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Cardiac vulnerability under anesthesia; an epidemiologic review of the cardiology-anesthesiology interface

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Abstract

Perioperative cardiac complications remain a major source of morbidity and mortality in surgical patients, particularly in the context of an aging global population and rising cardiovascular disease prevalence. This narrative review synthesizes epidemiologic evidence, risk factors, underlying pathophysiological mechanisms, anesthetic considerations, and interdisciplinary management strategies at the cardiology–anesthesiology interface to inform perioperative care and improve outcomes. Current evidence shows that perioperative cardiac complications, including myocardial injury after non-cardiac surgery, perioperative myocardial infarction (PMI), heart failure, arrhythmias, and cardiac arrest, occur in approximately 3–8% of major non-cardiac surgeries and are associated with substantial short- and long-term mortality. Risk is highest among elderly individuals, patients with established cardiovascular disease, and those undergoing high-risk or urgent procedures. Mechanisms of vulnerability include myocardial oxygen supply–demand imbalance, plaque rupture, systemic inflammation, and anesthesia- or surgery-induced hemodynamic instability. Anesthetic agents exert variable effects on cardiac function, underscoring the importance of vigilant intraoperative monitoring and hemodynamic optimization. Evidence supports routine risk stratification using validated tools, perioperative troponin surveillance in high-risk patients, individualized anesthetic and hemodynamic strategies, and multidisciplinary collaboration.

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Introduction

Perioperative cardiac complications are a leading cause of morbidity and mortality in surgical patients, particularly among those with pre-existing cardiovascular disease or advanced age (1-3). As global demographics shift toward an aging population and the burden of cardiovascular comorbidities increases, the intersection between cardiology and anesthesiology has become a critical focus in perioperative medicine (1). Cardiovascular events such as myocardial injury after noncardiac surgery (MINS), perioperative myocardial infarction (PMI), heart failure exacerbation, arrhythmias, and cardiac arrest contribute significantly to adverse postoperative outcomes, with reported incidence rates ranging from 3% to 8% in major noncardiac surgeries (4). These complications are associated with prolonged hospital stays, increased healthcare costs, and elevated mortality (5,6). The pathophysiology underlying perioperative cardiac events is multifactorial, involving a complex interplay of myocardial oxygen supply–demand mismatch, systemic inflammation, neurohormonal activation, and hemodynamic perturbations induced by anesthesia and surgical stress (7,8). Anesthetic agents and techniques can modulate cardiovascular function, influencing myocardial contractility, heart rhythm, vascular tone, and autonomic balance, thereby affecting perioperative risk (9,10). Despite advances in perioperative monitoring and risk stratification tools such as the revised cardiac risk index (RCRI) and the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) calculator, challenges persist in accurately predicting and mitigating cardiac events, particularly in high-risk and understudied populations (11-13). Furthermore, the increasing complexity of surgical procedures and the growing use of minimally invasive and ambulatory surgeries necessitate a reevaluation of traditional risk models and management strategies. This narrative review aims to synthesize current epidemiologic evidence, elucidate key risk

Key point

Perioperative cardiac vulnerability remains a significant challenge at the cardiology–anesthesiology interface, driven by an aging population and increasingly complex surgical care. Effective prevention hinges on accurate risk stratification, understanding of key pathophysiological mechanisms, and individualized anesthetic and hemodynamic management supported by advanced monitoring and timely detection of complications. Interdisciplinary, evidence-based, team-centered care further enhances outcomes.

factors and mechanisms of cardiac vulnerability under anesthesia, and highlight interdisciplinary approaches to optimize perioperative cardiovascular outcomes.

Search strategy

A literature search was conducted in valid databases, including PubMed (MEDLINE), Scopus, Web of Science, Cochrane Library, Embase, and Google Scholar search engine to identify peer-reviewed, English-language articles relevant to perioperative cardiac complications at the cardiology–anesthesiology interface, with the final search updated in January 2026. Eligible publication types included original research, meta-analyses, systematic and narrative reviews, clinical guidelines, and expert consensus statements published between 2010 and 2026, with emphasis on recent high-impact studies. The search strategy incorporated both keywords and MeSH terms using the following combined terms: ("perioperative" OR "postoperative" OR "intraoperative" OR "surgical") AND ("cardiac complications" OR "myocardial injury" OR "myocardial infarction" OR "MINS" OR "heart failure" OR "arrhythmia" OR "atrial fibrillation" OR "cardiac arrest") AND ("anesthesia" OR "anesthesiology" OR "anesthetic agents" OR "hemodynamic monitoring" OR "cardiac devices" OR "perioperative optimization" OR "risk factors" OR "guideline-directed medical therapy" OR "interdisciplinary management"). Titles and abstracts were screened for relevance, and full texts were reviewed to confirm eligibility and exclusion criteria. Additionally, reference lists of included studies and relevant clinical guidelines were manually searched to identify supplementary articles.

Epidemiology of perioperative cardiac complications

Incidence and prevalence

Perioperative cardiac complications are a major source of morbidity and mortality in surgical patients worldwide. Large cohort studies estimate that over 300 million surgeries are performed annually, with major adverse cardiovascular and cerebrovascular events occurring in approximately 3% of patients undergoing major noncardiac surgery (1). The MINS, defined by elevated cardiac troponin levels within 30 days of surgery, is observed in 8–20% of patients, depending on the population and sensitivity of troponin assays used (4). The vascular events in noncardiac surgery patients' cohort evaluation study, a landmark international prospective cohort, found that 8% of patients experienced MINS, with most cases being asymptomatic and detected only through routine troponin surveillance (14). The incidence of PMI is lower, typically 1–3%, but is associated with a disproportionately high risk of mortality (1). Heart failure, arrhythmias (notably postoperative atrial fibrillation), and cardiac arrest also contribute significantly to perioperative morbidity (15).

Temporal trends and global variation

The burden of perioperative cardiac complications has evolved. While advances in surgical and anesthetic techniques have improved safety, the increasing age and comorbidity burden of surgical patients have offset some gains; recent studies indicate a rising incidence of perioperative cardiac events, particularly in the oldest-old (≥80 years) and those with established coronary artery disease (CAD) (16). For example, a single-center study of patients over 80 with CAD undergoing noncardiac surgery reported a perioperative cardiac event rate of 12.2%, with significant increases over a nine-year period (17). Regional variation exists, with higher rates of complications reported in countries with older populations and greater prevalence of cardiovascular risk factors. However, the global trend is toward increasing surgical volumes and complexity, underscoring the need for robust perioperative cardiac risk assessment and management strategies (1).

Outcomes and prognosis

Perioperative cardiac complications are associated with substantial short- and long-term mortality. In patients with MINS, 30-day mortality rates range from 3% to 9%, compared to less than 1% in those without MINS. One-year mortality remains elevated, with rates of 15–25% in affected patients (1). PMI, heart failure, and postoperative atrial fibrillation are also linked to increased risk of readmission, prolonged hospitalization, and reduced quality of life (15). Notably, most perioperative cardiac events occur within the first week after surgery, and the majority of MINS cases are clinically silent, highlighting the importance of routine surveillance in high-risk populations (4).

Risk factors and patient populations at risk

Patient-related risk factors

A wide range of patient characteristics contribute to perioperative cardiac vulnerability, with advanced age being one of the strongest predictors, as risk rises substantially in individuals aged 65 years and older and is highest among those over 80 (16). Pre-existing cardiovascular disease, including CAD, heart failure, prior myocardial infarction, valvular heart disease, and arrhythmias, remains a major determinant of adverse outcomes. Multiple comorbidities such as diabetes mellitus, hypertension,

chronic kidney disease, cerebrovascular and peripheral vascular disease, and chronic obstructive pulmonary disease independently heighten perioperative cardiac risk (7). Frailty and reduced functional capacity, particularly an inability to perform activities equivalent to at least 4 metabolic equivalents, further increase susceptibility to complications (18). Additionally, laboratory abnormalities such as preoperative anemia, hypoalbuminemia, elevated creatinine, and electrolyte disturbances, especially hypokalemia, have been consistently associated with higher perioperative cardiac event rates, particularly in elderly and medically complex patients (7).

Surgery-related risk factors

Surgery-related factors play a major role in determining perioperative cardiac risk, with the highest vulnerability observed in patients undergoing aortic, major vascular, thoracic, or other high-risk procedures, as well as in those requiring emergency operations, where limited time for optimization contributes to poorer outcomes (7). Urgency itself is a strong predictor, as emergency and urgent surgeries consistently demonstrate higher rates of cardiac complications compared with elective procedures (18). Additionally, surgical complexity, including operations associated with substantial blood loss, large fluid shifts, prolonged operative duration, or extensive tissue manipulation, further increases the likelihood of myocardial stress, hemodynamic instability, and subsequent cardiac events (7).

Special populations

Several patient groups warrant particular attention due to their heightened susceptibility to perioperative cardiac complications. Elderly individuals experience disproportionately higher rates of adverse cardiac events and poorer postoperative outcomes, compounded by frailty, multimorbidity, and frequent underrepresentation in clinical trials. Patients with heart failure or significant valvular disease face an elevated risk of perioperative decompensation, necessitating meticulous preoperative assessment and tailored hemodynamic management. Those with pulmonary hypertension are especially vulnerable to right ventricular failure and hemodynamic instability during anesthesia and surgical stress (16). Additionally, patients with cardiac implantable electronic devices—including pacemakers, implantable cardioverter-defibrillators (ICDs), and left ventricular assist devices (LVADs)—present unique perioperative challenges related to device interrogation, electromagnetic interference, and the need for specialized intraoperative monitoring and coordination with cardiology and electrophysiology teams (19).

Risk prediction tools

Validated risk prediction tools play a central role in stratifying perioperative cardiac risk, with commonly used models including the RCRI (20,21), the NSQIP surgical risk calculator (11,22,23), the myocardial infarction or cardiac arrest (MICA) model (24,25), and the geriatric-sensitive cardiac risk index (26). These instruments help estimate the likelihood of major adverse cardiac events by integrating clinical variables, comorbidities, and surgical factors; however, their predictive accuracy may be limited in older adults, frail individuals, and patients with multiple complex comorbidities. As a result, clinical judgment remains essential, and the incorporation of supplementary biomarkers, such as NT-proBNP and high-sensitivity troponin, can enhance risk discrimination and improve identification of patients at highest risk for perioperative cardiac complications (18).

Pathophysiological mechanisms of cardiac vulnerability under anesthesia

Myocardial oxygen supply-demand imbalance

The perioperative period is marked by rapid and often profound fluctuations in myocardial oxygen supply and demand, creating conditions that predispose vulnerable patients to ischemia. Increases in myocardial oxygen demand commonly arise from tachycardia, hypertension, pain, and heightened sympathetic activation triggered by surgical stress and anesthetic stimulation. Conversely, oxygen supply may be compromised by hypotension, anemia, hypoxemia, or coronary vasoconstriction, all of which reduce myocardial perfusion and impair oxygen delivery. These opposing forces frequently converge to produce a sustained supply–demand mismatch, which is the predominant mechanism underlying perioperative myocardial injury (1). As a result, most perioperative myocardial injuries are classified as type 2 myocardial infarction, reflecting ischemia caused by imbalance rather than acute plaque rupture, and highlighting the importance of meticulous hemodynamic control throughout the perioperative course (4).

Plaque rupture and thrombosis

A subset of perioperative cardiac events is due to type 1 myocardial infarction, characterized by acute coronary plaque rupture and thrombosis. Surgical stress and catecholamine surges can destabilize vulnerable plaques, leading to occlusive thrombus formation (4).

Systemic inflammation and neurohormonal activation

Surgery and anesthesia induce a systemic inflammatory response, with increased cytokine production such as interleukin-6 and tumor necrosis factor-alpha, acute phase reactants, and activation of the hypothalamic-pituitary-adrenal axis. These changes promote endothelial dysfunction, hypercoagulability, and myocardial injury (4).

Hemodynamic instability induced by anesthesia

Anesthetic agents can profoundly alter cardiovascular

physiology, often creating hemodynamic instability that increases perioperative cardiac risk. Many commonly used anesthetics produce systemic vasodilation and hypotension, which can reduce coronary perfusion pressure and precipitate ischemia in susceptible patients. In addition, several agents exert direct myocardial depressant effects, lowering contractility and cardiac output and thereby exacerbating oxygen supply–demand imbalance. Certain anesthetics and neuromuscular blockers also carry arrhythmogenic potential, predisposing patients to bradyarrhythmias, atrial fibrillation, or other conduction disturbances during the perioperative period (15).

Other mechanisms

Additional mechanisms further contribute to perioperative cardiac vulnerability, including anemia and hypoxemia, which commonly arise from intraoperative blood loss or impaired oxygenation and subsequently diminish myocardial oxygen delivery (4). Electrolyte disturbances such as hypokalemia, hypomagnesemia, and related imbalances heighten the risk of perioperative arrhythmias by destabilizing cardiac conduction (15).

Interdisciplinary management and perioperative optimization

Multidisciplinary team-based care

The complexity of perioperative cardiac risk underscores the need for a coordinated, multidisciplinary approach in which anesthesiologists, cardiologists, surgeons, and, when appropriate, geriatricians and intensivists collaborate to provide comprehensive preoperative assessment and optimization. Shared decision-making is essential, particularly for high-risk or elective procedures, ensuring that patient preferences, goals of care, and risk–benefit considerations are fully integrated into the perioperative plan. For patients with substantial cardiac risk or complex comorbidities, multidisciplinary team meetings are recommended to evaluate surgical appropriateness, optimize medical therapy, and develop individualized perioperative management strategies that enhance safety and improve outcomes (27).

Perioperative medication management

Optimal perioperative medication management is essential for reducing cardiac risk, and several drug classes require careful, individualized consideration. Beta-blockers should be continued in patients already receiving them, while initiation in high-risk individuals is recommended only when started well in advance of surgery to avoid perioperative bradycardia or hypotension. Statins should be continued and initiated when indicated for secondary prevention, as they are associated with reduced perioperative cardiac events (28). Management of angiotensin-converting enzyme (ACE) inhibitors and angiotensin II receptor blockers (ARBs) should be individualized: these agents may be withheld preoperatively in patients prone to hypotension, but are generally continued in those with heart failure or chronic kidney disease (29). Antiplatelet therapy requires nuanced decision-making; aspirin for secondary prevention is typically continued unless bleeding risk is prohibitive, and the timing of surgery after percutaneous coronary intervention, as well as the management of dual antiplatelet therapy, necessitates close coordination with cardiology. Anticoagulation strategies, including bridging for warfarin or temporary interruption of direct oral anticoagulants, depend on the balance between thrombotic and bleeding risk, underscoring the importance of multidisciplinary input in complex cases (28).

Cardiac devices and perioperative considerations

Patients with cardiac implantable electronic devices, such as pacemakers and ICDs, must undergo preoperative interrogation, appropriate perioperative reprogramming or magnet application to prevent electromagnetic interference, and postoperative reactivation to ensure proper device function. Individuals supported by LVADs or other advanced cardiac devices present additional challenges, necessitating specialized protocols that address anticoagulation management, continuous hemodynamic monitoring, and device-specific operational considerations (19).

Enhanced recovery and quality improvement

Enhanced recovery and quality-improvement initiatives play an increasingly important role in reducing perioperative cardiac complications and improving overall surgical outcomes. Enhanced recovery after surgery pathways, which integrate multimodal, protocol-driven strategies, have been shown to decrease postoperative complications, reduce opioid requirements, shorten hospital stays, and may also lower the incidence of postoperative atrial fibrillation and other cardiac events. Broader safety interventions, including the use of standardized checklists, simulation-based team training, and evidence-based perioperative protocols, further enhance reliability and reduce preventable errors in cardiac anesthesia and perioperative care (30).

Conclusion

Perioperative cardiac vulnerability remains a major challenge at the intersection of cardiology and anesthesiology, with an aging population and increasing surgical complexity amplifying the burden of cardiac complications. Effective mitigation relies on accurate risk stratification, a clear understanding of underlying pathophysiology, and individualized anesthetic and hemodynamic management tailored to patient comorbidities and surgical demands. Advanced monitoring, perioperative biomarker surveillance, and early recognition of complications further enhance safety, while interdisciplinary, team-based care grounded in evidence-based protocols and shared decision-making

optimizes outcomes. Despite meaningful progress, important gaps persist in prediction, surveillance, and management, particularly for high-risk and special populations, highlighting the need for future research to refine risk models, validate monitoring strategies, and evaluate targeted interventions.

Authors' contribution

Conceptualization: Mahdi Amirdosara and Malihe Abniki.
Data curation: Malihe Abniki and Sara Rashki Ghalehnoo.
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Supervision: All authors.
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Writing–original draft: All authors.
Writing–review and editing: All authors.

Conflicts of interest

The authors declare that they have no competing interests.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors utilized Copilot to refine grammar points and language style in writing. Subsequently, the authors thoroughly reviewed and edited the content as necessary, assuming full responsibility for the accuracy and content of the publication.

Ethical issues

Ethical issues (including plagiarism, data fabrication, and double publication) have been completely observed by the authors.

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