

Myocardial infarction in major noncardiac surgery: Epidemiology, pathophysiology and prevention

STEFANO LUCREZIOTTI¹, FRANCESCA CARLETTI¹, GIULIA SANTAGUIDA², CESARE FIORENTINI³

¹ Unità Operativa di Cardiologia, Azienda Ospedaliera S. Paolo, Polo Universitario, Milano - Italy

² Unità Coronarica, IRCCS Centro Cardiologico Monzino, Milano - Italy

³ Cattedra di Cardiologia, Università degli Studi di Milano, IRCCS Centro Cardiologico Monzino, Milano - Italy

ABSTRACT: The number of subjects undergoing major noncardiac surgery who are at risk for perioperative myocardial infarction (MI) is growing worldwide.

It has been estimated that 500,000 to 900,000 patients suffer major perioperative cardiovascular complications every year, with consequent heavy, long-term prognostic implications and costs.

It is well known that perioperative MIs don't share the same pathophysiology as nonsurgical MIs but the relative role of the different, potential triggers has not been completely clarified.

Many aspects of the perioperative management, including risk-stratification and prophylactic or postoperative interventions have also not been completely defined.

Throughout recent years many resources have been invested to clarify these aspects and experts have developed indices and algorithm-based strategies to better assess the cardiac risk and to guide the perioperative management.

The scope of the present review is to discuss the main aspects of perioperative MI in noncardiac surgery, with particular regard to epidemiology, pathophysiology, preoperative risk stratification, prophylaxis and therapy. (Heart International 2006; 2: 82-93)

KEY WORDS: Myocardial infarction, Noncardiac surgery, Cardiac risk

Throughout recent years the approach to candidates for noncardiac surgery has significantly evolved.

Due to the wide diffusion of less invasive surgical approaches and the improvement in anesthetic techniques and perioperative monitoring, indications to major noncardiac surgery have been extended to individuals prone to cardiac complications.

As a result, noncardiac operations may treat disease and improve quality of life even in such categories of patients, but at the expense of cardiac mortality and morbidity, prolonged hospitalizations, and consequent costs.

About half of the 100 million/year adults undergoing noncardiac surgery worldwide are old and it is likely that

the number of old patients undergoing noncardiac operations in the USA will double within the coming years (from 6 million to 12 million/year) (1, 2).

EPIDEMIOLOGY: AS A CORRECT DIAGNOSIS MAY INFLUENCE THE PRECISE ESTIMATION OF THE INCIDENCE OF CARDIAC EVENTS

It has been estimated that 500,000 to 900,000 patients suffer from fatal and nonfatal perioperative cardiovascular complications annually (2).

Excluding cardiac arrest which portends a risk of in-hospital mortality of 65% (3), the most threatening com-

plications are represented by the wide spectrum of acute coronary syndromes. Perioperative myocardial ischemia is significantly associated with a high risk of subsequent cardiovascular events (OR: 2.8; 95%CI: 1.6-4.9), while perioperative myocardial infarction (MI) is associated with an in-hospital mortality of 15%-25% (4-8).

Unfortunately, a large proportion of ischemic episodes go undetected during surgery and in the postoperative period.

Thus, myocardial ischemia occurs undiagnosed and physicians do not administer therapy and do not program secondary prevention in patients who have suffered from perioperative unstable angina or MI. The lack of an adequate management further raises the risk of subsequent cardiac events.

The correct estimation of the perioperative incidence of myocardial ischemic events, particularly MI, is hampered by the low accuracy of the traditional diagnostic criteria (i.e. typical symptoms, electrocardiographic (ECG) modifications, elevations in plasma levels of markers of myocardial injury) (9) during and after surgery.

It has been shown that:

- Patients rarely experience angina pectoris and other ischemic symptoms immediately after surgery, because of the persistence of somatic pain secondary to surgical trauma and the effect of anesthetic and analgesic drugs (4, 5, 7).
- ST-segment changes, either on continuous monitoring or on 12-lead ECG, have been shown to have a low sensitivity and specificity ($\approx 70\%$). Moreover, significant ST-segment changes may resolve before the time the 12-lead ECG is repeated (1, 10).

New Q-waves appear infrequently on 12-lead ECG because most perioperative MIs are non-transmural.

Moreover, some ECG analyses are influenced by Pace-Maker rhythm, left bundle branch block or chronic ST-segment changes.

- The perioperative measurements of the creatine-kinase (CK)'s cardiac-specific subunit (CK-MB) are prone to false-positive and false-negative results (11). Thus, physicians should consider a more specific and more sensitive cardiac marker in the diagnosis of MI after surgery.

A perioperative rise in plasma level of cardiac Troponin (cTn), has been demonstrated to be more effective

than traditional diagnostic methods, such as ECG, echocardiography, and CK-MB (12).

However, it should be specified that myocardial damage in the absence of either ischemic symptoms or diagnostic ECG, may be secondary to mechanisms other than ischemia (9).

The incidence of perioperative MI, when diagnosed by elevation in cTns (12,14-27), is higher than that reported in the pre-cTns studies ($<1\%$ in the general population and 15% in high-risk patients undergoing vascular surgery) (13). Moreover, the elevation in cTns has been demonstrated to predict short- and long-term prognosis in most studies (Tab. I) (12,14-27).

In the study by Higham et al, the correlation between cTns and future cardiac events was not statistically significant when authors considered cTnT, while cTnI maintained its one-year predictive power (23).

Also in the study by Filipovic et al, elevations in cTn didn't correlate with one-year cardiac mortality, but the analysis excluded those patients who died in the first 30 postoperative days (22). When the whole population was included in the analysis, the correlation resulted significant ($p < 0.0001$) (17).

Inter-study discrepancies may depend on the difference in cTns cut-off, enrolled population, type of surgery length of follow-up, and in the definition of cardiac end-points.

PATHOPHYSIOLOGY OF PERIOPERATIVE MI

Atherosclerosis is the common substrate of almost every MI, but the trigger is the formation of a luminal thrombus on a ruptured/fissured atherosclerotic plaque.

Acute coronary syndromes presenting with ST-segment elevation are determined by an occlusive luminal thrombus, while non ST-segment elevation acute coronary syndromes present a non-occlusive thrombus.

Vessel spasm, microvascular dysfunction, a rise in myocardial oxygen consumption may also play a role in acute coronary syndromes (28-30).

The pathophysiology of perioperative MI is more complex because during and after surgery, unlike the nonsurgical setting, many alterations in homeostasis may favor or initiate the ischemic cascade itself. This aspect may have important management implications.

In the perioperative period, metabolic factors sec-

TABLE I - PERIOPERATIVE ELEVATIONS IN CARDIAC TROPONIN I OR T: INCIDENCE AND PROGNOSTIC POWER

Study	Type of surgery	Pts n°	>cTn (%)	Association of >cTn with outcome	Outcome	F-U
Adams (12)	Vascular; spinal	108	8	NR	NR	NR
Jules-Elysee (27)	Orthopedic	85	6	NR	NR	NR
Rapp (24)	Vascular	20	15	NR	NR	NR
Higham (23)	Vascular; orthopedic	157	10	OR: 4.2 (95%CI: 1.2-14.9) with cTn I OR: 2.4 (95%CI: 0.7-8.6) with cTn T	Cardiac death; MI; unstable angina; arrhythmias; heart failure	1 year
Lee (14)	Vascular; orthopedic; thoracic; abdominal; other operations	1175	17	RR: 9.1	IM; acute pulmonary edema; VF; cardiac arrest; heart block	In-hospital period
Oscarsson (16)	General; orthopedic; vascular; gynecologic; urologic	564	9.7	HR: 14.9 (95%CI: 3.7-60.3)	Death	1 year
Filipovic (17)	Vascular; abdominal; orthopedic; thoracic; other operations	173	16	OR: 9.8 (95%CI: 3-32)	Death	1 year
Kim (18)	Vascular	229	12	OR: 5.9 (95%CI: 1.6-22.4)	Death	6 months
Landesberg (20)	Vascular	447	24	OR: 2.2 (95%CI: 1.4-3.4)	Death	32 months
Le Manach (21)	Vascular	1136	14	OR: 8.1 (95%CI: 2.9-22.8) with cTnI>1.5 ng/mL OR: 3.9 (95%CI: 1.8-8.4) with cTnI<1.5 ng/mL	Death	In-hospital period
Bursi (26)	Vascular	391	22	HR: 5.5 (95%CI: 3.2-9.4) HR: 4.7 (95%CI: 2.9-7.7)	Death; MI	30 days 18 months
Vikenes (25)	Thoracic	24	0	NR	NR	NR
Studies which excluded patients with early postoperative events						
Lopez-Jimenez (15)	Vascular; orthopedic; thoracic; abdominal; other operations	772	12	RR: 5.4 (95%CI: 2.2-13)	Death; MI; angina pectoris requiring hospital admission	6 months
Kertai (19)	Vascular	393	14	HR: 1.9 (95%CI: 1.1-3.1)	Death	4.3 years
Filipovic (22)	Vascular; abdominal; orthopedic; thoracic; other operations	167	NR	Association statistically not significant if patients who have died in the first 30 postoperative days were excluded from the reference population of the original study (17)	Death	2 years
Bursi (26)	Vascular	373	NR	HR: 5.5 (95%CI: 3.2-9.4)	Death; MI	18 months

Abbreviations: >cTn: elevated cardiac troponin; F-U: follow-up; MI: myocardial infarction; NR: not reported; OR: odds ratio; Pts: patients; RR: relative risk; HR: hazard ratio; VF: ventricular fibrillation

ondary to surgical trauma, anesthesia withdrawal, pain, shift in volume, hypothermia, and fasting may activate coagulation, platelet activation, inflammation, oxygen consumption, catecholamines and cortisol secretion (31-34).

Conflicting evidence emerges from angiographic and autopsy studies which have been conducted to better

clarify the pathophysiology of perioperative MI (35-37): the non-homogeneous characteristics of the populations enrolled and the lack of standardization of cardiac events may in part explain those differences.

The relative role of fixed coronary artery stenoses and plaque thrombosis in the pathophysiology of perioperative MIs is not clear.

TABLE II - FACTORS WHICH MAY DETERMINE PERIOPERATIVE MYOCARDIAL ISCHEMIA AND MYOCARDIAL INFARCTION

Reduction of myocardial oxygen supply	Increase of myocardial oxygen's requirement
<p><u>Ipxemia</u> changes in pulmonary function weaning from the ventilator</p>	<p><u>Increased myocardial wall stress</u> hypervolemia rise in blood pressure rise in end-diastolic left-ventricular pressure</p>
<p><u>Reduced blood pressure</u> left ventricular dysfunction hypovolemia systemic vasodilatation</p>	<p><u>Arrhythmias</u> elevation in plasma catecholamines withdrawal of β-blockers hypotension postoperative pain</p>
<p><u>Coronary vasospasm</u> <u>Endoluminal thrombosis</u> enhanced platelet aggregation hypercoagulability impaired fibrinolysis</p>	<p><u>Changes in body temperature</u></p>

TABLE III - ESTIMATION OF PERIOPERATIVE CARDIAC RISK ACCORDING TO THE "REVISED CARDIAC RISK INDEX" (38)

Risk factors n°	Major cardiac complications *
0	0.4 %
1	1.1 %
2	4.6 %
≥ 3	9.7 %

Risk factors: high-risk surgery (abdominal aortic aneurysm, thoracic, abdominal); ischemic heart disease; heart failure; cerebrovascular disease; insulin-treated diabetes; creatinine > 177 μ mol/L).

* myocardial infarction, pulmonary edema, primary cardiac arrest, complete heart block

It is likely that both the rapid increase in oxygen demand in the presence of severe coronary stenoses and the sudden decrease in oxygen delivery secondary to acute coronary thrombosis may determine perioperative myocardial ischemia (Tab. II).

HOW TO IDENTIFY HIGH-RISK PATIENTS

Given the clinical relevance of cardiac complications in the setting of noncardiac surgery, different approaches for preoperative risk stratification have been proposed which can be divided into clinical indices and consensus-derived guidelines.

Clinical indices

Clinical indices are derived from statistical analysis of a data-base of thousands of patients and assign a specific score according to the weight given to each cardiac risk factor (8, 38-42). The best validated among those indices is the "Revised Cardiac Risk Index" by Lee et al (Tab. III) (38).

The advantages of risk indices are the simplicity and the precision in risk stratification, although the main limit is the lack of indications for perioperative management, particularly supplemental preoperative testing and prophylactic therapy.

Guidelines

The American College of Cardiology (ACC)/American Heart Association (AHA) and American College of Physicians (ACP) guidelines were developed in order to guide physicians in perioperative management. They suggest consensus-derived algorithms which allow preoperative cardiac risk assessment, patient's information and clinical decision making about perioperative diagnostic testing, monitoring, and therapy (1, 43, 44).

ACP guidelines are based on Detsky's "Modified Cardiac Risk Index" (42), while ACC/AHA guidelines derive from the interpretation of data from various studies by a specific Task Force.

The overriding theme of the ACC/AHA guidelines is

that intervention is rarely required to lower the perioperative cardiac risk unless such intervention is indicated irrespective of the surgical context (1).

The nature of the surgical disease must be also considered. In case of urgent surgery, preoperative evaluation should be rapid, so as not to delay the operation, while a more precise evaluation can be conducted soon after surgery.

Sometimes an extensive workup may add significant delays to surgery without adding any further advantage and with possible, heavy consequences in certain groups of patients, for example those affected by cancer and waiting for life-saving operations.

Extensive and redundant preoperative cardiac evaluation can also result in morbidity, higher costs and refusal to undergo surgery (45).

The stepwise approach is based on the definition of the patient's clinical status and the surgery's cardiac risk (Tabs. IV and V). Supplemental testing should be performed only if it is likely to influence the patient's treatment and outcome (1).

Unlike ACP guidelines, which have never been validated prospectively, some studies have demonstrated that application of the ACC/AHA guidelines in daily clinical practice may help physicians in risk stratification, may reduce hospital length of stay and costs, and may improve prognosis (26, 46-50).

However, Bursi et al have recently demonstrated that despite a rigorous implementation of ACC/AHA algorithms, patients undergoing major vascular surgery still remain at high risk of perioperative cardiac events (26).

In particular, among clinically stable patients who had undergone coronary revascularization in the last 5 years, about 50% had a postoperative elevation in cTnl and the event-free survival at 30 days was as high as 72% (26).

According to the recommendations of the ACC/AHA guidelines, those patients were scheduled for surgery without any supplemental tests, but this strategy may have underestimated the real cardiovascular risk (1, 26, 51).

Some authors suggest that the stepwise approach of the ACC/AHA guidelines, based on a detailed clinical evaluation with selective use of supplemental testing may be of limited use in some circumstances, for a variety of reasons (51).

First of all, ACC/AHA guidelines are founded on ob-

servational data obtained several years ago, when perioperative care was different and cTns analysis was not available. As a consequence, the real incidence of perioperative MIs and the efficacy of preventive strategy may have been underestimated.

Moreover, the current ACC/AHA guidelines state that in the presence of favorable stress test within the last two years and stable symptoms, patients can undergo surgery: this time span is probably too long.

A procedure of coronary revascularization in the previous 5 years doesn't warrant a favorable outcome. This may be due to an incomplete/failed revascularization or a progression of atherosclerotic disease in grafts or in native vessels.

Silent ischemia and limited functional capacity may mask high-risk features if the clinical evaluation is limited to history and physical examination. Therefore, non-invasive screening may unmask high-risk situations in some subgroups of patients and in some types of surgery, independent of clinical history.

Noninvasive testing for myocardial ischemia

In a large number of surgical patients, noninvasive testing plays an important role in defining the risk profile.

In general, both exercise and pharmacological stress testing have a high negative predictive power (90-100%) and a non-uniform but generally low positive predictive power (6-67%) (2).

Results from a meta-analysis that compared the prognostic accuracy of 6 noninvasive tests suggest a superiority of echo-dobutamine in predicting postoperative cardiac events (cardiac death and nonfatal MI) (52).

These data call for cautious interpretation because of the limitations which emerge from many studies: weak methods, low event-rate, heterogeneity across the results for individual test, dichotomized (positive or negative) compared to semiquantitative (extent of reversibility of myocardial defect) results, the nearly exclusive application to vascular surgery patients which precludes broad generalizations to other surgical settings.

Besides the ischemic threshold, noninvasive tests may investigate different parameters: an ergometric test can determine the functional capacity, while echo-dobutamine may assess hemodynamic parameters and

valvular function (1). Moreover, pharmacological testing may be the sole option in patients with severe exercise restrictions.

Moreover, in the absence of definitive data about the efficacy of the different noninvasive testing, the consultant should consider that the availability and the local expertise in diagnosing coronary artery disease is more important than the particular type of test (1).

Coronary angiography

Coronary angiography should be prescribed on the basis of the results of noninvasive testing, while for certain categories of patients with baseline high cardiac risk, diagnostic cardiac catheterization may be performed without any previous noninvasive testing.

Recommendations for preoperative coronary angiography don't differ from those for the nonsurgical setting published by ACC/AHA (1, 53).

PREVENTION OF PERIOPERATIVE MI

Different prophylactic strategies have been tested in order to reduce the incidence of ischemic events after noncardiac surgery.

The cornerstones of preventive strategy are adrenergic modulation, atherosclerotic plaque stabilization, and coronary artery revascularization.

Given the complex and multifactorial pathophysiology of perioperative MI, a relative risk reduction of more than 35% by a single intervention is unlikely (1).

β -blockers

β -blockers enhance coronary flow, reduce myocardial oxygen consumption by modulation of systemic blood pressure, heart rate and contractility, and have anti-arrhythmic effects.

Although earlier studies have documented a beneficial effect in patients treated with β -blockers in the perioperative period (54,55), results from recent meta-analysis are controversial (56-58).

Such a discrepancy may probably depend on various reasons: the inadequate statistical power and the lack of randomization in several studies; the lack of predefined target heart rate (usually, about 60 beats/min); the

TABLE IV - CLINICAL PREDICTORS OF INCREASED PERIOPERATIVE CARDIOVASCULAR RISK (MYOCARDIAL INFARCTION, HEART FAILURE, DEATH) (1)

Major

Acute coronary syndromes

- acute (< 7 days) or recent (7-30 gg) myocardial infarction with evidence of important ischemic risk by clinical symptoms or non-invasive studies
 - unstable or severe angina (Canadian class III/IV)
- Decompensated heart failure
Significant arrhythmias
- high-grade atrioventricular block
 - symptomatic ventricular arrhythmias in the presence of underlying heart disease
 - supraventricular arrhythmias with uncontrolled heart rate
- Severe valvular disease

Intermediate

Mild angina (Canadian class I/II)
Previous myocardial infarction
Compensated or previous heart failure
Diabetes mellitus (particularly insulin-dependent)
Renal insufficiency

Minor

Advanced age
Abnormal electrocardiogram (left bundle-branch block, left ventricular hypertrophy, ST-T abnormalities)
Rhythm other than sinus
Reduced functional capacity
History of stroke
Uncontrolled hypertension

paucity of data about patients at low to intermediate cardiac risk; the lack of comparison studies between different molecules and different routes of administration (intravenous vs oral agents).

A recent, retrospective, and very large observational study compared the in-hospital outcome of patients receiving β -blocker therapy and those not treated with β -blockers (59). All patients underwent major noncardiac surgery and were matched according to the Revised Cardiac Risk Index (38).

Surprisingly, perioperative β -blockade wasn't associated with an overall reduced mortality, although a step gradient in treatment effect was observed in relation to the Revised Cardiac Risk Index score (59). β -blocker use was associated with increased mortality among low-risk patients, was neutral among intermediate-risk patients and had a beneficial effect in high-risk patients (59).

According to the results of the few studies and the

TABLE V - CARDIAC RISK STRATIFICATION (COMBINED INCIDENCE OF CARDIAC DEATH OR NONFATAL MYOCARDIAL INFARCTION) FOR NONCARDIAC OPERATIONS (1)

High (cardiac risk > 5%)

Emergent major operations, particularly in the elderly
Aortic and other major vascular surgery
Peripheral vascular surgery
Anticipated prolonged surgical procedures associated with large fluid shifts and/or blood loss

Intermediate (cardiac risk < 5%)

Carotid endarterectomy
Head and neck surgery
Intraperitoneal and intrathoracic surgery
Orthopedic surgery
Prostate surgery

Low (cardiac risk < 1%)

Endoscopic and superficial procedures
Cataract surgery
Breast surgery

opinions of some authors, the use of β -blockers should be at present limited to high-risk patients undergoing major noncardiac surgery.

No data are available for short-stay procedures and for minor operations.

Until the results from two ongoing randomized trials (POISE, DECREASE IV) on the efficacy of β -blockers are available (60,61), we suggest that physicians in charge and consultants refer to the recently updated ACC/AHA guidelines about perioperative β -blocker therapy (62).

α 2-adrenergic agonists

α 2-adrenergic agonists may reduce perioperative cardiac events because they suppress the release of catecholamines.

A meta-analysis, which included 12 randomized controlled trials, demonstrated a beneficial effect of α 2-adrenergic agonists in reducing mortality (RR: 0.47; 95%CI: 0.25-0.90) and myocardial infarction (RR: 0.66; 95%CI: 0.46-0.94) in patients undergoing vascular surgery (63).

This trend was confirmed by another meta-analysis (57) and by one subsequent randomized study which compared clonidine with placebo in 190 patients undergoing non-cardiac surgery, with or at risk for atherosclerotic disease (64). In the latter study, clonidine was sig-

nificantly associated with a reduced incidence of ischemic events (14% vs 31%; $p = 0.01$) and reduced two-year mortality (15% vs 29%; RR: 0.43; 95% CI 0.21-0.89; $p = 0.035$) (64).

Although the results of randomized trials and meta-analysis on α 2-adrenergic agonists are encouraging, they should be confirmed by large, randomized and well powered trials.

Other anti-ischemic agents

At the moment, no definitive data support the administration of calcium-channel blockers or nitrates (57), although a meta-analysis has demonstrated a benefit of calcium-channel blockers, particularly diltiazem, in reducing the risk of supraventricular arrhythmias, ischemia or the combined end-points of death, myocardial infarction, supraventricular arrhythmias, heart failure (65).

Statins

Statin therapy may reduce perioperative cardiac events through stabilization of coronary atherosclerotic plaques and anti-thrombotic and anti-inflammatory effects. Their efficacy has been demonstrated in several primary and secondary prevention studies conducted in nonoperative setting.

Data about the efficacy of perioperative statin therapy derive from some observational studies (66-68) and one small randomized trial (69): they showed a significant reduction of cardiac mortality and morbidity in the statin-treated group.

However, in the absence of evidence of a broad benefit of perioperative statins, they should be given only in those patients already assuming them as home-therapy or as new prescription in patients who meet the classical indications for the nonsurgical setting (70, 71).

Coronary revascularization

Flow-limiting coronary stenoses play an important role in the pathogenesis of perioperative MI.

Therefore, surgical or percutaneous coronary revascularization may help in preventing ischemic complications. However, perioperative MIs frequently develop at the site of non-severe stenoses.

The available evidence on the overall benefit of coro-

nary revascularization (particularly coronary bypass surgery) derive from few retrospective studies and from one randomized clinical trial which compared coronary revascularization with medical therapy in stable patients with a coronary anatomy suitable for revascularization, undergoing major vascular surgery (72-74).

Taken together, these results suggest that prophylactic coronary revascularization is of little or no benefit before noncardiac surgery.

It must also be considered that specific data relative to patients with very high-risk conditions (unstable angina, severely depressed left ventricular function, aortic stenosis...) are lacking because those categories of patients have been excluded from any analysis or randomization.

Moreover, when planning preoperative coronary revascularization, the relative benefit should be weighed against the inevitable risk and the delay related to the procedure itself (either surgical or percutaneous) (75, 76).

The time-delay attributable to coronary revascularization may be unacceptable in certain subgroups of patients, such as those waiting for urgent surgery (1, 70).

Noncardiac surgery may be performed as soon as two weeks after balloon angioplasty, about one month after coronary artery bypass surgery, and at least six weeks after positioning of a bare metal stent (70, 77).

Preoperative implantation of a drug-eluting stent is not indicated because the need for long-term, double anti-platelet therapy contrasts with the surgery-specific hemorrhagic risk.

In conclusion, the indication for surgical or percutaneous coronary revascularization of the ACC/AHA practice guidelines on perioperative cardiovascular evaluation for noncardiac surgery are essentially identical to those for the nonoperative setting (78, 79). As a consequence, the decision to revascularize just to lower the cardiac risk of noncardiac surgery is appropriate only in a small subset of high-risk patients (1).

POSTOPERATIVE MONITORING AND MANAGEMENT

Given the silent and subtle nature of perioperative myocardial ischemia, postoperative monitoring is needed in order to promptly identify acute ischemic events.

Unresolved issues in monitoring strategy are which diagnostic test to perform, for how long, and in which patients.

ACC/AHA recommendations (1) for postoperative monitoring include the execution of 12-lead ECGs soon after surgery and on postoperative days 1 and 2 in patients with intermediate/major cardiac risk predictors who have undergone intermediate to high-risk operations.

On postoperative days 1 and 4 (or at hospital discharge, whichever comes first) plasma levels of cTns should be measured (1).

Continuous ST-segment monitoring in patients affected by ischemic heart disease and/or undergoing high-risk surgery may enhance sensitivity to detect perioperative myocardial ischemia (1). However, in certain subgroups of patients at low cardiac risk, the specificity of ST-segment changes is questionable.

No randomized clinical trial has specifically evaluated the optimal medical strategy in patients with perioperative MI. Therefore, it seems reasonable to correct eventual precipitating factors (for example, hypoxia) and to administer those therapies which have been demonstrated to be effective in nonoperative MI (ACE-inhibitors, statins, β -blockers).

Given the high bleeding risk at the surgical site, great caution should be used when considering aggressive anticoagulant and antiplatelet therapy. In the absence of definitive data from randomized clinical trials, the risk of bleeding must be weighed against the risk of suboptimal therapy.

Thrombolytic therapy has been demonstrated to reduce mortality in ST-segment elevation MI unrelated to surgery, but recent noncardiac surgery is a strong contraindication to thrombolytic therapy.

When angiography and revascularization may be rapidly performed, reperfusion therapy with primary coronary angioplasty may be the first choice in ST-segment elevation MI (1).

Early coronary angiography with eventual coronary revascularization is also a valid option in patients with non ST-elevation acute coronary syndromes with high-risk features and who are able to take antiplatelet and anticoagulant therapy (1).

Long-term management and secondary prevention should include evaluation for left ventricular function, residual ischemia and electrical instability, strict control

of traditional risk factors, adequate medical therapy and eventual coronary revascularization.

CONCLUSIONS

Acute MI complicates a relevant number of noncardiac surgical procedures and is associated with an unfavorable short- and long-term prognosis.

Implementation of risk indices and algorithm-based guidelines may result in improved outcomes and optimization of resources.

There is also evidence that perioperative medical therapies may prevent cardiac events in selected patients, while no data support the protective role of preoperative coronary revascularization in clinically stable patients.

However, given the lack of well-powered randomized clinical trials, many aspects are still not defined.

Therefore, future research is needed to investigate the complex pathophysiology of perioperative myocardial ischemia and to determine:

- the correct strategy for preoperative risk-stratification and the use of noninvasive testing to identify patients prone to cardiac complications;
- the role of prophylactic medical therapy and coronary

revascularization in relation to the characteristics of patient and surgery;

- the best monitoring strategy to promptly detect MIs and to administer an adequate therapy;
- the role of the different classes of drugs, whose benefit has been demonstrated in nonoperative MIs, in the early postoperative period;
- the optimal approach to long-term postoperative management and secondary prevention.

Abbreviations:

Myocardial infarction: MI
Electrocardiogram: ECG
Creatine-kinase: CK
Cardiac Troponin: cTn
American College of Cardiology: ACC
American Heart Association: AHA
American College of Physicians: ACP

Address for correspondence:

Dr. Stefano Lucreziotti
U.O. Cardiologia
Azienda Ospedaliera S. Paolo
Via di Rudini, 8
20142 Milano
lucre.sp@libero.it

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