Cardiac Evaluation and Monitoring of Patients Undergoing Noncardiac Surgery

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ABSTRACT: Surgical management of disease has a tremendous impact on our health system. Millions of people worldwide undergo surgeries every year. Cardiovascular complications in the perioperative period are one of the most common events leading to increased morbidity and mortality. Although such events are very small in number, they are associated with high mortality rate making it essential for physicians to understand the importance of perioperative cardiovascular risk assessment and evaluation. Its involves a detailed process of history taking, patient's medical profile, medications being used, functional status of the patient, and knowledge about the surgical procedure and its inherent risks. Different risk assessment tools and calculators have also been developed to aid in this process, each with their own advantages and limitations. After such a comprehensive evaluation, a physician will be able to provide a risk assessment or it may all lead to further testing if it is believed that a change in management after such testing will help to reduce perioperative morbidity and mortality. There is extensive literature on the significance of multiple perioperative testing modalities and how they can change management. The purpose of our review is to provide a concise but comprehensive analysis on all such aspects of perioperative cardiovascular risk assessment for noncardiac surgeries and provide a basic methodology toward such assessment and decision making.

KEYWORDS: Perioperative cardiac evaluation, noncardiac surgery, risk assessment

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Introduction

Worldwide it is estimated that around 200 million people undergo noncardiac surgery annually.1 Cardiovascular complications account for majority of the cause of postoperative morbidity and mortality with incidence ranging from 0.5% to 30%,2,3

The main purpose of perioperative cardiac evaluation involves answering few basic questions. What are the underlying cardiac risk factors which a patient might have before he undergoes noncardiac surgery? Will such cardiac evaluation change the management of the patient? Will it defer surgery altogether in favor of resolving the patient’s cardiac disease and hence reducing perioperative mortality? What will be the course of management in the postoperative period?

Communication among the complete medical team involved in patient care, including the internist, cardiologist, anesthesiologist, surgeon, and ancillary staff, is of utmost importance, along with the facilitation of shared decision making by the patient. In this review article, we will provide information and recommendations based on current guidelines related to perioperative evaluation and management. Our discussion will include perioperative cardiac risk evaluation and assessment of functional capacity, role of ancillary preoperative cardiac evaluation, recommendations related to perioperative medical therapy, perioperative cardiac intervention including management of patients with prior coronary intervention, perioperative anticoagulant therapy, intraoperative monitoring, and postoperative evaluation and management.

Perioperative Cardiac Testing—A Systematic Approach

Before we go into the details of perioperative cardiac evaluation, it is important to know the different categories of noncardiac procedures. Procedure in which there is minimal or no time for clinical evaluation, as it involves a life-saving or limb-saving surgery, is termed as an Emergent procedure. Usually this involves patient to be taken to operating room within 6 hours. Urgent procedures are those where there is limited time for clinical evaluation prior to a life-saving or limb-saving procedure. This involves the patient to be taken to the operating room between 6 and 24 hours. In Time-sensitive procedures, a delay of around 1 to 6 weeks is acceptable to allow for evaluation, and further changes in management can affect outcomes. Patients undergoing oncologic procedures fall in this category. Finally, an Elective procedure is one which can be delayed for up to 1 year. Pertaining to the risk of the procedure itself, they can be divided into low-risk and elevated-risk procedures. Low-risk procedures have a risk of <1% for major adverse cardiac event (MACE) of death or myocardial infarction (MI) as predicted by combined surgical and patient characteristics, whereas elevated-risk procedures have a risk of >1% for MACE of death or MI.4

Emergent or nonemergent surgery

Emergent surgical procedures inherently have a very high risk of cardiovascular complications. Emergent life-saving or
limb-saving procedures do not require any cardiac evaluation as time is of critical importance. Hence, patients requiring emergent noncardiac surgeries proceed directly to the operating room after assessing clinical risk factors that may influence management in the perioperative period (Figure 1).

In case of urgent or elective noncardiac surgery, the next step is to determine whether the patient has active acute coronary syndrome or not. If the patient has active ischemic heart disease, management is guided by established guidelines of the American College of Surgeons (ACS), and a formal cardiology evaluation is recommended.4

Perioperative cardiac morbidity risk calculation

Perioperative risk of MACE is to be determined in the next step when a patient has risk factors for stable coronary artery disease (CAD). Different tools and calculators are available to predict perioperative cardiac mortality. Every surgery has a different risk of morbidity and mortality, with highest being that of vascular surgeries and emergency surgeries. In some surgeries, risk can be lowered by opting for a less invasive approach.

To determine the risk of perioperative MACE in patients undergoing noncardiac surgery, a validated risk-prediction tool can be very helpful.4

Revised Cardiac Risk Index. The Revised Cardiac Risk Index (RCRI) is a simple tool that has been validated to assess the perioperative risk of major cardiac events (Table 1). Patients having zero or only one risk factor have a low risk of MACE, whereas those with 2 or more risk factors have elevated risk.1,4,5

ACS National Surgical Quality Improvement Program surgical risk calculator. The ACS National Surgical Quality Improvement Program (NSQIP) surgical risk calculator uses procedural codes to predict procedure-specific risk with a large number of outcomes. It takes into account whether the procedure is emergent or not and 21 patient-specific variables. It then calculates the risk of MACE along with 8 other outcomes (Table 2).6

ACS NSQIP Myocardial Infarction and Cardiac Arrest risk calculator. The ACS NSQIP Myocardial Infarction and Cardiac Arrest (MICA) risk calculator incorporates adjusted odds ratio for different surgical sites and takes inguinal hernia as the reference group. There were defined target complications which included the following:

1. Cardiac arrest defined as chaotic cardiac rhythm requiring initiation of basic or advanced life support;
2. Myocardial infarction defined as ≥ 1mm ST-segment elevation in more than one contiguous leads, new left bundle branch block, new Q-waves in 2 or more
contiguous leads, or elevation in level of troponins more than 3 times normal with suspected ischemia.

Using these definitions along with patient variables, a risk index is calculated which predicts risk of perioperative myocardial infarction and cardiac arrest (Table 3).7

**Limitations of NSQIP-based calculators**

1. These are not validated in an external population outside the NSQIP.

2. Definition of MI only includes ST-elevation MIs or a large increase in troponin in symptomatic patients.

3. Use of American Society of Anesthesiology Physical Status Classification which has poor inter-rater reliability even among anesthesiologists.

On the basis of calculated risk, the surgical procedure is classified to be either low risk (risk of MACE <1%) or elevated risk (risk of MACE >1%).

**Assessment of exercise and functional capacity**

Perioperative cardiac events and even long-term outcomes can be reliably predicted via functional status of the patient. Patients with preoperative reduced functional capacity are at increased risk of perioperative and postoperative complications, in contrast to those with good functional status who have a very low risk of such adverse outcomes.

Asymptomatic patients undergoing noncardiac surgery with a low risk of perioperative MACE and a high functional status should not have any further cardiac evaluation before the planned surgery.4,8

It is very easy to assess the functional status of a patient by assessing his activities of daily life (Table 4).9 Metabolic equivalents (METs) are how functional status is expressed. One MET is defined as resting or basal oxygen consumption of a 40-year-old, 70-kg man. On the basis of METs, functional capacity is classified as poor (<3 METs), moderate (4-6 METs), good (7-10 METs), and excellent (>10 METs). Patients having functional status of less than 4 METs are at increased risk of perioperative complications. In one study, it showed that perioperative cardiovascular events were more common in patients who had the inability to walk 4 blocks or climb 2 flights of stairs, even after adjustment for other risk factors.4,9

Functional status can also be determined by using the Duke Activity Status Index10 and Specific Activity Scale.11 Patients who have good or excellent functional capacity with METs of greater than 4 do not require any further testing and should proceed for surgery. Also patients scheduled for low-risk procedure do not require any testing at all. However, decision has to be made in patients who have either a poor functional capacity (METS <4) or in patients in whom functional capacity could be formally assessed or is unknown. If further testing would lead to a perioperative change in management and will have an impact on decision making regarding patient care, pharmacologic stress testing is recommended prior to noncardiac surgery. Depending on the result of stress test, patients proceed to coronary revascularization and then proceed for surgery with guideline-directed medical therapy or opt for noninvasive alternatives of the proposed noncardiac surgery (Figure 1).4

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**Table 1. Revised Cardiac Risk Index.**

|   |   |
|---|---|
| 1. | Creatinine ≥2 mg/dL |
| 2. | Heart failure |
| 3. | Insulin-dependent diabetes mellitus |
| 4. | Intrathoracic, intra-abdominal, or suprainguinal vascular surgery |
| 5. | History of transient ischemic attack or cerebrovascular accident |
| 6. | Ischemic heart disease |

Single point is assigned to every risk factor present.

**Table 2. American College of Surgeons National Surgical Quality Improvement Program surgical risk calculator.**

|   |   |
|---|---|
| 1. | Age |
| 2. | Acute renal failure |
| 3. | Functional status, body mass index |
| 4. | Emergency case |
| 5. | Diabetes mellitus, hypertension, heart failure |
| 6. | Procedure Current Procedural Terminology code |
| 7. | American Society of Anesthesiologists Physical Status class |
| 8. | Wound class |
| 9. | Sex, dyspnea, smoker, ascites, ventilator dependent, disseminated cancer, steroid use |
| 10. | Systemic sepsis, previous cardiac event, chronic obstructive pulmonary disease, dialysis |

Web-based calculator: [www.riskcalculator.facs.org](http://www.riskcalculator.facs.org).

**Table 3. American College of Surgeons National Surgical Quality Improvement Program Myocardial Infarction and Cardiac Arrest risk calculator.**

|   |   |
|---|---|
| 1. | Age |
| 2. | Creatinine >1.5 mg/dL |
| 3. | Partially or totally dependent functional status |
| 4. | Type of surgery |

Web-based calculator: [http://www.surgicalriskcalculator.com/miocardiacarrest](http://www.surgicalriskcalculator.com/miocardiacarrest).
Ancillary Preoperative Cardiac Testing—Recommendations

12-lead electrocardiogram

It is reasonable to perform a 12-lead electrocardiogram (ECG) preoperatively in patients with known CAD, peripheral arterial disease, significant arrhythmia, cerebrovascular disease, or other structural heart diseases, except for those patients who are going for low-risk procedure. Routine use of preoperative 12-lead ECG is not useful and is not recommended.12,13

A 12-lead ECG gives important prognostic information in patients with known CAD related to short-term and long-term morbidity and mortality. It also provides a baseline that can be compared postoperatively if any change in the clinical status of the patient occurs.13 An interval of 1 to 3 months is considered to be an acceptable time interval between the scheduled noncardiac surgery and obtaining a 12-lead ECG; however, optimal timing is unknown.4

Assessment of left ventricular function

In patients with unknown cause of dyspnea or in patients with heart failure (HF) with worsening dyspnea or any change in clinical status, it is reasonable to assess left ventricular (LV) function preoperatively. Reassessment of LV function can be considered in clinically stable patients if it was done more than a year ago. However, routine evaluation LV function is not recommended preoperatively.14

There is an association documented in literature between reduced LV systolic function and perioperative complications, more so in patients with postoperative HF. Greatest risk is seen in patients with left ventricular ejection fraction (LVEF) of <35% at rest. There are very little data on assessment of diastolic dysfunction preoperatively. However, it is recommended to perform LV function in patients who are candidates for potential solid organ transplantation as per transplantation-specific guidelines.

Exercise stress testing

In patients undergoing elevated-risk procedure with unknown or poor (<4 METs) functional capacity, it is reasonable to assess the functional capacity by exercise stress testing, only if it will change management. In patients with excellent exercise tolerance (>10 METs) or those with moderate to good exercise tolerance (>4 METs) scheduled for elevated-risk noncardiac surgery, it reasonable to proceed for surgery without any further stress testing. Routine screening with noninvasive stress testing is not recommended.4,15–17

Cardiopulmonary testing

In patients in whom functional capacity is not known, cardiopulmonary testing may be considered prior to elevated-risk noncardiac surgery.18–20

Many studies have shown that a low anaerobic threshold predicts perioperative cardiac complications and postoperative death.18,20–22 The proposed discriminative anaerobic threshold ranges between 9 and 11 mL O2/kg/min.4

Pharmacological testing

In patients who have poor functional capacity, scheduled for elevated-risk noncardiac surgery, it is reasonable to evaluate with either dobutamine stress echocardiogram or pharmacologic stress myocardial perfusion imaging (MPI), only if it changes further management. However routine

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Table 4. Daily activities and associated values of metabolic equivalents (METs).

| LEVEL                  | PHYSICAL ACTIVITIES                        | METS |
|------------------------|--------------------------------------------|------|
| Light intensity (<3 METs) | Sleeping                                   | 0.9  |
|                        | Watching television                        | 1.0  |
|                        | Writing, desk work, typing                 | 1.8  |
|                        | Walking 1.7 mph on level ground, strolling very slow | 2.3  |
|                        | Golf with cart                             | 2.5  |
|                        | Walking 2.5 mph                            | 2.9  |
| Moderate intensity (3-6 METs) | Bicycling (stationary 50W), very light effort | 3.0  |
|                        | Walking 3.0 mph, vacuuming                  | 3.3  |
|                        | Walking 3.4 mph                            | 3.6  |
|                        | Stair climbing at slow pace                | 4.0  |
|                        | Gardening                                  | 4.4  |
|                        | Swimming slowly                            | 4.5  |
|                        | Golf without cart, brisk walking at 4 mph   | 4.9  |
|                        | Bicycling (stationary 100W)                | 5.5  |
|                        | Doubles tennis                             | 6.0  |
| Vigorous intensity (>6 METs) | Jogging, swimming fast, general soccer    | 7.0  |
|                        | Singles tennis                             | 7.5  |
|                        | Pushups, situps, pullups, rock or mountain climbing | 8.0  |
|                        | Stair climbing at fast pace                | 8.8  |
|                        | Rope jumping 100-120 skips/min             | 10.0 |
|                        | Running 7.5 min/mile                       | 13.2 |

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4 Health Services Insights
screening is not recommended in patients going for low-risk noncardiac surgery.23–25

There is a lack of randomized controlled trials (RCTs) on use of preoperative stress testing. Evidence is based on large number of studies which have shown that the presence of moderate to large areas of myocardial ischemia predicts increased perioperative MI and/or death. Also if a patient has a normal study, it has a high negative predictive value for perioperative MI and/or cardiac death. Also, fixed defects seen on MPI have a low perioperative predictive value for cardiac events compared with normal MPI, but have an increased risk of long-term events, likely related to the presence of underlying CAD.4

Stress echocardiography appears to be slightly superior in predicting postoperative cardiac events compared to nongated MPI with thallium. However, there is a lack of RCTs for such comparison.26 It should be noted that these do not address evaluation of patients scheduled for liver or kidney transplantation that has its own specific set of guidelines.27

In ambulatory patients, exercise electrocardiography can provide useful information related to any underlying ischemia and functional status. This is at times combined with either echocardiography or MPI. However, in patients who have ECGs that limit interpretation (like LV hypertrophy, left bundle branch block, etc.), imaging with either echocardiography or MPI should be pursued. In patients having left bundle branch block who undergo exercise MPI, septal perfusion defects are seen, which are not related to CAD and decrease the specificity of the study. Hence, in such cases, pharmacological stress testing is preferred with adenosine, dipyridamole, or regadenoson. In patients with valvular heart disease or pulmonary hypertension, an echocardiographic stress test is preferred as it provides clinically important information.4

**Coronary angiography**

There is insufficient data to recommend routine use of coronary angiography preoperatively for noncardiac surgical procedures (excluding patients undergoing kidney or liver transplantation). There is also very little information regarding the significance of coronary computed tomographic (CT) angiography and calcium scoring due to limited data.4,28

**Perioperative Medical Therapy and Interventions—Recommendations**

**Coronary revascularization**

*Preoperative revascularization for noncardiac surgery is recommended only when it is indicated as per guidelines for acute coronary syndrome. Routine coronary revascularization to reduce perioperative cardiac events in noncardiac surgery is not recommended.*29–32

There are no prospective RCTs supporting either coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI) to decrease intraoperative or postoperative cardiac events as part of perioperative management for noncardiac surgery. However, patients with acute coronary syndrome prior to noncardiac surgery should be managed according to guideline-directed therapy for acute coronary syndrome. In those who are scheduled for time-sensitive noncardiac surgery, balloon angioplasty or bare-metal stent (BMS) placement is preferred for management.29,33

**Elective noncardiac surgery in patients with prior PCI—timing and recommendations**

Elective noncardiac surgery, in whom dual anti-platelet therapy (DAPT) has to be discontinued prior to surgery, should not be performed within 30 days after BMS implantation or within 3 months of drug-eluting stent (DES) implantation with newer generation stents.

Noncardiac elective surgery should be delayed for 14 days after balloon angioplasty and 30 days after BMS implantation. It should be optimally delayed for 6 months after DES implantation. If risk of delay in noncardiac surgery is greater than risk of ischemia and stent thrombosis, and for whom P2Y12 inhibitors need to be discontinued, elective noncardiac surgery may be performed 90 days after DES implantation with newer generation stents.30,34–38

Prior to proceeding for noncardiac surgery, urgency for the surgery itself and risk of bleeding along with risk of ischemic events and stent thrombosis should be taken into account. If PCI is required in a patient who needs time-sensitive noncardiac surgery, implantation of a BMS or balloon angioplasty should be considered. BMS has higher rates of stenosis compared with DES; however, these restenotic lesions are not life-threatening and can be managed with repeat PCI if needed. In case of urgent or emergent surgery, risk of bleeding and ischemia should be taken into consideration.4

**Anti-platelet therapy**

In patients undergoing urgent noncardiac surgery within the first 4 to 6 weeks after BMS or DES implantations, it is important to continue DAPT unless risk of bleeding outweighs the benefit of stent thrombosis prevention.

In patients who must undergo surgical procedures requiring discontinuation of P2Y12 platelet receptor-inhibitor therapy and have received coronary stents, aspirin should be continued if possible and P2Y12 platelet receptor–inhibitor therapy should be restarted as soon as possible after the surgery.

It is reasonable to continue aspirin in patients undergoing elective noncardiac surgery who have no prior coronary stents when risk of cardiac event outweighs bleeding risk from surgery. However, unless risk of cardiac event outweighs surgical
bleeding risk, initiation or continuation of aspirin is of no benefit in patients undergoing elective noncardiac noncarotid surgery.\(^{39,40}\)

Highest risk of stent thrombosis is in the first 4 to 6 weeks after stent implantation.\(^{41,42}\) In case DAPT has to be discontinued for urgent or emergent surgery, such a decision should be individualized, weighing the risk and benefit (Figure 2).\(^{43}\)

**Anticoagulant therapy**

Benefit of continuation of anticoagulants should be weighed against risk of bleeding prior to any surgical procedure.

Low bleeding risk surgeries, like, for example, cataract surgery or minor dermatological surgeries, do not predispose to prolonged bleeding, and in such cases, anticoagulant therapy can be continued.\(^{4,44}\)

There are no studies on the prevention of perioperative myocardial ischemia or MI by anticoagulants in perioperative period for noncardiac surgeries. Depending on the location of the prosthetic valve along with associated risk factors for thromboembolism (which include the presence of atrial fibrillation (AF), previous thromboembolism, LV dysfunction, hypercoagulable condition, or older generation prosthetic aortic valve), patients on vitamin K antagonist (VKA) may or may not require bridging with either unfractionated heparin or low-molecular-weight heparin.

In patient having a mechanical mitral valve, bridging anticoagulation is appropriate with interruption of anticoagulation in perioperative period regardless of the presence or absence of risk factors of thromboembolism. Same is true for patients with mechanical aortic valve with one or more risk factors of thromboembolism.\(^{44,45}\)

Bridging anticoagulation is recommended in the time period when then international normalized ratio (INR) is subtherapeutic preoperatively.

Patients with AF who are managed with VKA therapy and are at low risk of thromboembolism (CHA\(_2\)DS\(_2\)-VASc score of zero to 1) or those who are back to normal sinus rhythm, undergoing surgery with increased risk of bleeding, holding VKA therapy for 1 week to allow normalization of INR without bridging anticoagulation is acceptable. VKA therapy is then resumed once hemostasis is achieved.\(^{45,46}\)

In patients who have high risk of thromboembolism (prior strokes, mechanical valves, CHA\(_2\)DS\(_2\)-VASc score ≥ 2), bridging anticoagulation is preferred once VKA therapy is withheld and INR is subtherapeutic.\(^{45}\)

In patients on direct thrombin inhibitors (eg, dabigatran) undergoing noncardiac surgery with normal renal function, anticoagulation can be discontinued 48 to 72 hours before the procedure. In those with mildly impaired renal function (with creatinine clearance of >50 mL/min), this can be withheld 4 to 5 days prior to procedure. Longer duration may be required in case of severe renal insufficiency (creatinine clearance <50 mL/min).\(^{47,48}\)

For patients on oral direct factor Xa inhibitors having normal renal function undergoing elective procedures, anticoagulation can be stopped 48 hours prior to the scheduled noncardiac elective surgery. Prolonged discontinuation can be exercised in patients with high risk of bleeding or with mild renal insufficiency (creatinine clearance >50 mL/min).

Due to the rapid offset and onset, bridging anticoagulation is not required on patients on newer oral anticoagulants. This is reserved only for patients with a very high risk of postoperative thromboembolism and requires extended interruption of such as in cases where oral diet is restricted for some time (eg,
intestinal surgeries). It should be resumed when hemostasis is achieved. Caution should be exercised in patients with high risk of bleeding as onset of action is rapid (within 2-3 hours). Resuming dabigatran can be delayed in patients with high risk of bleeding or can administer a lower dose for the first 2 to 3 days.  

Activated partial thromboplastin time for dabigatran and prothrombin time for apixaban and rivaroxaban can be monitored; levels close to control levels suggest a low serum concentration of these agents.  

In case emergent reversal of anticoagulation is required for VKA, vitamin K is not recommended because the effect is not predictable and not immediate. This can even delay the return to therapeutic level of anticoagulation when VKAs are restarted.  

**β-blocker therapy**  

Patients who are on β-blocker should be continued on them if they are well tolerated. Changes can be made before, during, or after surgery depending on clinical circumstances. Modification or even discontinuation may be necessary in patients with hypotension, bradycardia, bleeding, etc. Abrupt withdrawal of β-blocker therapy in perioperative period has shown to be harmful.  

**In patients with preoperative testing suggestive of moderate- to high-risk myocardial ischemia, it is reasonable to begin perioperative β-blockers, if not contraindicated.**  

It is also reasonable to initiated β-blockers in patients who have 3 or more RCRI risk factors. Here, it is also important to take into consideration any risk of stroke or any other contraindication to β-blocker therapy prior to surgery.  

Initiation of β-blocker therapy in less than 1 day prior to surgery has minimal effect, if any, and can even be harmful. It can be started 2 to 7 days prior to surgery, but some data show that it is preferable to initiate β-blockers more than 30 days from surgery. It should never be started on the day of surgery.  

There are limited data related to titration of dose of β-blockers, and studies that were conducted to evaluate dose titration also began therapy more than 1 day before surgery. This makes it difficult to ascertain whether it is the dose titration or timing of initiation that has resulted in potential benefit. Also, the benefit of β-blockers is offset by a high risk of perioperative strokes and uncertain benefit in risk or mortality. However, the incidence of stroke is less common than MACE.  

**Statin therapy**  

**Perioperative statin therapy for noncardiac surgery should be continued in patients taking them.**  

It is also reasonable to initiate statin therapy in those going for vascular surgery.  

Statins may also be considered in patients scheduled for elevated risk procedure who have clinical indications for initiation of statin therapy.  

**Alpha-2 agonist therapy**  

In patients who are undergoing noncardiac surgery, use of alpha-2 agonist for prevention of cardiac events is not recommended.  

Benefit of alpha-2 agonist in perioperative period comes from a number of trials which showed overall reduced myocardial ischemia and death. However, later a large multicenter trial showed that clonidine, an alpha-2 agonist, does not reduce perioperative cardiac events in patients undergoing noncardiac surgery. It in fact increases the rate of nonfatal cardiac arrest and clinically significant hypotension.  

**Calcium channel blockers**  

There is limited data on the efficacy of calcium channel blockers in perioperative therapy for patients undergoing noncardiac surgery. Most the benefits shown are attributed to diltiazem. There was no decrease in the incidence of myocardial ischemia with the use of dihydropyridines and verapamil. Verapamil also showed increased incidence of supraventricular tachycardia. It should be kept in mind that verapamil and diltiazem can worsen and even precipitate HF in patients with decreased EF and/or clinical HF. More studies are needed to make specific recommendations regarding perioperative use of calcium channel blockers.  

**Angiotensin-Converting Enzyme Inhibitors**  

It is reasonable to continue angiotensin-converting enzyme (ACE) inhibitors or angiotensin-receptor blockers perioperatively. If they are held before, it is reasonable to restart as soon as possible postoperatively.  

**Intravenous nitroglycerin**  

Use of intravenous nitroglycerin prophylactically to prevent myocardial ischemia has shown to be ineffective in patients undergoing noncardiac surgery.  

**Preoperative Evaluation in Specific Patient Population—General Considerations**  

**Age**  

Age plays an important role in determining MACE as there is an increased prevalence of cerebrovascular disease,
cardiovascular disease, diabetes mellitus, and other medical condition as age increases.74–76

Coronary artery disease

Cardiac morbidity during and/or after noncardiac surgery depends on how it is defined.37–39 These can just be elevation in cardiac biomarkers alone or may involve typical symptoms and signs of ischemia. There is an association of prior cardiovascular (CAD) events with MACE after noncardiac surgery. A study by Livhits et al77 showed that the rate of postoperative MI decreased significantly with increase in time from prior MI and date of procedure. It also showed an improved 30-day mortality. This suggests that a noncardiac surgery should be performed after at least 2 months of MI in the absence of coronary intervention. Risk of MACE depends on the type of coronary intervention at the time of MI prior to surgery.

A recent MI (occurring within 6 months of noncardiac surgery) is also an independent risk factor of perioperative stroke, associated with an increase in perioperative mortality of 8-fold.78

Heart failure

Active HF or patients with history of HF are at a higher risk of perioperative complications, based on data from many studies.79,80 One such study involved population-based data analysis of 38,047 patients. This study showed that compared with 30-day postoperative mortality rate in patients with CAD (2.9%), risk was higher in patients with nonischemic HF (9.3%) and ischemic HF (9.2%).81 An LVEF <35%, in the absence of symptoms, itself is an independent risk factor for perioperative morbidity and mortality in patients undergoing elevated-risk noncardiac surgery.82 Studies in patients having symptomatic diastolic dysfunction, with and without systolic dysfunction, has also been shown to be associated with higher incidence rate of MACE, high rates of postoperative HF, and prolonged length of hospital stay.83,84

Nonischemic cardiomyopathy

There is limited data on perioperative evaluation of patients with different types of nonischemic cardiomyopathies. Hence, the decision of perioperative evaluation and management should be individualized based on the underlying pathophysiological mechanism of cardiomyopathy and the presence of symptomatic disease with or without HF.

For example, in patients with restrictive cardiomyopathy, cardiac output is dependent on both preload and heart rate. Hence, monitoring and management to prevent reduction in blood volume and prevention of arrhythmias are recommended. The pathophysiology of hypertrophic cardiomyopathy would not allow tolerance of reduced preload, reduction in LV filling, volume loss, and decreased systemic vascular resistance.4

Valvular heart disease

Having significant valvular heart disease in patients undergoing noncardiac surgery confers increased cardiac risk in perioperative period. It is recommended that

1. Patients with clinically suspected significant valvular regurgitation or stenosis should undergo echocardiography in perioperative period if
   a. No prior echocardiogram within 1 year, or
   b. A significant change in clinical status or examination since last evaluation.85
2. Intervention for correction of valvular heart disease is effective in reducing perioperative risk in adults who meet standard indications for valve replacement or repair, based on symptoms and severity of stenosis or regurgitation.44

In cases of emergency noncardiac surgery in patients with uncorrected significant valvular heart disease, risk of perioperative MACE can be reduced by determining the type and severity of the valvular heart disease, proper anesthetic approach, and high level of perioperative monitoring which can include monitoring of pulmonary artery pressure and use of transesophageal echocardiogram.4

Aortic stenosis

The underlying pathophysiology of MACE in patients with aortic stenosis (AS) likely involves the effects of anesthetic agents and surgery itself leading to deranged hemodynamics. This can lead to hypotension and tachycardia resulting in decreased coronary perfusion, risk of arrhythmias, ischemia, myocardial infarction, HF, and even death.

Studies have shown increased risk of postoperative MI in patients with AS compared with patients without AS. The former also had worse 30-day mortality. There are other predictors of postoperative MI and 30-day mortality in patients with moderate and severe AS which include high-risk surgery, symptomatic severe AS, coexisting moderate or severe mitral regurgitation (MR), and preexisting CAD.86

It is recommended that elevated-risk elective noncardiac surgical procedures can be performed in patients with asymptomatic severe AS with appropriate intraoperative and postoperative hemodynamic monitoring.4,86

Certain patients will meet criteria for aortic valve replacement at the time of noncardiac surgery, but are not candidates for surgical aortic valve replacement or are high-risk patients.

In such cases, it is advised that either they undergo noncardiac surgery with invasive hemodynamic monitoring along with optimization of hemodynamic conditions or have percutaneous
aortic balloon dilation as bridging or transcatheter aortic valve replacement (TAVR).\textsuperscript{87,88} Percutaneous aortic balloon dilation has a mortality rate of 2\% to 3\% with stroke rate of 1\% to 2\%. However, it is important to keep in mind that recurrence rate and mortality after 6 months approach to around 50\%.\textsuperscript{88,89} Outcomes for TAVR are superior in patients not candidates for surgical AVR compared with standard therapy; however, safety or efficacy data in those who undergo noncardiac surgery are not available.\textsuperscript{89–91}

**Mitral regurgitation**

Asymptomatic patients with severe mitral stenosis, having unfavorable valve morphology for percutaneous mitral balloon commissurotomy, and undergoing elevated-risk elective noncardiac surgery are at increased risk, and it is important in such cases to maintain good hemodynamic status with intraoperative and postoperative monitoring of intravascular volume and avoid tachycardia and hypotension. Maintenance of intravascular volume should be titrated enough to provide adequate forward flow and to prevent increase in left atrial pressure and pulmonary capillary wedge pressure which can lead to acute pulmonary edema.\textsuperscript{4}

In cases where patients meet standard criteria for open mitral commissurotomy or percutaneous mitral balloon commissurotomy, they should undergo valvular intervention prior to elective noncardiac surgery.\textsuperscript{4,92}

**Aortic regurgitation**

Aortic regurgitation (AR) is associated with volume overload; however, it is better tolerated than AS. It is important to maintain a good preload, and excessive systemic afterload should be avoided as it can hinder cardiac output and lead to increased AR. A study by Lai et al\textsuperscript{93} showed increased morbidity and mortality in patients with moderate to severe AR undergoing noncardiac surgery compared with patients without AR.

It is recommended that patients with asymptomatic severe AR and having a normal LVEF undergoing elevated-risk elective noncardiac surgery should have appropriate intraoperative and postoperative hemodynamic monitoring. It is reasonable to admit such patients in intensive care unit postoperatively.\textsuperscript{4}

**Mitral regurgitation**

As seen with AR, patients with moderate to severe MR have a higher rate of worse outcomes after nonemergency noncardiac surgery compared with patients without MR. It is important in such patients to maintain adequate forward flow and prevent increase in afterload which can precipitate pulmonary edema by increasing MR.\textsuperscript{94}

It is reasonable that asymptomatic patients with moderate to severe MR undergoing elective elevated-risk noncardiac surgery should have appropriate intraoperative and postoperative hemodynamic monitoring and echocardiography. Such patients can be admitted to an intensive care unit when undergoing such procedures.\textsuperscript{4}

**Perioperative arrhythmias**

It is important to seek underlying cause of any arrhythmia that occurs in the perioperative period as it can be precipitated by underlying cardiopulmonary disease, ischemia, drug toxicity, metabolic derangements, etc. These can alter outcomes in patients undergoing noncardiac surgery. Specific recommendations related to perioperative arrhythmias cannot be provided due to the limited number of studies to determine surgical risk in such cases. Few studies have shown supraventricular and ventricular arrhythmias to have low risk of perioperative cardiac events.\textsuperscript{95,96} There is no increase in cardiac complications or any increased risk of nonfatal MI or cardiac death in patients seen to have frequent ventricular premature beats, couplets or nonsustained ventricular tachycardia, and couplets in perioperative period for noncardiac surgery.\textsuperscript{97,98} Patients who develop such arrhythmias may require referral to cardiologist for further evaluation. AF is very common, especially in older patients. Patients with preoperative AF who are asymptomatic and stable do not require any changes in their medical management, apart from adjustment of anticoagulation, in the perioperative period. There is potential, however, of perioperative formation of left atrial thrombus in patients with persistent AF undergoing thoracic surgeries or other noncardiac surgeries involving physical manipulation of the heart.\textsuperscript{4}

**Conduction abnormalities**

Asymptomatic patients with no history of advanced heart block having intraventricular delays, with or without left or right bundle branch block, very rarely develop complete atroventricular block in perioperative period. However, if patients do develop high-grade conduction defects, they may increase operative risk and require temporary or permanent transvenous pacing.\textsuperscript{99,100} Caution should be exercised in patients considered for perioperative β-blocker therapy who have history of preexisting sinus node dysfunction or atrioventricular block. However, these are not contraindicated in patients with bifascicular block or isolated bundle branch block.\textsuperscript{4}

**Cardiovascular implantable electronic devices**

The presence of cardiac implantable electronic devices (CIEDs) confers important perioperative and postoperative implications in patients undergoing noncardiac surgery. Their presence indicates the presence of underlying cardiac disease that necessitated CIED placement. Hence, preoperative evaluation as well as perioperative and postoperative monitoring
of such patients should take into account not only the CIED programming itself but also the underlying pathology that required such placement. This involved individualized evaluation and management as recommended by the Heart Rhythm Society/American Society of Anesthesiologists expert consensus statement.101

Management of such patients depends on the type of surgery, type of electrocautery used, CIED programming, patient symptoms, underlying pathology requiring CIED as mentioned above, etc. This may then require device interrogation prior to procedure, reprogramming of device, application of magnet over the CIED with or without postoperative CIED interrogation, or no perioperative CIED intervention.102,103

**Pulmonary vascular disease**

Patients having pulmonary hypertension undergoing noncardiac surgery have a high rate of complications, morbidity, and mortality. This is based on observational data, mostly on patients having group 1 pulmonary arterial hypertension.104–106 Such risk depends on the nature of surgery, degree right ventricular (RV) dysfunction, severity of pulmonary hypertension, severity of symptoms, and expertise of the surgical center in managing patients with pulmonary hypertension.

Unless contraindicated or not tolerated by patient, vascular-targeted therapy of chronic pulmonary hypertension (including phosphodiesterase type 5 inhibitors, endothelin receptor antagonist, etc.) should be continued in patients with pulmonary hypertension undergoing noncardiac surgery.4

Preoperative evaluation by a pulmonary hypertension specialist before noncardiac surgery can be beneficial for such patients, especially in those with high perioperative risk, if risk of delaying surgery does not outweigh such benefit.4,107

Such evaluation may involve assessment of hemodynamics, echocardiography, assessment of functional capacity, and even right heart catheterization. Certain factors have been shown to be associated with increased perioperative risk. These include the following:

1. Patients with group 1 pulmonary arterial hypertension;
2. Other forms of pulmonary hypertension with
   a. Elevated pulmonary systolic pressure of >70 mm Hg and/or
   b. Moderate or greater RV dilation and/or dysfunction and/or
   c. Pulmonary vascular resistance >3 Woods unit
3. World Health Organization/New York Heart Association class III or IV symptoms due to pulmonary hypertension.104–106,108

Perioperative management of patients with pulmonary hypertension is based on 2 key points. One is to prevent systemic hypotension which poses risk of RV ischemia and the other is to prevent acute elevations in pulmonary artery pressure which can further deteriorate RV failure. This involved strict monitoring of hemodynamic status, blood pressure optimization, oxygenation and proper ventilation, use of vasopressors, etc.106

**Adult congenital heart disease**

Patients with adult congenital heart disease (ACHD) undergoing noncardiac surgery have a greater risk of perioperative and postoperative complications compared with patients without ACHD.109–111 It is important that evaluation of such patients be performed in regional centers with expertise in ACHD.112,113

Patients with ACHD undergoing noncardiac surgery should have basic preoperative evaluation which should include systemic arterial oximetry, ECG, chest x-ray, transthoracic echocardiogram (TTE), and a full panel of baseline blood tests.113

There are certain high-risk patients with ACHD who should be managed at expert centers under all circumstances, unless the operative procedure is an emergency. These include patients with

1. Prior Fontan procedure;
2. Severe pulmonary arterial hypertension;
3. Cyanotic CHD;
4. Complex CHD with residua such as HF, need for anticoagulation, or valve disease;
5. Malignant arrhythmias associated with ACHD.

Risk assessment in patients with ACHD undergoing noncardiac surgery should be deferred to ACHD experts. Also consultation with a cardiac anesthesiologist for moderate- to high-risk patients is recommended.113

**Intraoperative Monitoring and Management**

There has been improvement in the standard of care and management with advancement in perioperative monitoring. The main purpose of having these monitoring systems and protocols is to obtain clinically relevant information which affects patient care and management. Perioperative complications and their prevention have implications on both our health care cost and system, as well as the patients. Continued advancements in our health care system with improved perioperative monitoring has led to improved patient outcomes.

**Choice of anesthetic agent**

There is no evidence to suggest the cardioprotective effect of use of neuraxial anesthesia (epidural or spinal anesthesia) in patients or even in those in whom neuraxial is opted against general anesthesia.114 Also, use of either total intravenous
anesthesia or volatile anesthesia has no difference in either myocardial infarction or MI, and their use is determined by factors other than prevention of myocardial ischemia or MI in patients undergoing noncardiac surgery.115,116

Transesophageal echocardiography

In patients undergoing noncardiac surgery with hemodynamic instability, emergency use of perioperative TEE is reasonable to determine cause when it persists despite adequate management. However, its routine intraoperative use in patients without risk factors or procedural risks for hemodynamic, neurologic, or pulmonary compromise, in noncardiac surgery, to screen cardiac abnormalities or monitor myocardial ischemia is not recommended.117–119

Maintenance of normothermia

Many perioperative complications can be attributed to hypothermia, including wound infection, immune dysfunction, coagulopathy, MACE, requirement of transfusions, and even death.

It is reasonable to maintain normothermia in patients undergoing noncardiac surgery to prevent perioperative cardiac events.120,121

Hemodynamic assist devices

In patients with acute severe cardiac dysfunction undergoing urgent or emergent surgery in which the acute cardiac dysfunction cannot be corrected prior to surgery, it is reasonable to use hemodynamic assist devices. Their routine use is not recommended as there are very limited data on their benefit and safety profile in noncardiac surgery. Outcomes for patients on mechanical circulatory support have been reported in few studies, with mortality ranging between 9% and 30% for those undergoing noncardiac surgeries.122,123

Pulmonary artery catheters

Routine use of pulmonary artery catheterization is not recommended even in patients going for elevated-risk procedures. However, their use may be considered in patients having severe cardiac conditions (such as severe valvular disease, HF) which cannot be corrected prior to surgery and require strict hemodynamic monitoring.124,125

Monitoring and management of perioperative anemia

Anemia can lead to increased incidence of cardiac complications especially in patients with CAD. This is secondary to both lack of oxygen delivery to ischemic myocardium and increased demand for cardiac output to supply oxygen to the rest of the body. On the basis of expert opinion and other studies, a restricted transfusion strategy with hemoglobin of <7 to 8 g/dL in asymptomatic patients without CAD is recommended. Even in patients with CAD, it is advised to adhere to restrictive transfusion strategy unless patient has symptoms, orthostasis, congestive HF, or hemoglobin <8 g/dL.126

Postoperative Management

Pain management

Pain management is one of the most important aspects of intraoperative and postoperative surgical management. It is one of the factors that can even contribute to myocardial ischemia and infarction.

Perioperative epidural analgesia has been shown to decrease incidence of preoperative cardiac events in patients with hip fracture.127

Postoperative pain relief can be achieved with neuraxial anesthesia in patients undergoing abdominal surgery to reduce incidence of perioperative MI.128,129

Postoperative myocardial infarction

It is recommended to obtain a 12-lead ECG in patients with symptoms and signs suggestive of myocardial ischemia, infarction, or arrhythmia. Measurement of troponins is also recommended in this setting.130,131

Postoperative screening with troponin levels or ECG in asymptomatic patients at high perioperative risk of MI is of uncertain significance with no established risks and benefits of a particular defined management.131–134

None of the studies carried out to evaluate the significance of elevated troponins in perioperative period for patients undergoing noncardiac surgeries take into account patients with elevated troponins prior to surgery which can be seen in up to 21% of high-risk patients. No study clarifies the cause of mortality, which is seen after a median time of more than 7 days between troponin elevation and mortality itself. Hence, the benefit of routine postoperative measurement of troponins to prevent deaths, of which a specific cause is unknown, remains uncertain even in high-risk patients. Therefore, it is of no significance unless the patient exhibits signs and symptoms of myocardial ischemia or MI. Use of creatine kinase (CK)-MB in perioperative period is also difficult to interpret as there is a significant rise in CK seen in perioperative periods.

Role of routine ECG monitoring in postoperative period for patients undergoing noncardiac surgery with no evidence of ischemia is also uncertain. It provides little information on asymptomatic patients. Also there is little correlation shown in studies with elevation in troponins and simultaneous ECG changes. In a study where 40% of patient had elevated troponin levels, only 6% had ischemic changes on ECG. Also ECG
changes provided no information to predict death at 1 year, whereas troponin elevation did.\(^{131,136}\) Also it has been shown that interpretation of ECG in critical illness even among expert readers is moderately reliable.\(^{137}\)

**Postoperative supraventricular arrhythmias**

The most common arrhythmias in the postoperative period are AF and atrial flutter. Incidence varies for postoperative AF which can range from 0.37% to 30% with peak incidence 1 to 3 days after surgery.\(^{138-141}\) Management does not differ except for assessing the benefit of anticoagulation and risk of postoperative bleeding. In acute setting, ventricular rate control is achieved with β-blockers or nondihydropyridine calcium channel blockers. Digoxin is mostly given in patients with systolic HF or in patients having inappropriate response or contraindications to other drugs.

Caution should be exercised in using nondihydropyridine calcium channel blockers in patients with LV dysfunction or acute clinical HF. Intravenous amiodarone can be used in patients in whom maintaining or achieving sinus rhythm is beneficial. Side effect profile of amiodarone should be kept in mind. Cardioversion is only performed in postoperative period in cases of hemodynamic instability due to arrhythmia.

Narrow complex tachycardias due to atrioventricular nodal reentrant tachycardia or atrioventricular reciprocating tachycardia can be terminated with the use of vagal maneuvers or intravenous adenosine or verapamil. Prevention of further episodes can be accomplished with the use of β-blocker, calcium channel blockers, and class IC antiarrhythmic agents.

In case of preexcited AF, atrioventricular nodal blocking agents, such as digoxin and calcium channel blockers, are avoided.\(^4\)

**Postoperative ventricular arrhythmias**

The presence of asymptomatic premature ventricular contractions (PVC) usually do not require any evaluation or management. Treatment is initiated only in cases of symptomatic frequent PVCs or runs of nonsustained ventricular tachycardia.\(^{142,143}\) Evaluation is required in patients who develop polymorphic ventricular tachycardia (VT) in postoperative period. Management of ventricular arrhythmias involves use of intravenous β-blockers, procainamide, amiodarone, or lidocaine. Cardioversion is used in hemodynamically compromised patients.

**Postoperative conduction disorders**

Conduction disorders in postoperative period are usually secondary to underlying electrolyte abnormality, acid-base disorder, medication, hypoxia, pain or ischemia. A common cause is the presence of sleep apnea in patients, which can lead to postoperative nocturnal bradycardia. In case these conduction disorders are symptomatic, temporary transcutaneous pacemakers are used. Permanent pacemakers are used according to general indications outside perioperative setting.\(^{99,144}\)

**Postoperative management of CIEDs**

For surgical procedures, it is necessary to inactivate tachytherapy preoperatively for patients having implantable cardioverter-defibrillators (ICDs). Such patients should be on continuous cardiac monitoring throughout the procedure with external defibrillation equipment readily available. Before discontinuation of cardiac monitoring and/or discharge, ICDs should be reprogrammed to activate tachytherapy.\(^{145}\)

Interaction with ICD and electromagnetic interference occurs with the use of monopolar electrocautery. Bipolar electrocautery or harmonic scalpel causes little interference with CIEDs, unless energy is applied in the operative field directly on the leads or on CIED generator. The use of monopolar cautery results in the inhibition of pacing, which can result in hemodynamic compromise in pacemaker-dependent patients. In case of ICDs, this can result in inappropriate shocks.

A magnet should always be available and response to magnet application should be known prior to initiating the surgical procedure. All patients having CIEDs should have arterial or plethysmographic pressure monitoring as electrocautery can result in interference with electrocardiographic recordings.

**Postoperative management of patients with pulmonary hypertension**

In patients with pulmonary hypertension, heavy doses of sedatives or their combination should be avoided as they can easily lead to respiratory compromise. Small doses, however, can be given to very anxious patients. Medications which were used to treat pulmonary hypertension preoperatively should also be continued in the postoperative period. Some of these medications have inhibitory effect on platelet aggregation, but this is usually minor and of little clinical significance as major bleeding has not been reported with their use. Oxygenation should be maintained throughout the procedure. Postoperative monitoring of hemodynamic status should be preferably done with use of arterial line as hypotension can lead to significant RV ischemia. In critically ill patients, use of central venous pressure or a pulmonary artery catheter can be used; however, it should be kept in mind that central venous pressure measurement in patients with pulmonary hypertension is not accurate to indicate LV preload.\(^{106}\)

Pain management is also of utmost importance as it can lead to increased pulmonary vascular resistance and RV ischemia. Systemic opioids can have the same effect; hence, neuraxial or regional blocks may be beneficial in such cases. Rebound pulmonary hypertension can also occur in patients on prolonged therapy with pulmonary vasodilators being weaned off in the perioperative period. In such cases,
sildenafil is helpful to prevent rebound which occurs during removal of inhaled nitric oxide. In case a patient develops hemodynamic instability from RV failure, dopamine or epinephrine is usually avoided as it increases heart rate and myocardial consumption more than norepinephrine, the latter being preferred in such cases. Once systemic hemodynamics are stabilized with pressors, attempts should be made to reduce pulmonary vascular resistance by use of pulmonary vasodilators. If all fails, intra-aortic balloon counterpulsation or other mechanical assist devices are available options. If still no recovery, then extracorporeal membrane oxygenation could be life-saving. Mechanical RV assist devices are not recommended as they can lead to damage to pulmonary vasculature. Atrial septostomy as palliation is a last resort as a bridge to lung transplant but has a high associated mortality.

**Postoperative management with ACHD**

Patients with ACHD require intensive care unit monitoring after noncardiac surgery even for minor procedures. Special consideration should be given to the following:

1. Endocarditis prophylaxis;
2. Need for anticoagulation perioperatively, if indicated;
3. Monitoring of hemodynamic status pertaining to the underlying CHD;
4. Filters for intravenous lines in cyanotic patients;
5. Venous thromboprophylaxis;
6. Monitoring of renal function;
7. Reduced arm blood pressure measurement in patients with prior Blalock-Taussig shunts;
8. Staff education pertaining to the underlying ACHD;
9. Patients with CHD surgery prior to 1992 should be screened for hepatitis C.

**Valvular heart disease**

Hemodynamic status monitoring should be continued throughout to prevent hypotension as cardiac output is dependent on preload and atrial contraction. Hence, in noncardiac patients with AS, arrhythmias are very poorly tolerated and prompt managements should be initiated. Tachycardia worsens cardiac output in AS as there is decreased diastolic filling in an already stiff left ventricle with reduced compliance. Efforts should be made to restore sinus rhythm in patients who develop AF. Cardioversion should be applied immediately in such patients with hemodynamic instability.

Patients with mitral stenosis should be managed in a similar way as those with AS as the underlying pathology and hemodynamics are mostly the same. This involves maintaining adequate volume status to maintain good forward flow but at the same time monitored to prevent increase in left atrial pressure. Avoidance of tachycardia and maintenance of sinus rhythm should be pursued.

Chronic volume LV overload is seen in patients with AR and MR; hence, factors promoting LV overload should be avoided. Blood pressure monitoring and control is the key in the management of such patients as decrease in the afterload leads to decrease in regurgitation and increase in forward flow. Combination of neuraxial anesthesia and opioids is preferred as it causes systemic vasodilation. However, preload should also be maintained because of increased LV diastolic compliance leading to larger LV volume. Monitoring with central venous catheters and even pulmonary catheters can be done in hemodynamically unstable patients.

**Conclusions**

Perioperative cardiovascular evaluation and management is of utmost significance in patients undergoing noncardiac surgery. It has been shown to improve patient outcomes and reduce health care costs. However, it is of benefit only in a specific group of patients with risk factors going for high-risk procedures. Its routine use in patients undergoing low-risk elective procedures is of no benefit and can even lead to harm by subjecting patients to unnecessary evaluations and management protocols. It is important to stress on the fact that most of these recommendations are based, to a large extent, on observational studies and clinical experience. There are only few RCTs that address this matter. It is prudent that more randomized trials are needed to improve on current recommendations, hence leading to further improvement in patient care and management in the perioperative period. There is constant evolution of technology as new modalities are being researched and developed: cardiac magnetic resonance imaging, coronary CT angiography, calcium scores, fractional flow reserve-CT, etc. More studies are needed to determine their significance and application in perioperative cardiovascular risk assessment.

The ideal approach toward perioperative cardiac risk assessment requires a multidisciplinary team or a dedicated perioperative team of physicians. This leads expert physicians in this field to be involved in patient care with improved communications among primary physicians, anesthesiologist, surgeons, the patient, family members of the patient, cardiologist, and all other ancillary departments of health care involved. This leads to a shared decision-making process in the light of contemporary guidelines to determine the best approach toward reducing perioperative cardiac morbidity and mortality, hence leading to improved patient care, quality of life, and reduced health care cost.

**Author Contributions**

All authors were involved in literature search, drafting the manuscript, editing and revision. All authors gave approval for publication of final version.

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