of stay, as well as reductions in postoperative opioid consumption, without an increase in postoperative complications.

A meta-analysis focused on valve surgery identified 5,142 patients across 14 studies (2,501 in ERAS Cardiac groups and 2,641 in control groups).[49] Seven studies exclusively included patients who underwent heart valve surgery. Despite high heterogeneity among the included protocols regarding key actions and measured outcomes, all studies indicated that ERAS Cardiac pathways can be safely adopted in cardiac surgery, often resulting in shorter mechanical ventilation times, reduced postoperative opioid use, and decreased ICU and hospital stays.

Our group studied 445 consecutive frail patients undergoing open-heart surgery managed by the ERAS Cardiac protocol versus 445 propensity score-matched patients.[50] We observed significantly better outcomes in early extubation, red blood cell transfusion, need for reintubation, ICU stay/readmission, and hospital stay/readmission in the study group. The EuroQol-visual analog scale score significantly improved in the ERAS Cardiac group compared to preoperative levels, with a 35% reduction in costs.

Despite these positive findings, many publications lack scientific rigor, often relying on cohort studies rather than clinical trials, focusing on incremental effectiveness, or involving small, highly select patient populations with limited external validity. While ERAS Cardiac protocols show potential advantages, further research into its components and their interactions is needed. More research is needed to optimize protocols for different cardiac procedures and patient populations. While short-term benefits are well-documented, there is a need for studies focusing on long-term outcomes, including quality of life, functional recovery, and healthcare costs. Exploring the integration of new technologies, such as enhanced monitoring systems and personalized medicine approaches, can further improve protocols and patient outcomes.

Challenges and limitations

The ERAS Cardiac programs aim to enhance patient outcomes and streamline recovery processes. Despite these advantages, several challenges and limitations exist. Patients undergoing cardiac surgery often have diverse medical histories and comorbidities. Customizing protocols to individual needs can be complex, requiring significant personalization, and potentially limiting standardized approaches. Smaller or resource-limited healthcare facilities may face difficulties meeting the necessary requirements, impeding widespread adoption. Coordinating these efforts can be challenging, particularly in environments with fragmented communication systems. Adherence to protocols is crucial for their success. Accurate data collection and outcome measurement are essential for evaluating the effectiveness of programs. Inconsistent data reporting, lack of standardized metrics, and challenges in tracking long-term outcomes can hinder comprehensive program assessments. Despite these challenges, ongoing research, continuous program refinement, and adaptive strategies can help mitigate limitations and enhance the overall success of ERAS Cardiac initiatives, ultimately leading to improved patient care and recovery.[51]

Future directions and innovations

The ERAS Cardiac initiative is a dynamic and evolving field. Emerging technologies, personalized ERAS Cardiac protocols, long-term follow-up studies, and broader application across cardiac procedures are critical for future development. By focusing on evidence-based practices, interdisciplinary collaboration, and patient engagement, ERAS Cardiac protocols have the potential to revolutionize cardiac surgery and improve outcomes for patients worldwide. Ongoing research, continuous improvement, and global dissemination are essential to realizing the full benefits of ERAS Cardiac.

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