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EXPERT CONSENSUS STATEMENT

Perioperative Care in Cardiac Surgery: A Joint Consensus Statement by the Enhanced Recovery After Surgery (ERAS) Cardiac Society, ERAS International Society, and The Society of Thoracic Surgeons (STS)

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Enhanced Recovery After Surgery (ERAS) programs have been shown to lessen surgical insult, promote recovery, and improve postoperative clinical outcomes across a number of specialty operations. A core tenet of ERAS involves the provision of protocolized evidence-based perioperative interventions. Given both the growing enthusiasm for applying ERAS principles to cardiac surgery and the broad scope of relevant interventions, an international, multidisciplinary expert panel was assembled to derive a list of potential program elements, review the literature, and provide a statement regarding clinical practice for each topic area. This article summarizes those consensus statements and their accompanying evidence. These results provide the foundation for best practice for the management of the adult patient undergoing cardiac surgery.

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Enhanced Recovery After Surgery (ERAS) is a multidisciplinary approach aimed at providing bundled best practice interventions and therapies throughout the perioperative encounter.[1] A central tenet of ERAS is the adoption of evidence-based protocols that have been published and serially updated across a number of surgical specialties.[2-4] Registry-based observational studies reveal that high compliance with these protocols is shown to reduce surgical insult, promote recovery, and prevent postoperative complications, thereby improving the value of delivered care.[5-8]

In 2019, the ERAS Cardiac Society published their original guidance, which reviewed the literature and provided recommendations regarding care elements for patients undergoing cardiac surgery.[9] In the interim, new clinical data as well as recognition of additional potential perioperative strategies have necessitated an update. The ERAS Cardiac Society, in collaboration with the affiliated ERAS International Society, has

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assembled a committee of experts to develop a consensus statement to optimize care for the adult cardiac surgical patient.

METHODS

This consensus statement was developed following the 2019 "Recommendations from the ERAS Society for Standards for the Development of Enhanced Recovery After Surgery Guidelines" (ERAS Standards), which standardizes the formation of an expert guidance development group, literature search, analysis of the evidence, statement formation, and creation of the manuscript.[10] The consensus statement development group, a multidisciplinary panel including cardiac surgeons, anesthesiologists, intensivists, and allied nurses, was identified based on individual expertise and experience with ERAS.

In 2021, the expert group convened an initial meeting and agreed on potential care elements, derived from a combination of prior guidelines, surrogate examples from other subspecialties, and expert opinion, and divided into respective phases of perioperative care. This effort was then aligned with the expert consensus protocols from The Society of Thoracic Surgeons (STS) and underwent a formal review by the STS Workforce on Evidence Based Surgery prior to endorsement and submission for publication.

Literature searches of individual topic areas were conducted with librarian assistance where necessary and included reviews, guideline documents, and clinical studies conducted on adult humans prior to December 2021, published in English, and retrievable from the PubMed, Embase, and Cochrane databases. Medical Subject Heading terms were identified for the care element or intervention, as were accompanying terms for the patient group, procedure, and outcome. Preference was given to meta-analyses, prospective randomized clinical trials, and well-designed, non-randomized studies. In the event a care element or intervention was not reported in the setting of cardiac surgery, evidence pertaining to noncardiac surgical settings was considered, where appropriate. Most of the data outlined in this manuscript pertain to the elective cardiac surgical population, with any exceptions explicitly stated in the accompanying prose, along with a description of the individual case types (ie, coronary artery bypass grafting [CABG], valve, aortic, etc).

A series of virtual and in-person meetings were conducted to present and discuss results as well as resolve any controversies regarding interpretation of the available evidence. Summary statements and accompanying text were modeled after prior ERAS guidelines. Quality of evidence was assessed, and designations were rendered based on whether further research is unlikely (high), likely (moderate), or very likely (low) to have an important impact on the statement of the effect of the intervention.[10] A minimum of 70% committee agreement was required for consensus.

RESULTS

Summary statements and associated quality of evidence are provided in Table 1, organized into general, preoperative, intraoperative, postoperative, and multiphase sections.

GENERAL ELEMENTS

SHARED DECISION MAKING, PATIENT ENGAGEMENT, AND EDUCATION. Engagement of patients and their social network is an important component of perioperative care, both to foster education and establish realistic expectations. Although patient engagement and education are endorsed by multiple other ERAS subspecialty guidelines,[2-4] cardiac surgery has also reinforced the principle of shared decision making, where patients and their representatives work directly with their clinicians to review the available evidence to determine the best therapeutic course of action while explicitly incorporating the patient's values and preferences into the decision-making process.[11]

Patient engagement can be augmented through the use of digital technologies, including wearable remote monitors and interactive applications, which have been shown to improve adherence to the plan of care as well as facilitate data collection and analysis on social determinants of health and the value of familial involvement.[12-16] Data emanating from these digital tools may include physiological data, including vitals, sleep statistics, and movement, as well as patient-reported outcomes,[17-21] modifications to traditional metrics, and an increased emphasis on the recovery of physical, psychological, and functional status after cardiac surgery.[22,23] The use of digital engagement tools, such as personal phone applications and activity trackers, has been shown to correlate with disposition (ie, home vs facility) and optimize health care utilization.[24-26]

Summary Statement: Patient engagement is improved through the incorporation of shared decision-making principles.

Quality of Evidence: Low

ESTABLISHMENT OF A MULTIDISCIPLINARY TEAM. The cardiac surgery perioperative multidisciplinary team (MDT) represents an extension of the Heart Team model

TABLE 1 Summary of Statements and Level of Evidence

Statement	Level of Evidence
Patient engagement is improved through the incorporation of shared decision-making principles.	Low
Program implementation and sustainment is facilitated through the establishment of a multidisciplinary team, including a dedicated coordinator, as an extension of the Heart Team.	Moderate
Routine auditing and evaluation of perioperative process measure adherence and clinical outcomes is a necessary component of high-quality perioperative care.	Moderate
Multifaceted patient screening and risk assessment improves the informed consent process and allows for advanced perioperative planning.	Moderate
Multicomponent prehabilitation may be considered to optimize patients prior to nonurgent cardiac surgery.	Low
Limiting nil per oz status for clear liquids (>2 hours before surgery) is reasonable after assessment of potential risk factors for aspiration.	Low
Transesophageal echocardiography is encouraged in patients with moderate or high risk of perioperative morbidity or mortality.	Moderate
Mechanical ventilation with lung-protective strategies is associated with improved mechanics and fewer pulmonary complications.	High
The role of mechanical ventilation during cardiopulmonary bypass is uncertain.	Moderate
Pulmonary artery catheters use in low-risk patients or procedures incurs greater health care resource utilization without improving morbidity or mortality.	Moderate
Central nervous system monitoring may provide an early indication of neurologic risk, but additional study is necessary to identify strategies to prevent and mitigate injury.	Moderate
Standardized risk factor assessment and prophylaxis has been shown to prevent postoperative nausea and vomiting.	Moderate
Goal-directed perfusion may play a role in preventing organ injury associated with cardiopulmonary bypass.	Low
Structured strategies to facilitate extubation within 6 hours of surgery have been shown to be safe and potentially hasten recovery after elective procedures.	Moderate
Highly selective intraoperative or immediate postoperative extubation may be appropriate for patients undergoing low-risk cardiac surgery.	Low
Routine screening for and, where appropriate, the use of a comprehensive treatment care bundle can reduce the incidence and severity of postoperative acute kidney injury.	Moderate
Early postoperative ambulation and upper extremity exercise is well tolerated and associated with hastened recovery.	Moderate
Goal-directed fluid and hemodynamic therapy can guide perioperative resuscitation and prevent postoperative organ injury.	Moderate
A multimodal approach reduces reliance on opioid-based analgesia and optimizes perioperative pain management.	Moderate
Chest wall regional analgesia can be an effective component of a multimodal approach to perioperative pain management.	Moderate
Blood product utilization and associated outcomes are optimized through the implementation of a comprehensive patient blood management program.	Moderate
Postoperative atrial fibrillation is optimally addressed through the use of a multifaceted prevention strategy.	Moderate
Routine use of a systematic delirium screening tool and nonpharmacologic strategies aid the identification and prevention of postoperative delirium.	High
The bundled application of evidence-based best practices has been shown to prevent surgical site infection.	High

proposed by other guidelines, which has traditionally included representatives from cardiac surgery and cardiology working in concert to determine the ideal procedural intervention.[11] The MDT also includes core representatives from noncardiac surgical disciplines, such as anesthesiologists, nurses, allied health, pharmacists, and dietitians, as well as those more fundamental to cardiac surgery, including intensivists, perfusionists, and cardiac rehabilitation specialists. Multiple studies describe resistance to change and poor communication as a barrier to ERAS implementation, whereas an effective MDT that establishes clear communication among all disciplines is recognized as a facilitator for program success.[27-31] A designated coordinator to improve pathway development, implementation, education, data collection, and reporting of outcomes should be a part of the MDT.[32-34] An effective MDT gains "buy-in" of stakeholders by effectively communicating vision with supporting evidence and provides ongoing collaboration with all team members. An effective MDT is crucial for the cultural shift for successful ERAS implementation.[35-38]

Summary Statement: Program implementation and sustainment is facilitated through the establishment of a multidisciplinary team, including a dedicated coordinator, as an extension of the Heart Team.

Quality of Evidence: Moderate

COMPLIANCE AND OUTCOMES AUDITING. The STS has established a data registry, the Adult Cardiac Surgery Database (ACSD), for patients undergoing major cardiac surgical operations, which promotes performance

TABLE 2 Recommended Preoperative Risk Assessment Components

Component	Rationale
STS predicted risk of mortality and morbidity, EuroSCORE II	Stratified in-hospital and short-term postoperative morbidity and mortality.
Frailty assessment	Prefrail and frail status is associated with a marked increase in adjusted morbidity and mortality. There are several validated tools to assess for frailty.
Delirium risk factors	Patient risk factors that are associated with delirium include age, frailty, preexisting cognitive issues and/or mood disorders, and excessive alcohol use.
Hemoglobin A_{1c}	Hemoglobin A_{1c} >6%-7% is a marker of poorly controlled diabetes and a predictor of postoperative complications, including deep sternal wound infection.
Serum albumin	Hypoalbuminemia (<4.0 g/L) is an indicator of malnutrition and an independent predictor of increased morbidity and mortality after cardiac surgery.
Urine albumin	Urine albumin independently correlates with the risk of postoperative acute kidney injury regardless of baseline estimated glomerular filtration rate and other comorbidities.
Obstructive sleep apnea screening	Preoperative questionnaire positively identifies patients with undiagnosed obstructive sleep apnea, which is strongly associated with postoperative respiratory complications after surgery.
Opioid tolerance assessment	Chronic pain and substance use contributes to hyperalgesia and opioid tolerance. A preoperative assessment can identify patients with opioid tolerance, establish appropriate expectations, and individualize their pain management plan.

EuroSCORE II, European Heart Surgery Risk Assessment System 2011 revision; STS, The Society of Thoracic Surgeons.

benchmarking and informs a number of successful quality improvement programs.[39-42] There is an opportunity for expansion of the current data set to include variables specific to additional perioperative care elements.[43] In addition, multi-institutional ERAS registries have been developed for other subspecialities that include data for key process measures and their associated outcomes and allow clinicians and researchers to critically analyze and assess the quality of care.

Numerous observational studies across multiple noncardiac surgery service lines and health care environments have reported a dose-response relationship between adherence to enhanced recovery care measures and improved clinical outcomes.[44-48] Regular auditing of ERAS program adherence, in addition to participation in other data registries, aides in identifying associations between care elements and clinical outcomes as well as highlights opportunities for program iteration and improvement.[49-53]

Summary Statement: Routine auditing and evaluation of perioperative process measure adherence and clinical outcomes is a necessary component of high-quality perioperative care.

Quality of Evidence: Moderate

PREOPERATIVE PROCESS MEASURES

PREOPERATIVE SCREENING AND RISK ASSESSMENT. Preoperative risk assessment in cardiac surgery is important to determine a patient's suitability for surgery and identify areas for optimization. Table 2 provides a summary of preoperative laboratory and assessment criteria that may be considered as part of a comprehensive preoperative screening and risk assessment. The STS predicted risk of mortality and morbidity and the European Heart Surgery Risk Assessment System 2011 revision (EuroSCORE II) calculators are the 2 most widely used tools to determine in-hospital and early postoperative mortality and morbidity, and their use has been endorsed by other major guidelines.[11,54,55]

Providers may also consider screening for undiagnosed diabetes based on hemoglobin A_{1c}, which reflects glucose control in the previous 3 months. Elevated hemoglobin A_{1c} (>6%-7%) is associated with greater incidence of a number of postoperative complications, including deep sternal wound infections.[56-58] Hypoalbuminemia (serum albumin <4.0 g/L) is an independent predictor of worse outcomes after cardiac surgery, including greater likelihood of acute kidney injury (AKI), longer length of stay, and higher hospital costs.[59-62] In a large cardiac surgical cohort study, an increased urine albumin-to-creatinine ratio was independently associated with an overall increased incidence of mortality, AKI, and longer length of hospitalization, findings that were independent of estimated glomerular filtration rate level and other comorbidities.[63]

Frailty has become more prevalent and strongly contributes to poorer postoperative outcomes, with a recent meta-analysis of observational studies suggesting that prefrailty and frailty were associated with significantly greater postoperative morbidity and mortality.[64] Identifying patients with frailty goes beyond a subjective assessment but rather should be performed with validated tools.[65]

The prevalence of obstructive sleep apnea in cardiac surgical patients ranges from 48% to 74% and has been

associated with an increased incidence of postoperative complications, including postoperative atrial fibrillation, pulmonary complications, delirium, and a greater incidence of major adverse cardiovascular events.[66,67] Preoperative assessment for obstructive sleep apnea using the "STOP-BANG" questionnaire (Snoring, Tired, Observed [stop breathing or choking/gasping during sleep], high blood Pressure, Body mass index >35 kg/m^2; Age >50; large Neck size; Gender, male) has been advised in noncardiac surgery, permitting teams to appropriately triage and monitor patients at elevated risk for respiratory compromise in the postoperative period.[68,69] Although similar studies are generally lacking, initial experience has shown that this association translates to the cardiac surgical population as well.[70]

Chronic pain and substance use can lead to hyperalgesia and opioid tolerance.[71,72] A simple preoperative calculation based on the patient's recent opioid use[73] can identify patients with opioid tolerance and provide an opportunity to establish appropriate pain expectations and individualize their pain management plan.

Each preoperative screening component may allow for more accurate informed consent and contribute to shared decision making between the surgeon and patient as they contemplate surgery.

Summary Statement: Multifaceted patient screening and risk assessment improves the informed consent process and allows for advanced perioperative planning.

Quality of Evidence: Moderate

PREHABILITATION. Cardiac surgery is associated with significant stress on body systems, particularly in the older vulnerable adult with reduced physiological reserve. Previous investigations have identified that up to 50% of older adults undergoing cardiac surgery can be deemed as frail, defined as a cumulative decline in multiple physiological systems resulting in a vulnerability to stressor events.[74-76] These patients typically experience higher rates of postoperative morbidity, mortality, and prolonged hospital length of stay, with associated increased costs to the health care system.[77-80] This is further compounded by malnutrition, which is evident in 20% of the patients presenting for cardiac surgery.[81,82] Finally, the potentially prolonged preoperative waiting period has been associated with worry and fear of death for the patients and their caregivers.[83-86]

To address these perioperative issues, the process of preoperative rehabilitation (ie, prehabilitation or "prehab") has been proposed to enable patients to withstand the stressors of surgery by improving physical and emotional resilience. Several small randomized studies and meta-analysis of patients undergoing nonurgent cardiac surgery, including coronary artery bypass grafting (CABG), have demonstrated the benefits of prehabilitation, including reduced postoperative complications and increased pulmonary function and exercise capacity.[87-89] Preoperative exercise, in particular inspiratory muscle training, along with additional psychological, health-related quality of life and cognitive interventions, may also affect cognitive function and psychological readiness for surgery,[89-91] although additional study specific to the cardiac surgical domain is necessary.

A comprehensive prehabilitation program may include education, nutritional optimization, exercise training (where medically appropriate), social support, and anxiety reduction, although current existing evidence for the cardiac surgery patient is limited.[92,93] An earlier investigation in cardiac surgery patients observed a reduction in hospital length of stay in patients undergoing a prehab program[94]; however, more recent systematic reviews indicate variability of this outcome. This is primarily due to uncertainty regarding optimal patient selection and effective, feasible durations of the interventions.[87,88,95] Although there remains a high degree of variation in the available literature regarding prehab components, duration of intervention, and outcome definitions, the perioperative team may choose to implement an assessment and optimization strategy for preoperative frailty, malnutrition, and cognition/mood in preparation for surgical intervention.[65,96-98]

Summary Statement: Multicomponent prehabilitation may be considered to optimize patients prior to nonurgent cardiac surgery.

Quality of Evidence: Low

LIMITING NIL PER OS STATUS. Published guidelines from all international anesthesia societies have established a consensus on clear liquid fasting times of 2 hours and solid food fasting times of 6 to 8 hours prior to elective surgery.[99-102] The primary concern is the risk of pulmonary aspiration during the induction and maintenance of anesthesia. Patients undergoing cardiac surgery have several risk factors that may increase their risk of aspiration, including nonelective status, low cardiac output, delayed gastric emptying, and the frequent use of transesophageal echocardiography (TEE). As a result, additional research devoted to nil per os status in cardiac surgery is warranted.

Summary Statement: Additional data are needed prior to adjusting established nil per os policies in cardiac surgery although permitting clear liquids up to 2 hours prior to surgery may be reasonable for select patients deemed to be low risk of complications.

Quality of Evidence: Low

INTRAOPERATIVE PROCESS MEASURES

TRANSESOPHAGEAL ECHOCARDIOGRAPHY. TEE is an imaging method that allows for high-quality assessment

of heart anatomy, including structural anomalies, thrombus formation, and congenital abnormalities. Coupled with symptoms, physical examination findings, and catheter-based assessment, findings on TEE can be instrumental in procedural planning, particularly in patients with valvular pathology (ie, rheumatic, secondary, or infective etiologies) or congenital abnormalities. The utility of intraoperative TEE is intuitive in valvular and congenital surgery, where it is not only useful for the real-time assessment of the adequacy of surgical repair but is also associated with a significant reduction in stroke, reoperation, and 30-day mortality in cardiac valve and proximal aortic surgery.[11,103]

What is less well established is the role of TEE in CABG, an area of limited prior investigation. A recent observational study of >1.3 million patients undergoing isolated CABG revealed that not only is the use of intraoperative TEE increasing linearly over time, but patients managed with the aid of TEE also experienced a significant reduction in postoperative mortality compared with those who were not, a finding anchored by mortality benefits associated with moderate-risk (STS risk 4%-8%) and high-risk (STS risk >8%) patients.[104]

TEE allows for the assessment of coincident valvular derangement, regional wall motion abnormality, global ventricular function, and determination of the etiology for hemodynamic compromise, all of which positively influence surgical and anesthetic decision making in the cardiac surgical setting. Major complications associated with TEE use are rare (~1:1300), but higher than historically reported,[105] and patients should be counselled on the potential risk and benefits of its use.

Summary Statement: Transesophageal echocardiography is encouraged in patients with a moderate or high risk of perioperative morbidity or mortality.

Quality of Evidence: Moderate

PROTECTIVE LUNG VENTILATION. In patients undergoing cardiac surgery, measurable derangements in pulmonary function commonly emerge. Postoperative pulmonary complications, which develop in up to 25% of the patients, contribute to prolonged length of stay and greater mortality and require substantial health care resource utilization.[106-112] Data obtained from observational studies and randomized controlled trials (RCTs) in noncardiac surgical patients suggest that low tidal volume ventilation (6-8 mL/kg predicted body weight), in conjunction with positive end-expiratory pressure (PEEP) and alveolar recruitment maneuvers, reduces postoperative pulmonary complications.[113-116] A meta-analysis including 15 RCTs (n = 2121) in different surgical settings (ie, thoracic, cardiac, general) showed that low tidal volume ventilation (≤8 mL/kg predicted body weight) was protective against pulmonary dysfunction.[117] Modern lung-protective ventilation strategies have increasingly focused on targeting lower transpulmonary pressures (ie, driving pressure) in addition to lower tidal volumes and PEEP.[118-120] A recent observational study investigating the effects of intraoperative mechanical ventilation on postoperative pulmonary complications after cardiac surgery demonstrated that the application of an intraoperative lung-protective ventilation bundle, consisting of low tidal volume ventilation, modified driving pressure (peak inspiratory pressure – PEEP) <16 cm H_2O and PEEP ≥5 cm H_2O, was independently associated with reduced pulmonary complications after cardiac surgery.[121]

Summary Statement: Mechanical ventilation with lung-protective strategies is associated with improved mechanics and fewer pulmonary complications.

Quality of Evidence: High

VENTILATION ON CARDIOPULMONARY BYPASS. Cardiopulmonary bypass (CPB) permits blood oxygenation and carbon dioxide exchange, allowing for cessation of lung ventilation to improve surgical exposure. Previous observational data suggest that continuous positive pressure might improve postoperative gas exchange and prevent postoperative complications.[122,123] Several randomized studies investigated different ventilation strategies during CPB and did not find a difference in postoperative complications between the ventilation and nonventilation strategy.[124,125]

Summary Statement: The role of mechanical ventilation during cardiopulmonary bypass is uncertain.

Quality of Evidence: Moderate

USE OF PULMONARY ARTERY CATHETERS. Data from large observational trials have consistently revealed that the placement of pulmonary artery catheters (PACs) in low-risk patients (ie, aged <75 years with normal ventricular dysfunction and without evidence of significant valvular abnormality) and clinically stable patients undergoing elective procedures leads to increased interventions (ie, nonroutine vasopressor use, fluid administration), which although incurring greater health care expense and leading to additional length of stay, has not been associated with improved morbidity or mortality.[126-128]

The benefit of PACs in high-risk populations or those with clinical decompensation is less certain, because results have varied across the available trials.[129-131] One recent observational trial, involving the analysis of >2 million patients, suggested that PAC use in high-risk patients (ie, older adult, congestive heart failure, pulmonary hypertension) or high-risk operations (ie, multiple valve procedures) was associated with longer periods of mechanical ventilation and prolonged length of stay compared with patients who did not receive a

PAC.[129] Highly selective use of PACs in high-risk populations may be safe and potentially beneficial, but additional prospective studies are necessary to confirm this hypothesis.[130]

Summary Statement: Pulmonary artery catheters use in low-risk patients or procedures incurs greater health care resource utilization without improving morbidity or mortality.

Quality of Evidence: Moderate

CENTRAL NERVOUS SYSTEM MONITORING. Intraoperative central nervous system monitoring of patients undergoing CABG, depending on the method, has been hypothesized to identify and prevent periods of brain malperfusion and ensure adequate titration of anesthetics to prevent postoperative neurocognitive dysfunction as well as avoid excessive depth of anesthesia. A recent meta-analysis of RCTs showed that management associated with the use of near-infrared spectroscopy in the setting of cardiac surgery can be beneficial to prevent postoperative cognitive dysfunction.[132] Prior RCTs, as well that those included in the meta-analysis, are generally small and inconsistent in the definition of neurologic outcomes. Further, the management of cerebral hypoperfusion was wide-ranging, including blood product transfusion, provision of supplemental oxygen, and vasopressor titration.[133-138] Therefore, although the monitoring method can provide benefit, it is unclear which interventions are optimal for prevention of neurologic morbidity in patients undergoing CABG. Although an association has been established between persistently low intraoperative processed electroencephalogram (ie, bispectral index) and postoperative mortality,[139] the use of the monitoring method for prevention of recall, assessment of depth of anesthesia, and its association with improved recovery (ie, earlier extubation, shortened length of stay) has yielded inconsistent results.[140-142]

Summary Statement: Central nervous system monitoring may provide an early indication of neurologic risk, but additional study is necessary to identify strategies to prevent and mitigate injury.

Quality of Evidence: Moderate

POSTOPERATIVE NAUSEA AND VOMITING PREVENTION. Postoperative nausea and vomiting (PONV) is one of the greatest contributors to patient dissatisfaction after surgery, to a similar degree as poorly controlled pain.[143] Reported incidence of PONV after cardiac surgery varies from 10% to 70%, likely reflecting the known impact of various patient and perioperative factors on its cumulative risk.[144-148] Two recent prospective randomized studies investigated the effectiveness of chemical prophylaxis for the prevention of PONV after cardiac surgery, each of which revealed an ~20% reduction in the incidence of PONV with medication administration.[149-151] This is consistent with the findings and recommendations put forward by a recent multisociety consensus guideline for the management of PONV, which recommends screening for risk factors, administration of patient-specific prevention and rescue strategies, and inclusion of multimodal PONV prophylaxis in enhanced recovery pathways (Table 3).[152,153]

TABLE 3 Standard Approach to Risk Factor Identification and Prophylaxis Against Postoperative Nausea and Vomiting (PONV)

Step 1: Identify Risk Factors for PONV			
Female sex	Nonsmoker	History of PONV or motion sickness	Postoperative opioid use
Step 2: Administer Prophylaxis Based on Number of Risk(s)[a]			
0-1	2	3	4
Antiemetic #1	Antiemetic #1	Antiemetic #1	Antiemetic #1
	Antiemetic #2	Antiemetic #2	Antiemetic #2
		Antiemetic #3	Antiemetic #3
			Antiemetic #4

[a]Each additional agent is selected from a different class (ie, different mode of action) and provided based on its optimal timing/route of administration.[153]

Summary Statement: Standardized risk factor assessment and prophylaxis has been shown to prevent postoperative nausea and vomiting.

Quality of Evidence: Moderate

GOAL-DIRECTED PERFUSION. Traditionally, blood flow rates on CPB are derived primarily from a formula that correlates cardiac index with body surface area. Goal-directed perfusion (GDP), in contrast, establishes a formal algorithm to protocolize flow rates, hemoglobin levels, and vasopressor titration to achieve a targeted delivery of oxygen (DO_2) threshold. The original research in this area suggested that maintaining DO_2 $\geq$280 mL $\cdot$ min^{-1} $\cdot$ m^{-2} (for patients undergoing surgery with CPB with moderate hypothermia [32-34° C]) is associated with a reduction in the incidence of acute kidney injury.[154] This was reinforced in subsequent observational trials, including a recent retrospective study, where > 800 cardiac procedures were included, which found that low DO_2 on CPB may be associated with greater morbidity and mortality after cardiac surgery, particularly in patients undergoing nonisolated CABG.[155] Multiple studies have investigated the impact of GDP on AKI, including a recent meta-analysis of RCTs, which found that although GDP based on DO_2 during CPB was associated with a reduction in stage 1 AKI, the approach did not appear to significantly impact stage 2/3 AKI or mortality.[156-158] Additional research is necessary to determine other key aspects of GDP, including targeted

mean arterial pressure, acid-base balance, arterial oxygen saturation, and oxygen extraction ratio.

Summary Statement: Goal-directed perfusion may play a role in preventing organ injury associated with cardiopulmonary bypass.

Quality of Evidence: Low

POSTOPERATIVE PROCESS MEASURES

EARLY EXTUBATION STRATEGIES. Early postoperative extubation (<6 hours after surgery) for routine low-risk and certain high-risk (ie, aortic root, ascending aortic repairs) elective cardiac operations has been demonstrated to be safe, with some evidence of reduced intensive care unit (ICU) and hospital lengths of stay although with no difference in mortality.[159-161] This also applies to overnight extubation, provided appropriate staffing and oversight is in place.[153] One RCT demonstrated that management in a specialized postanesthetic care unit can significantly reduce extubation times compared with a cardiac ICU.[162] A number of quality improvement studies have confirmed that implementation of a structured extubation protocol, including greater compliance with an enhanced recovery pathway, can reduce time to extubation.[163-166] Caution should be exercised for patients undergoing ventricular assist device placement, cardiac transplantation, or emergency procedures because those populations are generally unstudied in the context of early extubation.

Summary Statement: Structured strategies to facilitate extubation within 6 hours of surgery have been shown to be safe and potentially hasten recovery after elective procedures.

Quality of Evidence: Moderate

INTRAOPERATIVE EXTUBATION. Intraoperative and immediate postoperative extubation (<1 hour) have been investigated, with published literature suggesting the practice to be both feasible and safe, because studies have reported similar reintubation and overall complication rates compared with standard extubation protocols.[167-171] One propensity-matched analysis of intraoperative extubation compared with early extubation among nonemergent cardiac surgical patients found the practice was associated with a significant reduction in ICU and hospital lengths of stay as well as a 20% reduction in the cost of care.[172]

Given certain characteristics unique to cardiac surgery, including the potential for early postoperative bleeding, acidosis, and delayed awakening, it may be appropriate to use predictive scoring rubrics[173] or establish a consensus intraoperative anesthetic,[166] particularly among centers with limited experience in intraoperative extubation. The limited availability of data directly comparing intraoperative with early extubation tempers the strength of this recommendation, and the approach should be reserved for select patient populations in highly specialized programs.

Summary Statement: Highly selective intraoperative or immediate postoperative extubation may be appropriate for patients undergoing low-risk cardiac surgery.

Quality of Evidence: Low

AKI PREVENTION AND MANAGEMENT. Approximately 20% to 40% of patients experience AKI after cardiac surgery,[174,175] which is associated with increased risk of developing chronic kidney disease as well as increased short- and long-term mortality.[176,177] AKI diagnosis and classification is based on the 2012 Kidney Disease: Improving Global Outcomes (KDIGO) consensus criteria,[178] and guidance for the management of cardiac surgery-associated AKI has been previously published.[179] There are limitations to this staging system because serum creatinine (SCr) and urinary output are surrogate markers of the glomerular filtration rate and are not specific for AKI. In healthy kidneys, the glomerular filtration rate, as measured by SCr, may not decrease until ≥50% of the functional nephrons are lost, and after cardiac surgery, volume overload may falsely indicate normal SCr values.[180,181] Novel kidney biomarkers may predict and detect AKI before a rise in SCr, allowing earlier initiation of preventive measures. Preoperatively, urinary uromodulin and postoperatively, urinary concentrations of tissue inhibitor of metalloproteinases 2 (TIMP-2) and insulin-like growth factor-binding protein 7 (IGFBP7) can predict the development of AKI.[182,183] Among patients with evidence of postoperative AKI, early implementation of KDIGO care bundles, including serial monitoring of SCr, strict urine output quantification, volume replacement based on advanced algorithms, maintenance of hemodynamic targets, and avoidance of nephrotoxic agents, has been demonstrated to reduce the rate of stage 2 and 3 AKI after cardiac surgery.[184-187]

Summary Statement: Routine screening for and, where appropriate, the use of a comprehensive treatment care bundle can reduce the incidence and severity of postoperative acute kidney injury.

Quality of Evidence: Moderate

POSTOPERATIVE ACTIVITY AND STERNAL PRECAUTIONS. Numerous other subspeciality guidelines have established the merits of early postoperative ambulation and physiotherapy, including walking, muscular exercise, cycling, and other activities in the initial 24 hours after surgery.[2-4] In cardiac surgery, early ambulation is safe and associated with decreased atelectasis, pleural effusion, and pneumonia, greater exercise capacity,

and shorter ICU length of stay.[188-193] The impact on overall length of stay and mortality rates is unclear.[194]

Early upper extremity exercise, which allows for greater range of motion based on patient comfort and strength training guided by specific ergonomic principles to avoid excessive tension on the sternum, has been shown to be a safe and potentially effective alternative to more traditional restrictive sternal precautions.[195-199] Formal involvement of physical therapists and protocolization within the ICU environment has been shown to be a cost-effective approach to improve compliance with individualized regimens and strength outcomes.[200-202] Finally, programs should evaluate patients and prescribe comprehensive home- or center-based cardiac rehabilitation that uses education, life style modification, and exercise training to hasten recovery, reduce readmission, and improve quality of life.[11,203,204]

Summary Statement: Early postoperative ambulation and upper extremity exercise is well tolerated and associated with hastened recovery.

Quality of Evidence: Moderate

MULTIPHASE PROCESS MEASURES

GOAL-DIRECTED THERAPY. Advanced monitoring with invasive arterial, central venous, and in select high-risk patients, PACs, is common practice in cardiac anesthesia. Goal-directed hemodynamic and fluid therapy (GDT) describes an algorithmic approach to achieve certain hemodynamic end points through the provision of fluid and vasopressor, and inotropic medications. The cornerstone of GDT suggests that patients who are responsive to fluid administration be identified through dynamic tests, including stroke volume or pulse pressure variation as well as cardiac output or stroke volume responsiveness, thus establishing a protocol for appropriate resuscitation interventions.

Whereas numerous observational, prospective studies, and meta-analyses, including several conducted exclusively in cardiac surgical patients, have revealed the approach is associated with reduced organ injury, medical complications, and hospital length of stay,[205-209] those findings are not universal, and results remain inconsistent. This is likely owing to high degrees of clinical heterogeneity, including varying algorithms, monitoring techniques, and study design.[210-212] As a result, although GDT for cardiac surgery may provide benefit, additional study is necessary to determine the ideal monitoring indicators and algorithm.

Summary Statement: Goal-directed fluid and hemodynamic therapy can guide perioperative resuscitation and prevent postoperative organ injury.

Quality of Evidence: Moderate

OPIOID-SPARING PAIN MANAGEMENT. Pain results in detrimental physiologic responses that may lead to postoperative complications, poor patient experience, and an increased risk of chronic pain, and is a standard metric for quality of recovery.[213-216] Opioid-based analgesia has historically held a primary role in the perioperative care of cardiac surgical patients.[217] Although effective in providing analgesia, opioids have numerous adverse effects that impede recovery and create a negative patient experience.[218] Additionally, there is growing awareness of the importance of new persistent opioid use, with an incidence in cardiac surgery of up to 10% to 15%, and recognition of the contributory roles of postoperative opioid administration and discharge prescribing practices.[218-222]

Multimodal analgesia aims to reduce or eliminate the reliance on opioids by using alternative therapies and is one of the foundations of enhanced recovery.[223,224] Although multimodal analgesia for cardiac surgery has been the subject of recent reviews, there are limited prospective data.[225-227] One RCT of 150 patients in which a multimodal bundle was compared with morphine-based analgesia demonstrated a significant reduction in average pain scores and less nausea and vomiting.[228] In another RCT, the ERAS group, which received a multimodal analgesia bundle, had lower pain scores at all assessment points in the first 72 hours and reduced hospital length of stay, although no differences in patient-reported functional recovery compared with standard of care.[229] Multimodal opioid-sparing analgesia, in isolation or as part of a larger ERAS program, has been shown retrospectively to reduce opioid requirements, facilitate early extubation, and contribute to a shorter length of stay, although improvement in pain scores is not reliably demonstrated, and metrics, such as common opioid/pain adverse effects, and patient-centered outcomes, are inconsistently reported.[230-233]

There are limited data on the use and effectiveness of individual nonopioid pharmacologic agents in cardiac surgery. A recent systematic review found 21 publications of prospective studies on intravenous analgesics: 14 comparing various opioids, 4 on paracetamol/acetaminophen, and 3 on nonsteroidal anti-inflammatory drugs.[234] Fortunately, there is well-established science on the full spectrum of nonopioid options in the noncardiac literature, which may provide the preliminary basis for development of an evidence-based analgesic strategy.[235] Incorporating multimodal analgesia within a cardiac enhanced recovery program requires assessment of each analgesic option regarding the presumed benefit, anticipated risks and adverse effects, cost, and barriers to implementation.

TABLE 4 Components of a Patient Blood Management Program

Preoperative Anemia and Iron Deficiency Screening and Optimization
A patient blood management program, led by a multidisciplinary team of health care providers, should be part of a comprehensive strategy to avoid unnecessary transfusion.
Anemia and iron deficiency assessment and treatment with B_{12}, folate, and intravenous iron preparations, as indicated, is reasonable to reduce blood transfusion.
Preoperative administration of intravenous iron and/or erythropoietin-stimulating agents is reasonable to increase red cell mass for anemic patients.
Minimize Blood Loss and Hemodilution
Laboratory measurement of antiplatelet drug effect for patients on preoperative dual antiplatelet therapy is reasonable to guide timing of surgery.
Use of synthetic antifibrinolytic agents such as epsilon-aminocaproic acid (EACA) or tranexamic acid are shown to reduce blood transfusion.
Reduced priming volume in the cardiopulmonary bypass circuit reduces hemodilution and blood transfusion.
Retrograde autologous priming of the cardiopulmonary bypass circuit reduces hemodilution and blood transfusion.
Routine use of intraoperative red blood cell salvage using centrifugation is indicated for blood conservation.
Use of a standardized hemostasis checklist during cardiac surgery, before closing, can reduce bleeding and blood transfusion.
Permissive Anemia in the Intraoperative and Postoperative Phases
A standardized, restrictive perioperative red blood cell transfusion protocol is favored in preference to a liberal strategy to reduce transfusion.
Goal-directed transfusion algorithms that incorporate point-of-care testing, such as with viscoelastic devices, are shown to reduce bleeding and transfusion.
Red blood cell transfusion is unlikely to benefit nonbleeding patients with a hemoglobin concentration >7.5 g/dL.

Summary Statement: A multimodal approach reduces reliance upon opioid-based analgesia and optimizes perioperative pain management.

Quality of Evidence: Moderate

REGIONAL ANALGESIA. A greater foundation of literature exists evaluating the effectiveness of thoracic epidural, intrathecal, and regional analgesia in cardiac surgery. A meta-analysis of 69 trials and 4860 patients showed reduced pain, intubation time, respiratory depression, and arrhythmias with the use of thoracic epidural analgesia.[236] These benefits must be balanced with the risk of epidural hematoma, a potentially catastrophic complication with an estimated incidence between 1:1000 and 1:30,000.[237,238] A 2009 systematic review showed intrathecal morphine reduced pain and opioid requirements, but there were inconsistent findings related to reduced adverse effects or other outcome benefits.[239]

Recently, there has been rapid growth in the classification and application of a variety of paraspinal and chest-wall regional anesthesia techniques.[240-242] Four recent systematic reviews have shown that these blocks may help reduce pain and opioid use compared with systemic analgesics alone. However, small sample sizes, poor methodologic quality, and high heterogeneity prevent comparing the relative efficacy of the various techniques, limit quantification of the additive benefit within a pharmacologic multimodal bundle, and indicate that further research is required.[243-246]

Summary Statement: Chest wall regional analgesia is an effective component of a multimodal approach to perioperative pain management.

Quality of Evidence: Moderate

PATIENT BLOOD MANAGEMENT PROGRAM. Patient blood management (PBM) involves establishing a comprehensive program to apply best practices to guide local use of allogenic blood products. Multiple observational studies in cardiac surgery have found an association between PBM and decreased transfusion rates, bleeding events, AKI, infection, length of stay, and health care costs.[247-253] A recent meta-analysis revealed that the greatest magnitude of benefit across the surgical specialties for many of the metrics analyzed occurred in cardiac surgery.[254] Components of a PBM program are highlighted in Table 4, organized based on 3 major pillars[254,255]: (1) preoperative anemia and iron deficiency screening and optimization, (2) minimization of intraoperative blood loss or hemodilution, and (3) permissive intraoperative and postoperative anemia.[256,257] Additional guidance regarding PBM has been previously published.[256]

Summary Statement: Blood product use and associated outcomes are optimized through the implementation of a comprehensive patient blood management program.

Quality of Evidence: Moderate

POSTOPERATIVE ATRIAL FIBRILLATION PREVENTION. Postoperative atrial fibrillation (POAF) after cardiac surgery has been extensively investigated, with an incidence ranging from 15% to 40% and associated with an increased risk of perioperative stroke and early and late mortality, and increased hospital length of stay and cost.[258,259] For patients who develop POAF and are discharged in sinus rhythm, nearly 30% will have recurrent POAF in follow-up within 1 month.[260] Identification of patients with a higher risk of POAF may allow for higher intensity prevention methods. The CHA_2DS_2-VASc score (C: congestive heart failure; H: hypertension [blood pressure consistently >140/90 mm Hg or treated hypertension on medication]; A_2: age ≥75

TABLE 5 Components of Postoperative Atrial Fibrillation Prevention

Preoperative Risk Scoring
CHA_2DS_2-VASc score
Medications
Preoperative or immediate postoperative oral or intravenous β-blocker
Preoperative (high risk) or immediate postoperative oral or intravenous amiodarone
Procedural Considerations
Posterior pericardiectomy
Avoidance of retained pericardial blood

CHA_2DS_2-VASc, C: congestive heart failure; H: hypertension (blood pressure consistently >140/90 mm Hg or treated hypertension on medication); A_2: age ≥75 years; D: diabetes mellitus; S_2: prior stroke or transient ischemic attack, or thromboembolism; V: vascular disease (previous myocardial infarction, peripheral arterial disease, or aortic plaque); A: age 65-74 years; Sc: sex category (female sex).

years; D: diabetes mellitus; S_2: prior stroke or transient ischemic attack, or thromboembolism; V: vascular disease [previous myocardial infarction, peripheral arterial disease, or aortic plaque]; A: age 65-74 years; Sc: sex category [female sex]) has been shown to be an independent predictor of the development of POAF.[261,262] Results of meta-analyses randomized trials show that prophylactic β-blockers and amiodarone, both preoperatively and postoperatively administered, reduce the incidence of POAF.[263-266] As treatment against the inflammatory state thought to be implicated in POAF, multiple randomized trials have been conducted looking at corticosteroids, *N*-acetylcysteine, polyunsaturated fatty acids, and vitamins. Owing to the significant heterogeneity in these studies, the treatment effect has been inconsistent.[267,268] The use of biatrial pacing after cardiac surgery has shown a reduction in POAF; however, right- or left-sided atrial pacing has not shown a consistent reduction in POAF.[269] Finally, the routine use of magnesium supplementation has not been shown to be beneficial in studies at low risk of bias.[270]

Pericardial effusion has been implicated as a pathophysiologic contributor to POAF,[271] and thus, strategies should be deployed to avoid retention of pericardial blood. The routine use of posterior pericardiotomy has demonstrated a reduction in residual pericardial effusion as well as POAF, with a systematic review of 3425 patients demonstrating a 90% reduction in tamponade and a 58% reduction in POAF.[272] Table 5 provides a summary of the potential strategies associated with a reduction in POAF.

Summary Statement: Postoperative atrial fibrillation is optimally addressed through the use of a multifaceted prevention strategy.

Quality of Evidence: Moderate

SYSTEMATIC DELIRIUM SCREENING AND PREVENTION. Delirium occurs in ~20% to 50% of patients after cardiac surgery and is associated with reduced in-hospital and long-term survival, freedom from hospital readmission, and cognitive and functional recovery.[273-275] Early delirium detection is essential in the management of delirium and should begin in the preoperative phase by identifying key risk factors for the development of delirium.[276] In the postoperative phase, the use of a systematic delirium screening tool in the ICU that assesses the full spectrum of delirium presentation (ie, hypoactive, hyperactive, and mixed) should be incorporated as part of routine monitoring at least once per nursing shift.[277] The Confusion Assessment Method for the Intensive Care Unit or the Intensive Care Unit Delirium Screening Checklist are the most commonly reported tools in the ICU.[278-280]

Once delirium is detected, it is important to determine the underlying cause (ie, pain, hypoxemia, low cardiac output, and sepsis) and initiate appropriate treatment.[277] Several randomized trials have not provided support for the use of prophylactic medicines, such as clonidine or antipsychotic agents, to reduce the occurrence of delirium in the ICU.[281-283] The use of antipsychotic medications should be limited to those patients with particularly distressing symptoms and/or who pose a safety risk to themselves or the health care team.

In contrast, nonpharmacologic strategies remain as the first-line component of management and should consider the implementation of the ICU "ABCDEF liberation bundle" (A: assess, prevent, and manage pain; B: Both spontaneous awakening and spontaneous breathing trials; C: Choice of analgesia and sedation; D: Delirium: assess, prevent, and manage; E: Early mobility and exercise; F: Family engagement and empowerment) in the postoperative cardiac surgery ICU.[277] A multicenter randomized trial examining a multicomponent family support intervention was associated with higher ratings of the quality of communication and a shorter ICU length of stay; however, this requires additional study in the postoperative cardiac surgery patient.[284]

Summary Statement: Routine use of a systematic delirium screening tool and nonpharmacologic strategies aid the identification and prevention of postoperative delirium.

Quality of Evidence: High

SURGICAL SITE INFECTION PREVENTION BUNDLE. A number of strategies applied across the perioperative continuum have been shown to reduce the incidence of postoperative surgical site infection (SSI). These can be quite extensive, including behavioral elements, such as

TABLE 6 Components of a Surgical Site Infection Prevention Bundle

Preoperative
Smoking cessation for 4 weeks before surgery
Topical intranasal staphylococcal decolonization
Chlorhexidine-alcohol–based bathing the night before surgery
Intraoperative
Clipping (as opposed to shaving) of hair immediately prior to incision
Chlorhexidine-alcohol–based solution for skin preparation prior to incision
Appropriately timed (<60 minutes prior to incision) and redosed antibiotic prophylaxis
Routine use of an insulin infusion for glucose management
Postoperative
Avoidance of hyperglycemia (goal glucose <140-180 mg/dL)
Maintenance of normothermia (>36° or <38° C)

preoperative smoking cessation,[285] surgical site preparation with chlorhexidine cleansing and hair clipping (as opposed to shaving),[286,287] antimicrobial prophylaxis with topical intranasal staphylococcal decolonization[288-290] and appropriately timed antibiotics,[291,292] and the routine maintenance of euglycemia[293-295] and normothermia.[296] Prior publications have not only revealed an association between individual interventions and SSI prevention but also reinforced the bundled application of numerous elements to obtain an additive, if not synergistic, reduction in subsequent infection.[297-300] Elements that may be potentially included in an SSI bundle are summarized in Table 6.

Summary Statement: The bundled application of evidence-based best practices has been shown to prevent surgical site infection.

Quality of Evidence: High

UNGRADED CARE ELEMENTS, FUTURE DIRECTIONS, AND CONTENT DISCLAIMER

Early removal of catheters and tubes is a cornerstone element of ERAS. Unfortunately, few studies have expressly evaluated the timing of removal of central catheters, arterial access, and chest tubes in the cardiac surgical setting. However, teams are recommended to formally assess daily and remove all indwelling catheters and chest tubes as early as possible after surgery.[2-4]

Heparin-induced thrombocytopenia (HIT) is a life-threatening complication associated with exposure to unfractionated heparin.[301] Owing to the preponderance of thrombocytopenia, multiple heparin exposures, and alternative bleeding dyscrasias, particularly in the early postoperative period, formal cardiac-specific HIT screening and management should be protocolized and requires additional study.[302]

Given the relatively high incidence of vocal cord injury associated with cardiac surgery, owing to higher incidence of prolonged intubation and increased vasopressor administration compared with other types of surgery, it may be advisable for programs to standardize postoperative screening for oropharyngeal injury, particularly in high-risk patients.[303]

Although a multimodal, opioid-sparing pain management plan is recommended, cardiac surgical patients with preoperative opioid-tolerance or chronic opioid use are underrepresented in the literature,[304] and additional study is necessary prior to providing formal recommendations regarding management of their pain and opioid administration.

Minimally invasive surgery is a common inclusion among other ERAS subspecialty guidelines because smaller incisions are associated with less surgical trauma, more modest analgesic requirements, and shorter recovery periods.[2-4] Although minimally invasive surgery has been described, including mini-thoracotomy, ministernotomy, and robotic approaches,[305-307] additional research is required to establish its association with key mid and long-term outcomes.[308-310]

In addition, patients with mechanical circulatory support devices, such as an intra-aortic balloon pump or a temporary or more durable ventricular assist device, will similarly benefit from protocolized evidence based perioperative care pathways. However, more research is needed to integrate into ERAS clinical pathways.

The statements provided in this document are the result of a recent review of published evidence and expert opinion. Although they are a reflection of the available evidence, limitations in study design, patient, or procedure inclusion characteristics, differences in regional and international practice patterns, and variation in interventions and surgical complexity suggest that this consensus statement should neither be considered standard of care nor a substitute for patient autonomy or clinical judgment. Providers and their teams are encouraged to deviate from these recommendations when patient preference, clinical condition, local expertise, or additional published literature warrant. Further, application of the statements provided in this document to urgent or emergent procedures should be done with caution because most of the evidence is based on data derived from elective surgery.

CONCLUSIONS. An aging patient population coupled with more sophisticated surgical technique has dramatically increased the complexity of perioperative care for the cardiac surgical patient. Although their origins can be traced back to fast-track cardiac surgery,[159,311] which involved a similar bundled approach to care, present-day cardiac surgical ERAS protocols require adoption of

a patient-centered, multidisciplinary pathway centered on elements shown to improve surgical outcome and contribute to high-value care. Despite a body of literature replete with examples of successful ERAS programs in noncardiac surgery, their application to the cardiac surgical setting is in its relative infancy. As outlined, most of the measures included in this document are based on a low- or moderate-level of evidence, and additional high-quality studies are warranted to tailor additional guidance in the future. The care elements assessed and reported on in this consensus statement can provide a foundation for ERAS program development to ensure optimal care for the cardiac surgical patient.

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