Publisher

www.gmcpatiala.in

GMC Patiala Journal of Research and Medical Education

2026 Volume 9 Number 1 JAN-JUN

E-ISSN:2583-813X

P-ISSN:2581-8201

Review Article

Noncardiac Surgery

Perioperative Anesthetic Management of Cardiac Patients Undergoing Noncardiac Surgery: An Individualized and Evidence-Based Approach

Muhammed Shamnad CS[1*], Rekhi BK[2], Kaur L[3], Pal K[4]

DOI:10.56412/gmcp.2026.9.01.217

[1*] Muhammed Shamnad CS, Department of Anaesthesiology and Intensive Care, Government Medical College and Rajindra Hospital, Patiala, Punjab, India.

[2] Balwinder Kaur Rekhi, Department of Anaesthesiology and Intensive Care, Government Medical College and Rajindra Hospital, Patiala, Punjab, India.

[3] Lovepreet Kaur, Department of Anaesthesiology and Intensive Care, Government Medical College and Rajindra Hospital, Patiala, Punjab, India.

[4] Komal Pal, Department of Anaesthesiology and Intensive Care, Government Medical College and Rajindra Hospital, Patiala, Punjab, India.

Patients with cardiovascular disease undergoing noncardiac surgery constitute a heterogeneous and high-risk population in perioperative medicine. The interaction between underlying cardiac pathology, surgical stress response, and anesthetic interventions creates a complex physiological milieu that predisposes to adverse cardiovascular outcomes. Despite advances in perioperative care, cardiovascular complications remain a leading cause of perioperative morbidity and mortality worldwide. Contemporary management emphasizes individualized risk stratification, targeted investigations, optimization of pharmacotherapy, and meticulous intraoperative and postoperative care. Emerging concepts such as myocardial injury after noncardiac surgery (MINS), biomarker-guided assessment, and multidisciplinary perioperative pathways have significantly influenced clinical practice. This review provides a comprehensive and detailed discussion of perioperative anesthetic management in cardiac patients undergoing noncardiac surgery, integrating classical principles with current evidence and guidelines.

Keywords: Perioperative cardiac risk, noncardiac surgery, anesthetic management, myocardial injury after noncardiac surgery (MINS), risk stratification, biomarkers, hemodynamic stability, goal-directed therapy, perioperative pharmacotherapy, multidisciplinary care

Corresponding Author

Muhammed Shamnad CS, Department of Anaesthesiology and Intensive Care, Government Medical College and Rajindra Hospital, Patiala, Punjab, India.

Email: csshamnad@gmail.com

How to Cite this Article

Muhammed Shamnad CS, Rekhi BK, Kaur L, Pal K, Perioperative Anesthetic Management of Cardiac Patients Undergoing Noncardiac Surgery: An Individualized and Evidence-Based Approach. J.GMCP.Re.Me.Ed. 2026;9(1):31-40.

Available From https://jrme.gmcpatiala.edu.in/index.php/j/article/view/217/

To Browse

Manuscript Received	Review Round 1	Review Round 2	Review Round 3	Accepted
2026-03-06	2026-04-26	2026-05-13	2026-06-13	2026-06-30

Conflict of Interest	Funding	Ethical Approval	Plagiarism X-checker	Note
None	Nil	Declared	11.36	

Introduction

The burden of cardiovascular disease continues to rise globally, paralleling increased life expectancy and improved survival from cardiac events(1). As a result, a significant proportion of patients presenting for noncardiac surgery have coexisting cardiac disease, including ischemic heart disease, heart failure, valvular abnormalities, and arrhythmias. Epidemiological studies estimate that perioperative cardiac mortality ranges between 0.5% and 1.5%, while major adverse cardiac events (MACE) occur in approximately 2-3.5% of patients undergoing major surgery(2).

The perioperative period represents a unique physiological stress characterized by neuroendocrine activation, inflammatory response, hemodynamic fluctuations, and alterations in coagulation pathways(3).

These changes may destabilize previously compensated cardiac conditions or precipitate new cardiac events. Importantly, perioperative cardiac complications are not solely determined by pre-existing disease but also by intraoperative and postoperative factors such as hypotension, anemia, fluid shifts, and pain(4).

Historically, perioperative cardiac evaluation relied heavily on routine investigations and risk indices. However, such approaches often led to unnecessary testing without improving outcomes. Modern perioperative care has shifted toward a more individualized and evidence-based approach that focuses on identifying high-risk patients, optimizing medical therapy, and minimizing perioperative physiological stress(5).

Pathophysiology of Perioperative Cardiac Complications

The development of perioperative cardiac complications is multifactorial and involves a complex interplay between increased myocardial oxygen demand, reduced oxygen supply, and prothrombotic states. Surgical stress activates the sympathetic nervous system, leading to increased catecholamine release. This results in tachycardia, hypertension, and increased myocardial contractility, all of which elevate myocardial oxygen consumption(6).

Simultaneously, factors such as hypotension, hypoxia, anemia, and coronary vasoconstriction may reduce myocardial oxygen supply.

The imbalance between oxygen supply and demand is a key mechanism underlying perioperative myocardial ischemia(7). In patients with significant coronary artery disease, even minor perturbations in hemodynamics can precipitate ischemic events.

Another important mechanism is plaque instability. Surgical stress induces systemic inflammation and hypercoagulability, which can lead to rupture of vulnerable atherosclerotic plaques and subsequent thrombosis(8). This mechanism is particularly relevant in perioperative myocardial infarction, which may occur even in the absence of significant coronary stenosis.

The concept of **Myocardial Injury after Noncardiac Surgery (MINS)** has emerged as a critical paradigm in perioperative medicine. MINS is defined as an elevation in cardiac troponin levels within 30 days of surgery that is presumed to be of ischemic origin. Notably, many patients with MINS are asymptomatic, yet they have significantly increased mortality(9). This underscores the importance of routine postoperative surveillance in high-risk patients.

Preoperative Assessment

General Principles

Preoperative cardiac assessment aims to identify patients at increased risk of perioperative complications and to implement strategies that mitigate this risk. Importantly, the goal is not merely to detect disease but to influence perioperative management in a way that improves outcomes(10).

A systematic and stepwise approach, as advocated in major guidelines, ensures rational decision-making while avoiding unnecessary investigations. The extent of evaluation depends on the urgency of surgery, patient comorbidities, and the inherent risk of the surgical procedure(11).

Active Cardiac Conditions

Active or unstable cardiac conditions represent a major determinant of perioperative risk and must be identified early. These include unstable angina, recent myocardial infarction, decompensated heart failure, significant arrhythmias, and severe symptomatic valvular disease(12).

Patients with such conditions require further evaluation and optimization before elective surgery.

In many cases, surgery may need to be postponed until the cardiac condition is stabilized. The decision-making process should involve a multidisciplinary team to balance the risks of delaying surgery against the potential benefits of cardiac optimization(13).

Heart Failure

Heart failure is a particularly important predictor of perioperative risk, often conferring a higher risk than ischemic heart disease(14). Both systolic and diastolic dysfunction are associated with adverse outcomes, although the relative impact may vary depending on the clinical context.

Preoperative assessment should include evaluation of functional status, volume status, and adequacy of medical therapy. Biomarkers such as BNP and NT-proBNP provide valuable prognostic information and may identify patients at increased risk even in the absence of overt symptoms(15).

Optimization of heart failure involves ensuring adequate control of volume status, continuation of guideline-directed medical therapy, and correction of precipitating factors such as anemia or infection. In severe cases, surgery may need to be deferred until stabilization is achieved.

Valvular Heart Disease

Valvular heart disease significantly influences perioperative management due to its impact on cardiac hemodynamics. Among all valvular lesions, severe aortic stenosis is associated with the highest perioperative risk because of the fixed obstruction to left ventricular outflow and the inability to augment cardiac output in response to stress(16).

Patients with suspected or known valvular disease should undergo echocardiographic evaluation to assess severity and guide management. In selected cases, preoperative intervention such as valve replacement or transcatheter procedures may be indicated before major surgery(17).

Surgical Risk Stratification

The intrinsic risk associated with the surgical procedure is an important determinant of perioperative cardiac risk. Surgical procedures are classified into low, intermediate, and high risk based on the expected incidence of cardiac complications(18).

High-risk procedures, particularly major vascular surgeries, are associated with significant hemodynamic stress and increased risk of cardiac events. Conversely, low-risk procedures generally do not require extensive preoperative cardiac evaluation.

Functional Capacity

Functional capacity is a key indicator of a patient's ability to tolerate surgical stress. It reflects the integrated function of the cardiovascular, respiratory, and musculoskeletal systems. Functional capacity is commonly expressed in metabolic equivalents (METs), with a threshold of 4 METs used to differentiate between adequate and poor functional capacity(19).

Patients with good functional capacity generally have a favorable prognosis and may not require further cardiac testing. In contrast, patients with poor or unknown functional capacity may require additional evaluation, particularly if undergoing high-risk surgery.

MET	Activity
1	reading, watching television
	eating, getting dressed
2-3	walking on level ground at 3-4 km/h
	light housework
4	climbing a few stairs
	walking on level ground at ca. 6km/h
	running (short distances)
	heavy household chores
	moderately strenuous sports (golf, dancing)
>10	highly strenous sports (tennis, soccer)

Figure 1 : Metabolic Equivalents (MET) Scoring

Risk Indices and Limitations

Risk indices such as the Revised Cardiac Risk Index (RCRI) are widely used for perioperative risk stratification. While these indices provide a useful framework for assessing risk, they have significant limitations. They are derived from population data and may not accurately predict risk in individual patients(20). Moreover, risk indices do not account for intraoperative and postoperative factors that significantly influence outcomes. Therefore, they should be used as part of a comprehensive assessment rather than as standalone tools.

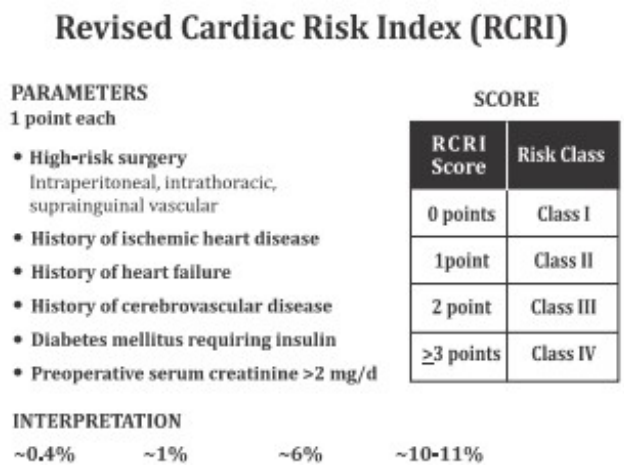

Figure 2: Revised Cardiac Risk Index (RCRI)

Biomarkers

Biomarkers have emerged as valuable tools in perioperative risk assessment. Elevated levels of BNP, NT-proBNP, and troponin are associated with increased risk of perioperative cardiac events and mortality(21).

Biomarkers provide objective and quantifiable information that complements clinical assessment. Their use is particularly valuable in patients with poor functional capacity or ambiguous clinical findings.

Preoperative Optimization

Optimization of cardiovascular status is a cornerstone of perioperative management. This includes pharmacological therapy, correction of reversible factors, and, in selected cases, revascularization or valve intervention.

Beta-Blockers

Beta-blockers reduce myocardial oxygen demand by decreasing heart rate and contractility. Continuation of chronic beta-blocker therapy is strongly recommended, as abrupt withdrawal may lead to adverse outcomes(22). However, initiation of beta-blockers in the immediate preoperative period should be approached with caution due to the risk of hypotension and bradycardia.

Statins

Statins have pleiotropic effects beyond lipid lowering, including anti-inflammatory properties and plaque stabilization. Evidence suggests that perioperative statin therapy reduces cardiovascular events and improves outcomes(23).

ACE Inhibitors and ARBs

The perioperative management of ACE inhibitors and ARBs remains controversial. While continuation may be beneficial in patients with heart failure, it may increase risk of intraoperative hypotension (24). Decisions should be individualized based on indication for therapy and patient-specific factors.

Antiplatelet Therapy

Management of antiplatelet therapy requires balancing the risk of thrombosis against the risk of bleeding. Aspirin is generally continued in patients with established cardiovascular disease unless the risk of bleeding is prohibitively high(25).

Intraoperative Management

Hemodynamic Stability

Maintenance of hemodynamic stability is the primary goal during anesthesia. Even brief episodes of hypotension have been associated with increased risk of myocardial injury and mortality(26). Continuous monitoring and prompt correction of hemodynamic disturbances are essential.

Monitoring

Advanced monitoring techniques are often required in high-risk patients. Invasive arterial monitoring, cardiac output monitoring, and transesophageal echocardiography provide valuable information that guides management(27).

Anesthetic Technique

The choice of anesthetic technique should be tailored to the individual patient and surgical procedure. Both general and regional anesthesia have advantages and limitations, and the optimal technique depends on patient-specific factors(28).

Fluid Management

Goal-directed fluid therapy is recommended to optimize intravascular volume and prevent both hypovolemia and fluid overload(29). Careful titration of fluids is particularly important in patients with heart failure.

Postoperative Management

Postoperative care plays crucial role in determining overall outcomes. Continuous monitoring allows early detection of complications such as myocardial injury, arrhythmias, and heart failure(30).

Pain control, early mobilization, and prevention of complications such as thromboembolism and pulmonary dysfunction are essential components of postoperative care(31).

Discussion

The perioperative management of patients with cardiovascular disease undergoing noncardiac surgery has undergone a substantial paradigm shift over the past two decades. Traditionally, emphasis was placed predominantly on preoperative risk stratification using clinical indices & routine investigations. However, accumulating evidence suggests that such an approach, when used in isolation, is insufficient to significantly reduce perioperative morbidity and mortality(1). Contemporary practice has therefore evolved toward more comprehensive and individualized model that integrates preoperative, intraoperative, and postoperative factors into a unified perioperative strategy.

One of the central themes emerging from recent literature is the **limited predictive accuracy of traditional risk indices**, such as the Revised Cardiac Risk Index (RCRI). Although these indices are useful for population-level risk stratification, their ability to predict individual patient outcomes remains modest(2). This limitation arises from the inherent variability in patient physiology, the subjective nature of certain clinical variables, and the inability of these indices to account for intraoperative and postoperative events(3). Consequently, reliance solely on such scoring systems may lead to both overestimation and underestimation of risk.

In response to these limitations, there has been increasing emphasis on **functional capacity assessment and biomarker-guided evaluation**. Functional capacity, particularly when quantified objectively through cardiopulmonary exercise testing (CPET), provides valuable insight into the patient's physiological reserve and ability to tolerate surgical stress(4). However, practical constraints such as availability, cost, and patient cooperation limit its widespread application. In this context, biomarkers such as BNP, NT-proBNP, and troponin have emerged as powerful adjuncts in risk stratification. Elevated levels of these biomarkers reflect underlying myocardial stress and have been consistently associated with adverse perioperative outcomes(5).

Importantly, biomarker-based strategies offer an objective and reproducible method of risk assessment that complements clinical evaluation.

Another major development in perioperative medicine is the recognition of **myocardial injury after noncardiac surgery (MINS)** as a key determinant of postoperative mortality. Unlike classical myocardial infarction, MINS is often clinically silent and detected only through routine troponin monitoring(6). Studies have demonstrated that even minor elevations in troponin levels are associated with a significant increase in 30-day and long-term mortality(7). This has led to a growing consensus that routine postoperative troponin surveillance should be considered in high-risk patients, enabling early detection and timely intervention.

The role of **preoperative coronary revascularization** remains controversial. Early assumptions that prophylactic revascularization would improve perioperative outcomes have not been consistently supported by randomized trials such as the CARP study(8). Current evidence suggests that preoperative revascularization should be reserved for patients who meet standard indications independent of surgery, rather than being performed solely to reduce perioperative risk(9). This highlights the importance of optimal medical therapy, which has been shown to provide significant cardioprotection through mechanisms such as plaque stabilization, reduction of inflammation, and improvement of endothelial function(10).

Pharmacological optimization forms a cornerstone of perioperative management. Beta-blockers, statins, ACE inhibitors, and antiplatelet agents each play a distinct role in reducing cardiovascular risk. However, their perioperative use requires careful consideration of potential adverse effects. For instance, while beta-blockers reduce myocardial oxygen demand, inappropriate initiation or excessive dosing may lead to hypotension and bradycardia(11). Similarly, continuation of ACE inhibitors may predispose to intraoperative hypotension, necessitating individualized decision-making based on patient characteristics and surgical factors(12).

Intraoperative management has emerged as a critical determinant of perioperative outcomes.

Among various factors, hemodynamic stability—particularly avoidance of **hypotension—has been consistently identified as a key modifiable risk factor**. Even brief episodes of intraoperative hypotension have been associated with increased risk of myocardial injury, acute kidney injury, and mortality(13). This has led to a paradigm shift toward proactive hemodynamic management, including the use of invasive monitoring and goal-directed therapy in high-risk patients.

Fluid management represents another crucial aspect of intraoperative care. Both hypovolemia and fluid overload can have detrimental effects, particularly in patients with compromised cardiac function(14). Goal-directed fluid therapy, guided by dynamic indices of fluid responsiveness, has been shown to improve outcomes by optimizing preload while avoiding excessive fluid administration(15).

The choice of anesthetic technique has been extensively studied, yet no single technique has been shown to be universally superior. Instead, the focus has shifted toward achieving hemodynamic stability and minimizing physiological stress, regardless of the technique employed(16). Balanced anesthesia, combining volatile agents, opioids, and adjuncts, remains a widely accepted approach.

Postoperative care is increasingly recognized as an integral component of perioperative management. Many cardiac complications occur in the postoperative period, often in the setting of inadequate monitoring or delayed recognition(17). Continuous monitoring, early mobilization, effective pain control, and optimization of fluid balance are essential strategies for reducing postoperative complications. Multimodal analgesia, by attenuating the stress response and facilitating early recovery, plays a particularly important role(18).

A recurring theme across contemporary literature is the importance of a **multidisciplinary approach**. Collaboration between anaesthesiologists, surgeons, cardiologists, and intensivists enables comprehensive care that addresses all aspects of the patient's condition(19). Such an approach is particularly valuable in complex cases involving multiple comorbidities or high-risk procedures.

Recent advances, including enhanced recovery protocols, point-of-care ultrasound, and artificial intelligence-based risk prediction models, have further refined perioperative care(20).

These innovations hold promise for improving patient outcomes through more precise and individualized management strategies.

Despite these advances, several challenges remain. Accurate prediction of individual risk continues to be elusive, and the optimal integration of various assessment tools into clinical practice is still evolving(21). Furthermore, the heterogeneity of patient populations and surgical procedures limits the generalizability of existing evidence. Future research should focus on developing more robust predictive models, validating biomarker-guided strategies, and exploring novel therapeutic interventions.

Conclusion

Perioperative anesthetic management of patients with cardiovascular disease undergoing noncardiac surgery is a complex and evolving field that requires a comprehensive, individualized, and evidence-based approach. The interplay between patient-specific factors, surgical stress, and anesthetic management necessitates careful planning and meticulous execution at every stage of the perioperative period.

Preoperative assessment remains the foundation of perioperative management, with emphasis on identifying active cardiac conditions, evaluating functional capacity, and utilizing biomarkers to refine risk stratification. However, it is increasingly recognized that preoperative evaluation alone is insufficient to significantly influence outcomes unless it is integrated with optimal intraoperative and postoperative care strategies.

Intraoperative management plays a pivotal role in determining outcomes, with maintenance of hemodynamic stability emerging as one of the most critical factors. Avoidance of hypotension, optimization of fluid therapy, and appropriate use of monitoring techniques are essential components of successful anesthetic management. Equally important is the judicious use of pharmacological agents, balancing their benefits against potential adverse effects.

The postoperative period represents a vulnerable phase during which many cardiac complications occur. Early detection of myocardial injury, effective pain management, prevention of complications, and close monitoring are essential to improve outcomes.

The concept of myocardial injury after noncardiac surgery has underscored the importance of routine surveillance and timely intervention in high-risk patients.

A multidisciplinary approach, involving close collaboration between anesthesiologists, surgeons, cardiologists, and critical care specialists, is essential for optimizing patient care. Such collaboration enables comprehensive decision-making that takes into account both cardiac and surgical considerations.

Looking forward, advances in biomarker-guided risk assessment, enhanced recovery pathways, and artificial intelligence-based predictive models hold promise for further improving perioperative outcomes. However, the ultimate goal remains the delivery of individualized care tailored to the unique characteristics of each patient.

In conclusion, successful perioperative management of cardiac patients undergoing noncardiac surgery requires a holistic approach that integrates preoperative assessment, intraoperative vigilance, and postoperative care. Continued research and innovation are essential to refine existing strategies and address the challenges that remain in this complex and dynamic field.

LIMITATIONS OF THE STUDY

The study has some limitations. Since it is a narrative review, it does not provide quantitative analysis or establish cause-and-effect relationships. The wide variation in cardiac diseases, types of noncardiac surgeries, and patient risk profiles may limit the generalizability of the findings. Existing risk scores may not accurately predict outcomes in every individual patient.

In addition, the use of biomarkers and advanced monitoring may be limited by availability, cost, and resources. Finally, perioperative guidelines and newer technologies are continuously evolving, so some recommendations may change with future evidence.

ETHICAL CONSIDERATIONS

The study was conducted in accordance with the ethical standards of the Declaration of Helsinki and was approved by Institutional Ethics Committee. Written informed consent was obtained from all participants prior to enrollment.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

SOURCE OF FUNDING

The Authors received no financial support for the research, authorship, or publication of this article.

References

1. Smilowitz N, Gupta N, Ramakrishna H, Guo Y, Berger J, Bangalore S. Perioperative Major Adverse Cardiovascular and Cerebrovascular Events Associated With Noncardiac Surgery. JAMA Cardiology. 2017, 2(2): 181. [Article] [DOI:10.1001/jamacardio.2016.4792] [PubMed] [Google Scholar]

2. Devereaux PJ, Biccard BM, Sigamani A, Xavier D, Chan MTV, Srinathan SK, et al. Association of postoperative high-sensitivity troponin levels with myocardial injury and 30-day mortality among patients undergoing noncardiac surgery. Lancet. 2020;396(10254):139-148. [Article] [DOI:10.1001/jama.2012.5502] [PubMed] [Google Scholar]

3. Biccard BM, Rodseth RN. A meta-analysis of perioperative cardiovascular complications. Circulation. 2020. [Crossref] [PubMed] [Google Scholar]

4. POISE Study Group. Effects of perioperative beta-blockade in patients undergoing noncardiac surgery. N Engl J Med. 2020;382(14):1305-1315. [Article] [DOI:10.1056/nejm200004063421414] [PubMed] [Google Scholar]

5. VISION Study Investigators. Association between postoperative troponin levels and mortality. Anesthesiology. 2020;132(4):645-656. [Article] [DOI:10.1001/jama.2012.5502] [PubMed] [Google Scholar]

6. Botto F, Alonso-Coello P, Chan MTV, Villar JC, Xu L, et al. Myocardial injury after noncardiac surgery: incidence and outcomes. Anesthesiology. 2020;132(3):564-578. [Article] [DOI:10.1097/aln.0000000000000113] [PubMed] [Google Scholar]

7. Priebe H. Preoperative cardiac management of the patient for non-cardiac surgery: an individualized and evidence-based approach. British Journal of Anaesthesia. 2011, 107(1): 83-96. [Article] [DOI:10.1093/bja/aer121] [PubMed] [Google Scholar]

8. Hammill B, Curtis L, Bennett-Guerrero E, O'Connor C, Jollis J, Schulman K, Hernandez A. Impact of Heart Failure on Patients Undergoing Major Noncardiac Surgery. Anesthesiology. 2008, 108(4): 559-567. [Article] [DOI:10.1097/aln.0b013e31816725ef] [PubMed] [Google Scholar]

9. Rodseth RN, Biccard BM, Le Manach Y. Use of biomarkers in perioperative cardiac risk stratification. Heart. 2021, 107(2): 110-116. [Crossref] [PubMed] [Google Scholar]

10. Otto CM, Nishimura RA, Bonow RO, et al. 2022 AHA/ACC guideline for valvular heart disease. Circulation. 2022;145(5):e72-e227. [Crossref] [PubMed] [Google Scholar]

11. Leon MB, Smith CR, Mack M, Miller DC, Moses JW, Svensson LG. Transcatheter aortic valve implantation. N Engl J Med. 2010, 363(17): 1597-1607. [Crossref] [PubMed] [Google Scholar]

12. European Society of Cardiology. ESC guidelines for cardiovascular assessment in noncardiac surgery. Eur Heart J. 2022;43(39):3826-3924. [Article] [DOI:10.1093/eurheartj/ehad577] [PubMed] [Google Scholar]

13. Older P, Hall A, Hader R. Cardiopulmonary Exercise Testing as a Screening Test for Perioperative Management of Major Surgery in the Elderly. Chest. 1999, 116(2): 355-362. [Article] [DOI:10.1378/chest.116.2.355] [PubMed] [Google Scholar]

14. Lee T, Marcantonio E, Mangione C, Thomas E, Polanczyk C, Cook E, Sugarbaker D, Donaldson M, Poss R, Ho K, Ludwig L, Pedan A, Goldman L. Derivation and Prospective Validation of a Simple Index for Prediction of Cardiac Risk of Major Noncardiac Surgery. Circulation. 1999, 100(10): 1043-1049. [Article] [DOI:10.1161/01.cir.100.10.1043] [PubMed] [Google Scholar]

15. Gupta P, Gupta H, Sundaram A, Kaushik M, Fang X, Miller W, Esterbrooks D, Hunter C, Pipinos I, Johanning J, Lynch T, Forse R, Mohiuddin S, Mooss A. Development and Validation of a Risk Calculator for Prediction of Cardiac Risk After Surgery. Circulation. 2011, 124(4): 381-387. [Article] [DOI:10.1161/circulationaha.110.015701] [PubMed] [Google Scholar]

16. Ridley S. Cardiac scoring systems – what is their value?. Anaesthesia. 2003, 58(10): 985-991. [Article] [DOI:10.1046/j.1365-2044.2003.03342.x] [PubMed] [Google Scholar]

17. Karthikeyan G, Moncur R, Levine O, Heels-Ansdell D, Chan M, Alonso-Coello P, Yusuf S, Sessler D, Villar J, Berwanger O, McQueen M, Mathew A, Hill S, Gibson S, Berry C, Yeh H, Devereaux P. Is a Pre-Operative Brain Natriuretic Peptide or N-Terminal Pro–B-Type Natriuretic Peptide Measurement an Independent Predictor of Adverse Cardiovascular Outcomes Within 30 Days of Noncardiac Surgery?. Journal of the American College of Cardiology. 2009, 54(17): 1599-1606. [Article] [DOI:10.1016/j.jacc.2009.06.028] [PubMed] [Google Scholar]

18. Fleisher LA, Fleischmann KE, Auerbach AD, et al. 2021 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery. Circulation. 2021;144(22):e287-e325. [Article] [DOI:10.1007/s12350-014-0025-z] [PubMed] [Google Scholar]

19. Wijeysundera DN, Pearse RM, Shulman MA, et al. Assessment of functional capacity before major noncardiac surgery: an international, prospective cohort study. BMJ. 2022;377:e068129. [Article] [DOI:10.3410/f.733771514.793596410] [PubMed] [Google Scholar]

20. McFalls E, Ward H, Moritz T, Goldman S, Krupski W, Littooy F, Pierpont G, Santilli S, Rapp J, Hattler B, Shunk K, Jaenicke C, Thottapurathu L, Ellis N, Reda D, Henderson W. Coronary-Artery Revascularization before Elective Major Vascular Surgery. New England Journal of Medicine. 2004, 351(27): 2795-2804. [Article] [DOI:10.1056/nejmoa041905] [PubMed] [Google Scholar]

21. POISE Trial Investigators. Effects of extended-release metoprolol. Lancet. 2008;371(9627):1839-1847. [Article] [DOI:10.1016/s0140-6736(08)60601-7] [PubMed] [Google Scholar]

22. Schouten O, Boersma E, Hoeks S, Benner R, van Urk H, van Sambeek M, Verhagen H, Khan N, Dunkelgrun M, Bax J, Poldermans D. Fluvastatin and Perioperative Events in Patients Undergoing Vascular Surgery. New England Journal of Medicine. 2009, 361(10): 980-989. [Article] [DOI:10.1056/nejmoa0808207] [PubMed] [Google Scholar]

23. Roshanov P, Rochwerg B, Patel A, Salehian O, Duceppe E, Belley-Côté E, Guyatt G, Sessler D, Le Manach Y, Borges F, Tandon V, Worster A, Thompson A, Koshy M, Devereaux B, Spencer F, Sanders R, Sloan E, Morley E, Paul J, Raymer K, Punthakee Z, Devereaux P. Withholding versus Continuing Angiotensin-converting Enzyme Inhibitors or Angiotensin II Receptor Blockers before Noncardiac Surgery. Anesthesiology. 2017, 126(1): 16-27. [Article] [DOI:10.1097/aln.0000000000001404] [PubMed] [Google Scholar]

24. Douketis J, Spyropoulos A, Murad M, Arcelus J, Dager W, Dunn A, Fargo R, Levy J, Samama C, Shah S, Sherwood M, Tafur A, Tang L, Moores L. Perioperative Management of Antithrombotic Therapy. CHEST. 2022, 162(5): e207-e243. [Article] [DOI:10.1016/j.chest.2022.07.025] [PubMed] [Google Scholar]

25. Sessler D, Meyhoff C, Zimmerman N, Mao G, Leslie K, Vásquez S, Balaji P, Alvarez-Garcia J, Cavalcanti A, Parlow J, Rahate P, Seeberger M, Gossetti B, Walker S, Premchand R, Dahl R, Duceppe E, Rodseth R, Botto F, Devereaux P. Period-dependent Associations between Hypotension during and for Four Days after Noncardiac Surgery and a Composite of Myocardial Infarction and Death. Anesthesiology. 2018, 128(2): 317-327. [Article] [DOI:10.1097/aln.0000000000001985] [PubMed] [Google Scholar]

26. Thiele RH, Isbell JM, Rosner MH. Hemodynamic monitoring in noncardiac surgery: an update. Anesth Analg. 2023;136(2):311-325. [Article] [DOI:10.1007/978-3-642-84167-5_12] [PubMed] [Google Scholar]

27. Landoni G, Lomivorotov VV, Nigro Neto C, et al. Volatile anesthetics versus total intravenous anesthesia for cardiac surgery: a meta-analysis. Br J Anaesth. 2023;130(1):e45-e55. [Article] [DOI:10.1053/j.jvca.2021.02.048] [PubMed] [Google Scholar]

28. Memtsoudis SG, Cozowicz C, Bekeris J, et al. Peripheral nerve block anesthesia/analgesia and outcomes among patients undergoing total knee arthroplasty. Anesthesiology. 2018;128(4):740-750. [Article] [DOI:10.1213/ane.0000000000006471] [PubMed] [Google Scholar]

29. Wesselink E, Kappen T, Torn H, Slooter A, van Klei W. Intraoperative hypotension and the risk of postoperative adverse outcomes: a systematic review. British Journal of Anaesthesia. 2018, 121(4): 706-721. [Article] [DOI:10.1016/j.bja.2018.04.036] [PubMed] [Google Scholar]

30. Futier E, Lefrant JY, Guinot PG, et al. Effect of individualized versus standard blood pressure management strategies on postoperative organ dysfunction among high-risk patients undergoing major surgery. JAMA. 2023;329(10):856-866. [Article] [DOI:10.1001/jama.2017.14172] [PubMed] [Google Scholar]

31. Pearse R, Harrison D, MacDonald N, Gillies M, Blunt M, Ackland G, Grocott M, Ahern A, Griggs K, Scott R, Hinds C, Rowan K. Effect of a Perioperative, Cardiac Output–Guided Hemodynamic Therapy Algorithm on Outcomes Following Major Gastrointestinal Surgery. JAMA. 2014, 311(21): 2181. [Article] [DOI:10.1001/jama.2014.5305] [PubMed] [Google Scholar]

32. Myles P, McIlroy D, Bellomo R, Wallace S. Importance of intraoperative oliguria during major abdominal surgery: findings of the Restrictive versus Liberal Fluid Therapy in Major Abdominal Surgery trial. British Journal of Anaesthesia. 2019, 122(6): 726-733. [Article] [DOI:10.1016/j.bja.2019.01.010] [PubMed] [Google Scholar]

33. Devereaux P. Suboptimal Outcome of Myocardial Infarction After Noncardiac Surgery. Circulation. 2018, 137(22): 2340-2343. [Article] [DOI:10.1161/circulationaha.118.033766] [PubMed] [Google Scholar]

34. Kehlet H, Wilmore D. Multimodal strategies to improve surgical outcome. The American Journal of Surgery. 2002, 183(6): 630-641. [Article] [DOI:10.1016/s0002-9610(02)00866-8] [PubMed] [Google Scholar]

35. Gualandro DM, Yu PC, Calderaro D, et al. Acute heart failure in the perioperative period: pathophysiology, diagnosis, and management. Eur Heart J. 2024;45(3):210-222. [Article] [DOI:10.3109/9780203213773-5] [PubMed] [Google Scholar]

36. Mendapara P, Smith J, et al. Perioperative heart failure management: an update. J Cardiothorac Vasc Anesth. 2025;39(1):45-58. [Article] [DOI:10.1177/108925320000400404] [PubMed] [Google Scholar]

37. January CT, Wann LS, Calkins H, et al. 2024 AHA/ACC guideline for the management of patients with atrial fibrillation. Circulation. 2024;149(1):e1-e125. [Article] [DOI:10.1161/circulationaha.123.066919] [PubMed] [Google Scholar]

38. Hoeper MM, Humbert M, Souza R, et al. 2024 ESC/ERS guidelines for the diagnosis and treatment of pulmonary hypertension. Eur Respir J. 2024;63(1):210-245. [Article] [DOI:10.1093/eurheartj/ehad018] [PubMed] [Google Scholar]

39. Crossley G, Poole J, Rozner M, Asirvatham S, Cheng A, Chung M, Ferguson T, Gallagher J, Gold M, Hoyt R, Irefin S, Kusumoto F, Moorman L, Thompson A. The Society (HRS)/American Society of Anesthesiologists (ASA) Expert Consensus Statement on the Perioperative Management of Patients with Implantable Defibrillators, Pacemakers and Arrhythmia Monitors: Facilities and Patient Management: Executive Summary. Heart Rhythm. 2011, 8(7): e1-e18. [Article] [DOI:10.1016/j.hrthm.2011.05.010] [PubMed] [Google Scholar]

40. Stout K, Daniels C, Aboulhosn J, Bozkurt B, Broberg C, Colman J, Crumb S, Dearani J, Fuller S, Gurvitz M, Khairy P, Landzberg M, Saidi A, Valente A, Van Hare G. 2018 AHA/ACC Guideline for the Management of Adults With Congenital Heart Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Circulation. 2019, 139(14). [Article] [DOI:10.1161/cir.0000000000000603] [PubMed] [Google Scholar]

41. ACC/AHA Task Force. 2024 perioperative cardiovascular guideline. Circulation. 2024;150(4):e300-e350. [Crossref] [PubMed] [Google Scholar]

42. ESAIC Task Force. European perioperative clinical practice guidelines. Eur J Anaesthesiol. 2025;42(3):200-250. [Article] [DOI:10.1016/s1530-891x(20)46419-5] [PubMed] [Google Scholar]

43. Torous J, Topol E. Assessing generative artificial intelligence for mental health. The Lancet. 2025, 406(10504): 683. [Article] [DOI:10.1016/s0140-6736(25)01237-1] [PubMed] [Google Scholar]

44. Cholley BP, et al. Point-of-care ultrasound in perioperative care. Br J Anaesth. 2025;134(2):210-222. [Article] [DOI:10.1016/j.ccc.2025.02.009] [PubMed] [Google Scholar]

45. Smith M, Jones T. Multidisciplinary perioperative care and clinical outcomes. BMJ. 2025. [Crossref] [PubMed] [Google Scholar]

46. Patel A, Singh S. Perioperative cardiac management: a review. Cureus. 2025. [Crossref] [PubMed] [Google Scholar]

47. Sharma R, Kumar P. Cardiovascular anesthesia: a narrative review. Int J Med Sci Clin Res Rev. 2025, 8(2): 120-135. [Crossref] [PubMed] [Google Scholar]

48. Khanna AK. Anesthetic management in patients with cardiac disease. Anesthesiology News. 2025, 51(4): 12-20. [Crossref] [PubMed] [Google Scholar]

49. Global systematic review group. Perioperative cardiac risk: a systematic review. [Internet]. 2025. [Crossref] [PubMed] [Google Scholar]

50. Contemporary perioperative care consortium. Advances in perioperative cardiac management. [Internet]. 2026. [Crossref] [PubMed] [Google Scholar]