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Review

Preoperative assessment of cardiac risk and perioperative cardiac management in noncardiac surgery

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ABSTRACT

More than 27 million Americans undergo noncardiac surgery annually. Cardiac complications can be a major source of morbidity and mortality in the perioperative period. Preoperative risk stratification, intraoperative ischemia monitoring and postoperative surveillance help to predict, identify and efficiently treat these adverse events. A renewed emphasis on preoperative evaluation has helped to identify patients at an increased risk for adverse cardiac events and thus, implement noninvasive or invasive cardio protective strategies in an attempt to minimize these complications. In this review we briefly describe the current evidence on perioperative management of patients presenting for noncardiac surgery. As the surgeon will remain one of the first to evaluate patients before noncardiac surgery it is essential he/she be well versed with this information.

1. Magnitude of the problem and the need for risk stratification

Most of the data regarding the incidence of perioperative cardiac events was collected in the 1980's and 1990's, before cardiac specific biomarkers became available. Major adverse cardiac events (ACE's) were found to occur in 2% of relatively unselected patients (not limited to patients with a known risk for coronary artery disease) undergoing noncardiac surgery (NCS)[1] to up to 34% in high risk patients. Observations, from recent placebo-controlled trials evaluating the efficacy of perioperative pharmacological interventions e.g. in the Metoprolol after Vascular Surgery (MaVS) study, ACE's were found to occur in 11.9%, 11.1%, 12.0% and 33.3% of the patients in the placebo group with 1, 2, 3 and 4 preoperative risk factors, respectively.[2] Similarly Poldermans et al[3] reported a 34% incidence of ACE's in high risk patients. Inspite of advancement in perioperative medicine this similar incidence of adverse postoperative cardiac events, over the years, can be attributed to an increasing number of elderly patients presenting for more invasive diagnostic and complex surgical procedures.[4]

It is projected that by 2030, there will be 71 million Americans older than 65 years.[5] This is the largest growing population cohort presenting for surgery. As the prevalence of chronic disease conditions including cardiovascular disease, cerebrovascular disease and diabetes increases with age[6] and 25% of surgical procedures performed in this elderly population, today, come under the category of high to intermediate risk, there will be a disproportionate increase in the number of patients at risk for perioperative ACE's.

2. Perioperative cardiac events and impact on health care

In a cohort of 3790 patients undergoing NCS Fleischmann et al[7] found that cardiac complications increased mean length of hospital stay by 11 days. Patients experiencing a myocardial infarction (MI) or cardiac arrest after NCS are known to have increased mortality in hospital and following discharge.[8–11] In total, perioperative ACE's and their consequent outcomes cause an astounding increase in health care costs of up to 20 billion per year.[12]

The impact of routine preoperative testing, on health care cannot be ignored. Asymptomatic patients with or without clinical risk factors are subjected to the so called "cardiac clearance". Auerbach et al[13] in an observation study of American Society of Anesthesiology (ASA) 4 and higher physical status patients presenting for NCS found inconsistent effects of specialist consultations on the quality of care. Delay in surgery as a result of testing increases hospital length of stay and also mortality after discharge.[14] Adherence to published perioperative screening guidelines has been shown to significantly reduce the cost of patient care.[15]

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3. Risk assessment

The goal of preoperative risk assessment is to identify patient and procedure factors that increase the risk for perioperative ACE's. These can be divided into following three broad but interrelated categories:

3.1. Surgery related risk factors

Need for emergent surgery, surgery specific factors (e.g. fluid shifts, blood loss, duration, laparoscopic or endovascular), and prevalence of co-morbidities known to be associated with certain surgical conditions, determine the risk associated with various surgical procedures. Based on this, noncardiac surgical procedures are classified as vascular, intermediate risk and low risk by the American College of Cardiology/American Heart Association (ACC/AHA) for the purpose of risk stratification. (Table 1).[16]

Patients presenting with emergent, sometimes, life- threatening conditions (Table 2), are at a 2–5 times increased risk of cardiac complications.[17–19] Lack of opportunity for adequate preoperative preparation and patient presentation in decompensated disease states contribute to the higher risk of cardiac complications in such situations. For elective NCS the nature and extent of the surgery determines risk for cardiac complication independent of overt clinical risk factors and patients functional status.[20] Many patients presenting for vascular surgery have risk factors for coronary artery disease (hypertension, diabetes mellitus, tobacco use, and hyperlipidemia), in addition to, asymptomatic, underlying coronary artery disease CAD).[21] The increased prevalence of CAD, complexity of open vascular procedures (fluid shifts, hemodynamic fluctuations), and postoperative thrombogenicity increase the risk of postoperative cardiac complications in these patients.[19]

The emerging evidence in support of decrease perioperative mortality in patients undergoing endovascular aortic aneurysm repair deserves special mention. As demonstrated by the DREAM (Dutch Randomized Endovascular Aneurysm Management)[22] trial and EVAR (Endovascular Abdominal aortic aneurysm Repair)-1 trial[23–25] 30-day mortality was lower in the endovascular repair group, but on 2 year follow-up cumulative survival was not found to be significantly different. Endovascular abdominal aortic aneurysm repair has been classified as an intermediate risk surgery, but long-term mortality should be taken into consideration during risk stratification.

Intermediate risk procedures cover a wide variety of surgical procedures and carry a 1% to 5% risk of ACE's. Location and extent of surgical procedure are important determinants of perioperative ACE's e.g. intrathoracic surgery for pulmonary neoplasm carries a relatively higher risk of ACE's than laparoscopic intraperitoneal surgery.[16,20,26]

Table 1
Cardiac Risk Stratification for Noncardiac Surgical Procedures.[16]

Risk Stratification	Procedure Examples
Vascular (reported cardiac risk often more than 5%)	Aortic and other major vascular surgery Peripheral vascular surgery
Intermediate (reported cardiac risk generally 1%–5%)	Intraperitoneal and intrathoracic surgery Carotid endarterectomy Head and neck surgery Orthopedic surgery Prostate surgery
Low (reported cardiac risk generally less than 1%)	Endoscopic procedures Superficial procedure Cataract surgery Breast surgery Ambulatory surgery

Table 2
Active Cardiac Conditions for Which the Patient should undergo Evaluation and Treatment Before Noncardiac Surgery.[16]

Condition	Examples
Unstable coronary syndromes	Unstable or severe angina Recent MI (7–30days)
Decompensated HF	NYHA functional class IV; worsening or new-onset HF
Significant arrhythmias	High-grade atrioventricular block Symptomatic ventricular arrhythmias Supraventricular arrhythmias (including atrial fibrillation) with uncontrolled ventricular rate (HR greater than 100 bpm at rest) Symptomatic bradycardia Newly recognized ventricular tachycardia
Severe valvular disease	Severe aortic stenosis (mean pressure gradient greater than 40 mm Hg, aortic valve area less than 1.0 cm^2, or symptomatic) Symptomatic mitral stenosis (progressive dyspnea on exertion, exertional presyncope, or HF)

Patients undergoing endoscopic procedures, cataract surgery and other ambulatory surgeries come under the low risk category. Warner et al[27] determined the incidence of perioperative MI to be 0.03% in 38,500 patients who underwent 45,090 consecutive ambulatory procedures involving general and local anesthesia techniques. As recommended by the ACC/AHA in 2007 patients undergoing such low risk procedures can proceed with surgery without further cardiac evaluation.

3.2. Patient related risk factors

A carefully conducted clinical evaluation based on history, physical examination, review of the electrocardiogram (ECG), and in certain situations review of echocardiographic findings provides adequate information to identify risk factors predictive of perioperative ACE's. The finding of active cardiac conditions (Table 2), demands delay in NCS, further evaluation, and management of these cardiac condition unless surgery is deemed emergent.

In patients undergoing NCS, various cardiac risk scoring systems to delineate perioperative cardiac risk have been investigated.[28–30] The multivariable, Revised Cardiac Risk Index (RCRI), developed by Lee et al, in 1999, is the one most widely used today.[1] Major ACE's are known to occur in 0.4%, 0.9%, 7%, and 11% in patients with 0, 1, 2, and 3 risk factors. In 2007 when the ACC/AHA published guidelines for perioperative cardiovascular evaluation and care for NCS, clinical, patient related risk factors were derived from the RCRI. (Table 3)

3.3. Patient's functional status

Determining the patient's functional capacity or exercise tolerance is a pivotal factor in risk assessment.[16] Self reported, limited, exercise tolerance has been shown to correlate with postoperative complications.[31] Functional status is most commonly estimated from the ability to perform tasks of daily living and expressed as metabolic equivalents (MET) of oxygen consumption. (One MET is defined as the resting oxygen consumption of a 70 kg, 40 year old male = 3.5 ml/kg/min).[32] Patients who are able to meet a 4 MET demand during activity have enough reserve to increase oxygen delivery and meet heightened oxygen requirements in the perioperative period.[31] They should be able to proceed with planned surgery without any further testing or medical interventions. On the other hand management of patients who have unknown or

Table 3
Clinical Risk Factors That Predict Risk of Cardiac Death and Nonfatal Myocardial Infarction at Time of Noncardiac Surgery.[16]

Clinical Risk Factor	Examples
History of ischemic heart	Previous myocardial infarction disease Previous positive result on stress test Use of nitroglycerin Typical angina ECG Q waves Previous PCI or CABG
History of compensated previous congestive heart failure	Previous pulmonary edema Third heart sound Bilateral rales Evidence of heart failure on chest radiograph
History of cerebrovascular	Previous TIA disease Previous stroke
Diabetes mellitus	With or without preoperative insulin therapy
Renal insufficiency	Creatinine level >2 mg/dL

limited functional capacity requires further risk stratification and has been an area of intense research.

4. Practice guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery

In 1996 the ACC/AHA published a consensus statement on the preoperative cardiac evaluation of patients presenting for NCS. These guidelines were revised in 2001 and extensively revised later in 2007. Throughout these revisions the basic algorithmic approach of risk stratification has remained the same, highlighting the interplay between nature and circumstance of surgery, patient's co morbidities and functional capacity. In 2009 the ACC/AHA republished the 2007 guidelines after incorporating the 2009 American College of Cardiology Foundation (ACCF)/AHA Focused Update on Perioperative Beta Blockers into the original document.[33,34] The ACC/AHA has segregated these guidelines into three categories based on the available level of evidence (Table 4)

The current algorithm delineates 5 key steps in the preoperative cardiac evaluation of patients presenting for NCS and is illustrated in Fig. 1. Following a similar algorithmic and step wise approach to evaluation and optimization of patients presenting for noncardiac surgery, the European Society of Cardiology (ESC) published guidelines for preoperative cardiac risk assessment and perioperative cardiac management in non cardiac surgery in 2010.[35] (The interested reader is referred to the ACC/AHA and ESC websites where complete versions of these documents are available).

5. Cardiac stress testing: role in risk stratification and therapy

Exercise ECG is a low cost method, of detecting inducible ischemia and provides objective measurement of functional capacity. The mean sensitivity and specificity of exercise ECG testing for the detection of underlying CAD has been found to be 68% and 77% respectively with a predictive accuracy of 73%.[36,37] Due to exercise limitation secondary to peripheral artery disease, degenerative joint disease or poor pulmonary reserve, 30–60% of patients referred for preoperative exercise cardiac evaluation are unable to undergo adequate testing.[38,39] As a result pharmacological testing using myocardial perfusion imaging (MPI) or dobutamine stress echocardiography (DSE) are used to detect inducible ischemia preoperatively.

MPI is performed at rest and during vasodilator stress, to detect adequate coronary vasodilator reserve, reversible perfusion defects (myocardium at risk) or fixed perfusion defects (scarred myocardium). Reversible perfusion defects are associated with a higher risk of ACE's.[40] DSE, involves evaluation of ventricle wall motion initially at rest and then during a dobutamine stress. Although superior to MPI the positive predictive value of DSE for cardiac death and MI still remains low, 17% and 26% respectively.[41–43] Further testing prompted by such positive results may lead to unnecessary coronary angiography, increased costs and delay in surgery. Negative predicative value of a normal cardiac stress test by both MPI and DSE has been found to be approximately 99%.[16]

Table 4
ACC/AHA guideline classification scheme.[16]

Class	Level of Evidence
Class I	Benefit outweighs the risk and the procedure/treatment **should** be performed/administered
Class IIa	Evidence is equivocal but it is **reasonable** that the procedure/treatment be performed/administered
Class IIb	Evidence is equivocal but the procedure/treatment **may be** performed/administered
Class III	Risk outweighs the benefit and the procedure/treatment **should not** be performed/administered

6. Perioperative management: revascularization strategies

As the focus of perioperative care of patients presenting for NCS shifts from risk stratification to risk management, surgical, and in particular, medical strategies are becoming an integral part of perioperative evaluation. Two recent landmark prospective studies, the CARP (Coronary Artery Revascularization Prophylaxis) randomized trial[44] and DECREASE (Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echo)-V pilot study[45] have failed to show any survival benefit with preoperative coronary revascularization. In the CARP trial 510 patients undergoing vascular surgery were randomized to coronary artery revascularization (258) before surgery or no coronary revascularization before surgery (252). Patients with left main CAD of >50%, left ventricle ejection fraction of less than 20%, and severe aortic stenosis were excluded from the trial. These exclusion criteria later became one of the biggest criticisms of the CARP trial as patients who probably would have benefited most from preoperative revascularization were not enrolled. Medical management with beta blockers, antiplatelet agents, angiotensin-converting– enzyme inhibitors, and statins were continued, throughout the follow-up period and was attributed to have negated any survival benefit of preoperative revascularization. The DECREASE-V pilot study, which proved to be an opposite extreme of the CARP trial, enrolled 101 patients with 3 or more clinical risk factors and extensive stress induced ischemia. Patients were strictly randomized to revascularization either by CABG or PCI (even those with coronary anatomy/condition unsuitable to revascularization) or no revascularization. β-blockers and dual antiplatelet therapy was continued in the perioperative period in patients who underwent PCI. Not only did the DECREASE-V pilot study fail to demonstrate any benefit of prophylactic coronary revascularization in high risk patients, 30- day all cause mortality was double in the revascularization group when compared to the control group. In both these studies intensive medical management in particular β-blockers, which favorably influence the oxygen supply-demand of the cardiac muscle and provide protection against plaque rupture, has been postulated to have eliminated any survival benefit provided by coronary revascularization.

Both of these trials were conducted in patients undergoing high risk vascular surgery. The CARP trial enrolled relatively low risk patients and the DECREASE- V pilot study enrolled significantly higher risk patients. The extent to which results of these RCT can be extrapolated outside the setting of vascular surgery can only be speculated but it does seem reasonable to do so. Even amongst patients undergoing vascular surgery the results of these studies should be

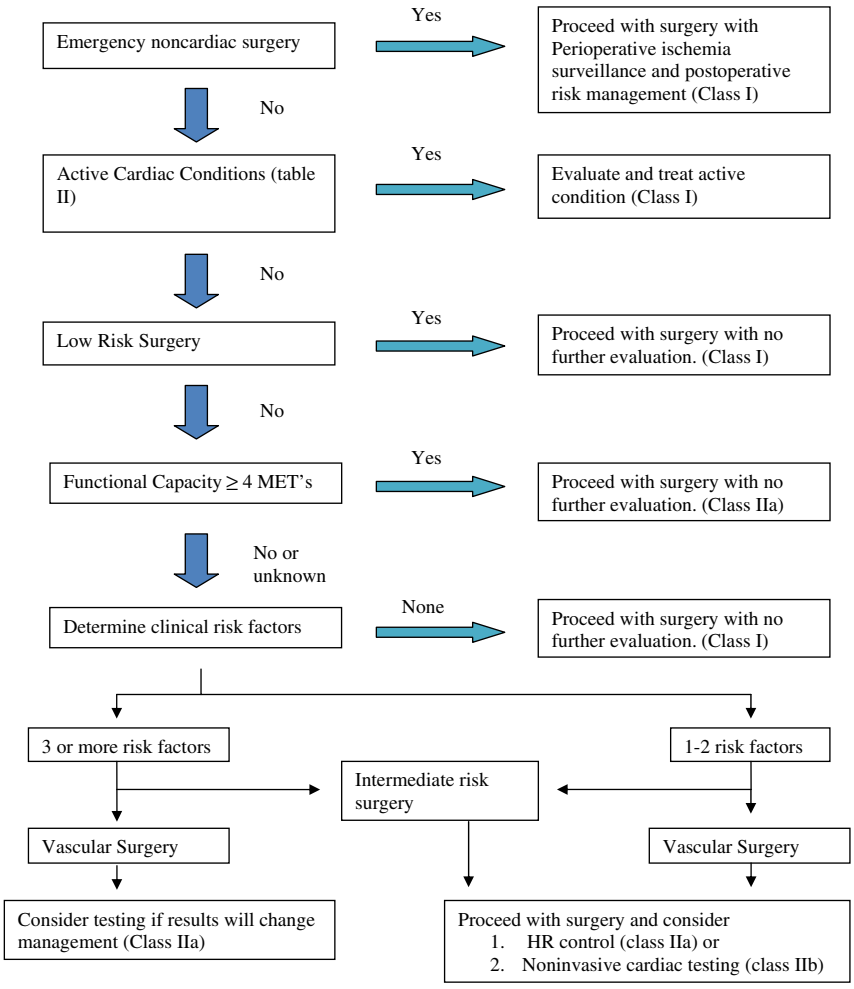

Fig. 1. American College of Cardiology (ACC)/American Heart Association (2009) algorithm for cardiac evaluation and care of patients presenting for noncardiac surgery.[16]

interpreted with caution. In the CARP trial patients from 18 Veterans Affairs medical centers across the United States were enrolled while the DECREASE–V study was conducted in 6 different countries. Although practice parameters and data collection can be controlled, genetic variability will always be a concern difficult to eliminate unless studies in specific population groups are undertaken.

One of the main objectives of preoperative cardiac evaluation should be the identification of patients with high risk coronary anatomy, amenable to coronary revascularization, by the utilization of appropriate noninvasive or invasive cardiac evaluation. Once identified the next question that needs to be answered is "what the best revascularization strategy would be, CABG or PCI?" In a core review of preoperative coronary revascularization in patients undergoing vascular surgery Kertai[46] has critically analyzed recent evidence on this subject. Long term outcomes appear to be better in patients undergoing coronary artery bypass grafting (CABG) when compared to percutaneous coronary intervention (PCI), but incomplete revascularization after PCI, impact of stent related complications and progressive occlusive coronary disease should be considered while evaluating the disadvantages of PCI over CABG.[47]

Soon after undergoing PCI with or without intracoronary stenting, a small but significant fraction of patients present for NCS. The heightened thrombogenic potential of newly implanted stents and prothrombotic state induced by the surgical stress; increases the risk of in stent thrombosis.[19,48] Premature discontinuation of antiplatelet therapy in patients with bare metal stents (BMS) or drug eluting stent (DES) is associated with a high rate of stent thrombosis and perioperative mortality.[49–53] In 2007 the AHA/ACC/Society for Cardiovascular Angiography and Interventions (SCAI)/American College of Surgeons (ACS) issued a scientific advisory recommending continuation of dual antiplatelet therapy for a minimum of 4–6 weeks in patients with BMS and 12 months in patients with DES.[54] Similar recommendations were published in the 2007 ACC/AHA guidelines on perioperative cardiovascular evaluation and care for NCS[16] and by the ASA in 2009.[55] Elective surgical procedures that carry a potential for increased perioperative bleeding should be postponed until a minimum course of dual antiplatelet therapy has been completed. In patients presenting for emergency NCS soon after coronary stent placement due consideration should be given to the risk of interrupting thienopyridine therapy compared with the risk of bleeding from surgical procedures, continuation of aspirin in the perioperative period and restarting thienopyridine as soon as possible.

7. Perioperative management: medical strategies

7.1. β-blockers

In the latter half of the 1990's two RCT enrolling a total of 312 patients' demonstrated decreased cardiovascular morbidity and mortality in patients treated with β-blockers.[3,56]. Over the next decade several investigators looked at the efficacy and safety of

β-blockers in the perioperative period. The ACC/AHA published recommendations for perioperative β-blockers in 2007 and recently impelled by the Perioperative Ischemia Evaluation (POISE) trial ACCF/AHA released a focused update on perioperative β-blockers.[33,57] The POISE trial was a large randomized control trial of fixed dose β-blockers enrolling over 8000 patients. Any benefit of β-blockers was offset by increased risk of stroke and mortality in the treatment group. Currently, the only class 1 indication is the continuation of β-blockers in patients already receiving β- blockers. Although β- blockers are still recommended in patients with known ischemic heart disease or congestive heart disease (CHD) undergoing vascular surgery or those with more than 1 risk factor undergoing vascular or intermediate risk surgery further RCT's are warranted to better determine their role in these scenarios. The guidelines are uncertain about the use of β-blockers in patients with only 1 clinical risk factor undergoing vascular or intermediate risk surgery.[16] Based on this paucity of data many experts have urged careful interpretation of the current guidelines and have advised not to use perioperative β-blockade as a performance measure.[58,59] Wherever indicated β- blockers should be started days to weeks before surgery, titrated to a target heart rate in an attempt to avoid perioperative hypotension and bradycardia.[3,60]

7.2. Statins

Perioperative statin therapy has been shown to reduce the risk adverse perioperative cardiac, major vascular, cerebrovascular events, shorten length of hospital stay, have renal protective effects,[61] and improve overall long-term survival.[62,63] Through their non-lipid lowering pleiotropic effects, statins help prevent perioperative MI.[64] The ACC/AHA in their 2007 guidelines do recommend the continuation of stains in the perioperative period in patients already taking statins. Although more compelling evidence clarifying the stance of perioperative statin therapy is eagerly awaited, because of their low risk profile in the perioperative period[65] and the increased mortality associated with acute withdrawal of statin therapy,[66] it is prudent to consider the inclusion and maintenance of statin therapy in the perioperative period.

8. Conclusion and Future Directives

As the population continues to age identification of the "at risk" patient and prevention of perioperative ischemia during non cardiac surgery continues to be a challenge. The approach to this challenge has evolved from risk stratification based on cardiac testing to clinical risk stratification and from risk stratification to risk management through perioperative medical strategies. When the need for surgery is established it is essential to determine the patients' perioperative cardiovascular risk. One of the key elements in determining this risk is a thorough yet focused history and physical examination to identify active cardiac conditions and the patient's functional status. This information has to be integrated with the risk associated with the planned surgical procedure. The surgeon will more than often be the first one to obtain this information and is compelled to initiate appropriate management instead of subjecting all patients with limited functional capacity or those undergoing complex, high risk procedures to extensive cardiac workup and evaluation. This also allows more timely and effective management of limited health care resources.

Much progress has been made over the last decade and half regarding the management of patients presenting for NCS but many questions still remained unanswered. Recent data has cast doubt on the role of preoperative pharmacological interventions, in particular the role of β- blockers. Dosage should be titrated over weeks and not just days to achieve a target heart rate while avoiding hypotension and bradycardia. It is yet to be determined if one β antagonist is superior to another. In view of the current evidence statin therapy should be started as soon as possible and continued throughout the perioperative period. Physicians should be wary of the fact that sudden withdrawal of statin therapy can increase the risk of ACE's.

In patients whom preoperative revascularization is indicated, consensus on the timing and best strategy for revascularization is still awaited. In the surgical patient with recently implanted coronary stents, the risks and benefits of stopping dual antiplatelet therapy versus delaying the procedure have to be duly considered. A multidisciplinary approach should be taken from the beginning with close cooperation between the surgeon, cardiologist and anesthesiologist. Due to increased thrombogenicity, current guidelines recommend continuation of dual antiplatelet therapy for a minimum of 4–6 weeks and 12 months in patients with BMS and DES, respectively. Management of antiplatelet therapy after this "high risk" period for stent thrombosis is yet to be determined. As we learn more about these perioperative events it is essential for all members of the perioperative team to be aware of perioperative evaluation strategies with equal emphasis on what might be beneficial and what might be ineffective or even detrimental to patient care.

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