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Risk Evaluation of Perioperative Acute Coronary Syndromes and Other Cardiovascular Complications During Emergency High Risky Noncardiac Surgery

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1. Introduction

The cardiac risk (CR) in noncardiac surgery represents the probability of acute cardiovascular conditions appearance, assessed as perioperative complications.

The most frequent perioperative complications are the acute manifestations of coronary or noncoronary ischemia; acute or exacerbated chronic heart failure (CHF); acute rhythm and conductive disorders; acute cardiac inflammatory processes; increased arterial blood pressure or hypertensive crisis; cardiogenic shock and sudden cardiac death. These conditions are either early signs, or represent a manifestation of progress or decompensation of present cardiac diseases. Specific indication may be found in their origin, if it is explicitly or implicitly associated with the present surgical disease or with a completed surgical intervention, giving weight to the special features of the perioperative period [1].

The major surgical interventions, e.g. in the thoracic cavity and the upper abdominal cavity, as well as the neurosurgical and the major orthopedic operations, are related to increased CR. Previous myocardial infarction, unstable stenocardia and decompressed chronic cardiac insufficiency are powerful predictors for the emergence of acute perioperative cardiovascular complications (CVC) and mortality. The patients with such specified pathologies need additional evaluation before major surgical intervention.

The cardiac postoperative morbidity and mortality are closely related to the basic surgical disease and the corresponding intervention. Many scientific publications report on the high number of complications, accompanying the major surgical abdominal and intrathoracic interventions, emergency surgical interventions, surgery of malignant neoplasm, major peripheral vascular manipulations [1, 2, 3].

The CR evaluation will not change the course and the result of the intervention in emergency conditions, e.g. rupture of abdominal aortic aneurism, heavy trauma, perforations etc., but may have influence upon the care during the early postoperative period. In emergency but noncritical states (e.g. biliary obstruction), the evaluation may contribute to risk reduction without influence upon the decision about the necessity of the intervention. In some cases, the CR evaluation may influence the surgical intervention planning and the choice of less invasive intervention, e.g. the preference for peripheral arterial angioplasty before infrainguinal bypass, even though the long-term result of the surgery may be altered. In other cases, the CR assessment must support the decision for a given intervention, e.g. for removal of small aneurisms from asymptomatic patients with carotidal stenosis, when the compromise is between the expected life duration and the risk of the intervention.

Below are presented some practices for cardiac risk assessment in emergency noncardiac surgery, including high risk one. Part of them are discussed on the basis of own studies over the applicability of models for CP evaluation in groups of subjects, differentiated upon the urgency, the severity of the surgical disease and intervention, with or without cardiovascular and other concomitant nonsurgical diseases [4, 5, 6, 7].

2. Short review of preoperative cardiac risk assessment schemes in major noncardiac surgery

2.1 General preoperative clinical assessment

The tentative general assessment of the cardiac perioperative risk may be completed on the basis of factors with known contribution.

2.1.1 Risk in patients with ischemic heart disease (IHD)

The perioperative mortality reaches 9.6% in case of IHD, otherwise it is just about 2.8% [8, 9]. Besides the hemodynamically induced complication, other manifestations like thrombosis, coronary spasm, serious rhythm disorder, spontaneous psychogenic nocturnal or preoperative complications, are also possible. The patients with IHD, subjected to major noncardiac surgery, can be divided into 3 groups:

a. Patients with angina pectoris (AP).

The preoperative assessment of patients with angina, who will be subjected to major noncardiac surgery (MNCS), has to clarify the following questions: stable or unstable angina; functional class (FC); is the medicamentous treatment adequate; necessity of specific diagnostic tests.

Except for the surgery of abdominal aortic aneurism, the patients with I-II FC stable stenocardia have the resources to bear the stress of MNCS, while this intervention presents serious threats to patients with III-IV FC.

The patients with I-II FC stable AP are with increased risk of cardiac complications after MNCS [10] (about 10 times higher relative risk compared to patients without IHD). However, this tenfold increase corresponds to a relatively low risk of myocardial infarction (MI), approximately of 4%, and of cardiac death, about 1-2% [8, 9]. FC is decisive in predicting the risk level of patients with stenocardia. Those of them that succeed to reach 85% of the maximum cardiac frequency (even with appearance of ST-depression) have no complications during surgery [11, 12]. Just the opposite, *the presence of ST-depression and the bad tolerance of physical stress identify the high-risk patients*.

b. Patients with MI

The number of perioperative reinfarctions decreases with the improvement of the anesthesiologic methods from 30% to 6% after survived MI during the last 3 months, and from 15% to 2% after preceding MI during the preoperative 3-6 months.

The MI manifestation during intra- or early postoperative periods is often preceded by prolonged or recidivistic ischemia. There are two important mechanisms in the context of the perioperative MI:

1. Chronic imbalance between the need and the providing of blood stream that is clinically manifested as stable IHD (due to coronary arteries' stenosis, limiting the blood stream);
2. Rupture of coronary plaque with clinical manifestation of acute coronary syndrome (ACS).

c. Patients with high risk of asymptomatic IHD.

Such are the patients with diabetes mellitus (DM) or peripheral vascular disease, when either the ECG stress-test cannot be carried out, or the results obtained are not reliable.

2.1.2 Risk in patients with heart failure (HF)

The congestive heart failure (CHF) increases the risk of postoperative complications. Here, it is important to clarify as far as possible, the HF etiology. For example, HF due to hypertension runs a different risk, compared to HF due to IHD [13, 14].

Many general anesthetics cause direct myocardial depression. Very often, a large quantity of liquids is infused during the perioperative period in MNCS and overburden the patients with left ventricular dysfunction or HF. The risk of perioperative cardiogenic pulmonary edema among subjects aged over 40 years, who have been subjected to MNCS, vary from about 2%, if CHF anamnesis is absent, through about 6% for patients with preceding HF, which is not present during physical and X-ray examinations, and reaches up to 16% with persisting physical and X-ray data about pulmonary stagnation [8].

Large abdominal or thoracic surgery, which is followed by CHF that has not been identified before the intervention, is usually associated with elderly patients with ECG abnormalities or other cardiac symptoms [15].

The presence of CHF represents another risk factor for perioperative MI [16, 17, 18, 19].

2.1.3 Risk in patients with heart valvular disease

The patients with heart valvular disease, who have been subjected to MNCS, are subject to an increased risk of cardiac complications, mostly because of their susceptibility for development of CHF, hypo- and hypervolemia and cardiac arrhythmias in the perioperative period [13]. About 20% of the patients with severe heart disease (II or higher FC) either evolve new or complicate the present cardiac decompensation during the MNCS [15]. It is accepted, that the subjects with aortic stenosis are the higher risk patients among these with valvular cardiac disease, as they bear with difficulty hypo- and hypervolemia [20].

The patients with combined rheumatic mitral and aortic heart disease represent a considerable group. Their risk during noncardiac intervention is high, because of their limited resources and capabilities to support changes in pre- and afterloads.

2.1.4 Risk in patients with cardiac arrhythmias

The arrhythmias, either atrial or ventricular, are often related to IHD or CHF and specify increased risk during MNCS. Although both arrhythmias are pointed out as independent risk factors in the perioperative period [20, 21, 22], they probably have significance only as a manifestation of serious heart disease, which itself increases the risk of CVC. In similar cases, the arrhythmias correlate as a marker of cardiac suffering with ischemic and HF complications and do not contribute additional risk during noncardiac surgery. According to Detsky *et al* and Goldman *et al,* the prognosis in patients with arrhythmias, but without supporting cardiac pathology, is usually good and the risk of intervention is very unlikely to be increased, although the same authors determine the atrial fibrillation as an independent risk factor [20, 23].

High risk of the supraventricular tachiarrhythmias progress subsists among elderly patients subjected to pulmonary surgery, patients with subcrucial valvular stenosis and patients with primary anamnesis of similar tachyarrhythmias [24].
Patients with anomalies in the conductive system as AV block, fascicular or bundle branch block often have cardiac diseases. Many anesthetics suppress the cardiac contractility and/or provoke peripheral vasodilatation. The anesthesia may give rise to further depression of the automatism and, consequently, of the ventricular frequency in patients with heart block. The complication of biphascicular block after MI may progress to a third degree AV block, often accompanied by serious hemodynamic disorders [24, 25].
Patients with bundle branch blocks are not subject to increased risk of third degree AV block progress in the perioperative period, although they may acquire it in a long-term context. The presence of bundle branch block does not represent an independent predictor of heavy postoperative cardiac complications if there is no evidence of other severe disease [15, 20].
According to the recommendations of the ACC/AHA the arrhythmias with high risk are as followed [2]:

- high-degree AV block;
- symptomatic ventricular arrhythmias, combined with presence of cardiovascular diseases (CVD);
- supraventricular arrhythmias at high and out-off-control heart rate (HR).

2.1.5 Arterial hypertension

Despite contemporary achievements in arterial hypertension (AH) diagnosis and monitoring, a large percent of the subjects with AH remain without diagnosis or have been inadequately treated. The patient arterial blood pressure (BP) may increase in a hospital environment as a result of a stress. Prys Roberts *et al*, report higher perioperative BP instability among subjects with high preoperative BP [26]. According to Goldman and Caldera [8], the mean intraoperative BP, the necessity of infusion and adrenergic agents for supporting the pressure during the intervention, as well as the progress of considerable postoperative hypertension, practically are not influenced by the fact whether the hypertension was not treated, inadequately treated or well monitored.
Several communications [15, 20, 23, 27] point out that patients with mild through moderate hypertension can be subjected to anesthesia and intervention without high risk of CVC [8]. Other studies cite as evidence that patients with AH are subjected to higher risks of cardiac complications during, or immediately after, MNCS, compared to normotensive subjects. The reasons of the increased risk are due to IHD, left ventricular dysfunction, renal failure, or other disorders commonly encountered among patients with AH [26]. The subjects with AH have increased IHD and CHF risk and tendency towards most frequent manifestations of silent myocardial ischemia during surgery [28].

2.1.6 Cardiomyopathies

The hypertrophic cardiomyopathy raises some specific problems. The reduction of the blood volume, the decreased vascular system resistance and the increased venous volume can reduce the left ventricular volume and increase the tendency towards obstruction of the left ventricular output tract. In addition, the decreased pressure of the ventricular filling may lead to considerable reduction of stroke volume, due to reduced compliance of the hypertrophic ventricle.

2.1.7 Peripheral vascular diseases

They add certain perioperative risks, since they are often associated with accelerated atherosclerosis and IHD [2].

2.1.8 Other risk factors

2.1.8.1 Age

Advanced age is an independent risk factor for perioperative complications [2, 17, 18, 25], not only because of the increased probability of coronary disease, but also because of the senescent effect on the myocardium – decrease of the myocytes number. The mortality caused by acute MI considerably increases with the age. The perioperative MI have higher mortality among the elderly patients [29].

2.1.8.2 Sex

The women have lower cardiac risk except for present early climax or DM [2]. They have lower frequency of IHD, and coronary disease is observed 10 years later, compared to men. In the case of early climax and DM, the risk is equal to that of men at the same age. Mortality, due to acute MI, is greater among women than men, and this difference is even more evident with advancement of age and presence of DM.

2.1.8.3 Diabetes mellitus

DM increases the probability of IHD appearance, but the myocardial ischemia is often silent. DM frequently is considered as a risk factor for cardiac complications in the MNCS perioperative period [17, 30, 31].

2.1.8.4 The chronic pulmopathies

The chronic pulmopathies present a high perioperative risk [32], which is dependent on the severity of the pulmonary disease and the intervention duration.

2.1.9 Type of surgical intervention

The surgical risk represents a complex assessment, which includes the severity of the basic surgical disease, the treatment method and the patient condition. In addition to the present data about cardiovascular pathology that influences the prognosis, other basic surgical factors can provoke exacerbation of present chronic cardiac diseases or appearance of perioperative CVC. Their number is twice higher with infectious inflammation (sepsis) or neoplastic disease [33].

The basic surgical disease is a leading factor for localization, size and duration of the intervention, as well as for the conditions necessary for its performance [34]. The surgery of the thoracic and abdominal aorta contributes the highest risk among the noncardiac interventions, because of the accompanying problems with the water balance, bleeding and oxygenation. The abdominal interventions take the second place in frequency of concomitant CVC, following the thoracic ones [35]. The interventions of carotidal and peripheral vessels are also associated with increased risk of cardiac complications. It is known, that up to 50% of patients undergoing interventions of the peripheral arteries suffer MI in the next 2-3 years [36].

2.1.9.1 Surgical factors

Surgical factors, which influence the cardiac risk, are associated with the emergency, the complication, the type and the duration of the intervention, as well as with the change of the body temperature, the loss of blood and the body liquids exchange. The intervention emergency represents an issue of special importance. The survival rate increases twofold with preoperative intensive cardiac care that is related to eventual delayed emergency intervention, whenever that is possible [37]. Each surgery provokes a stress reaction, due to tissue damages and is mediated by neuroendocrine factors that may lead to tachycardia and hypertension. The perioperative stress reaction includes effusion of catecholamine, provoked by the hemodynamic stress, vasospasm, reduced fibrinolitic activity, activated trombocytes and extracoagulation. Coronary plaque rupture leads to thromboses and subsequent vessel occlusion, which are important factors for the occurrence perioperative ACS. The MI among patients with significant IHD may be a result of a continuous imbalance between the available and the necessary myocardial blood steam (in cases of tachycardia and increased myocardial contractility). Studies on performed autopsies, demonstrate that half of the fatal MI have directly destroyed plaque fissure, rupture or plaque bleeding. Although the specific patient factors are more important for cardiac risk prediction than the surgical ones, the type of the surgical intervention cannot be ignored.

2.1.9.2 Type of the anesthesia

Recent studies indicate, that the operative period is more reliable than it was in the past, mostly because of the careful monitoring of hemodynamics and respiration during the anesthesia [20]. No data are available for determining some significant differences in the severity of the cardiac complications due to the different anesthesia techniques. However, the assessment of the type and the conditions of the anesthesia may have important implications for the cardiac risk prognosis.

2.2 Indices and scales for cardiac risk evaluation and their applicability on cardiac risk assessment in patients with emergency high risky noncardiac surgery

The preoperative assessment of cardiac risk during noncardiac surgery (specifically for emergency surgery) is based on quantitative indices and rated scales. They were proposed and introduced initially for assessment of the anesthesiology risk and consequently, for the cardiac one [20, 23, 38, 39].

The synthesis of methods for preoperative cardiac risk assessment began intensively at the end of the seventies, as a result of the communication by Goldman *et al* [17, 19, 20, 23, 40, 41, 42, 43, 44, 45, 46]. The methods and indices for the cardiac risk assessment can be characterized as:

- common for CR [20, 25, 27, 42];
- specifically related to the risk of ischemic complications – underestimated by Goldman *et al*, although it is the most dynamic and dangerous risk factor (RF) [17,19, 40, 41, 43, 44, 45, 46].

From another point of view, the methods and indices for cardiac risk assessment are:

- quantitative [20, 23, 27];
- qualitative [17, 19, 40, 41, 42, 43, 44, 45, 46, 47].

2.2.1 Quantitative (point) indices

The CR index in noncardiac surgeries that was introduced by Goldman et al [20] represents a point assessment and is still largely applied in practice. This index is derived over data of patients with MNCS, such as aortic, pleural, intraoperational and intrathoracic interventions. It includes 9 preoperative assessable indices with own quantitative contribution to the amount, which determines the perioperative CVC risk. The risk is distributed in 4 classes: I-st class (0 to 5 points) with live-threatening complications and cardiac death of 0.9%; II-nd class (6 to 12 points) with 7% rate of such complications; III-rd class (13 to 25 points) with 14% rate; IV-th class (26 and over points) with expected rate of live-threatening complications and cardiac death of 77%. The indicator "Poor general condition" includes the criteria: PO2 < 60; PCO2 > 50; K < 3; HCO3 < 20; BUN > 50; Creat > 3; elevated SGOT; chronic liver disease; bedridden.

Detsky *et al* [23] modified Goldman's index on the basis of clinical evaluation and monitoring of non-selected patients over 40 years old with MNCS. Within that index, the timing of the previous MI is divided into less or more than 6 mounts ago, while the influence of the stenocardia is specified according the adopted division as stable (with differentiated classes) and unstable; the anamnesis of the pulmonary edema is also included. It is accepted, that Goldman's index is equally informative as the extended index of Detsky *et al* [23], but the first does not include III and IV class stenocardia, while Detsky *et al* introduced such corrections. The atrial fibrillation is included as RF too. Subsequent studies establish its significance, whenever this cardiac disorder is currently manifested [53]. AH was also evaluated at a later stage, but from the heart defects, only aortic stenosis is included.

The pivotal points of Goldman's index are the presence of MI and HF. The index of Larsen *et al* [27] includes metabolic deviations in parallel with CVD. Here the volume, the nature and, especially, the surgical conditions (emergency or planned) are assessed in greater detail. On the basis of that, Larsen *et al* managed to integrate the CR index with the type of surgical intervention. The index of Larsen *et al* can reach a maximum value of 54 points – divided by the level and actuality of HF and IHD, as well as other conditions.

In 1999, Lee *et al* [48] reevaluated the significance of some clinic risk factors, associated with patients undergoing noncardiac surgery. The revised index sets 6 predictors of major cardiac complications: high risk surgery, IHD, HF, cerebrovascular disease, type 1 DM and renal insufficiency. The presence of 0, 1, 2 or 3 of the predictors sets the risk level of major cardiac complications at 0.4%, 0.9%, 7% and 11%, respectively. The index of Lee *et al* has better prognostic value than those of Goldman *et al* and Detsky *et al,* due to the smaller number of variable risk factors. For the time being, the clinicians and the researchers accept Lee's index as the most applicable for prediction of the perioperative cardiac risk in noncardiac surgery. However, the patients examined by Lee *et al* do not constitute a representative population of patients undergoing noncardiac surgeries, since the thoracic, the vessel and the orthopedic cases are over-represented.

2.2.2 Non-point scales for cardiac risk assessment

The scale of Kleinman [42] includes remoteness of MI, angina pectoris, valvular disease, rhythm disorders, arterial hypertension, abnormal ECG, peripheral vascular diseases.

The scale of Eagle *et al* [47] includes age over 70 years, DM, angina pectoris, presence of pathological Q-wave in ECG and ventricular extrasystoles. The presence of one RF determines low risk, the presence of 2 to 3 – moderate risk, while more than 3 risk factors leads to high risk assessment.

Later on, *diagrams and tables for risk assessment of ischemic complications* [19, 41, 43], life-threatening ischemic complications [17, 36, 44, 45], tachyarrhythmias [24], and ventricular arrhythmias [49] were proposed. The scales and the statements about the probability of ischemic complications comprise of several symptoms, derived from clinical, laboratory, imaging, and electrophysiological examinations. Hopf and Tarnow [41] propose intraoperative ECG monitoring, transesophageal echocardiography, which is a semi-invasive and expensive method, cardio-kymography, radio-marked erythrocytes and small gamma camera, as well as metabolic parameters. Lette *et al* [43] reach the conclusion that the clinical parameters can not predict incoming ischemic incidents. They accentuate on dipyridamole-thallium scintigraphy. Leppo [19] includes ECG examinations, treadmill, stress-echocardiography with dobutamine or exercise, thallium scintigraphy with test burden in the preoperative assessment. Symptomatic angina, CHF, survived MI, ventricular extrasystoles, and age over 70 years, are also taken into consideration.

Mangano *et al* [50] evaluate the significance of the following clinic symptoms, related to the appearance of post-operative ischemic complications: 1) presence of left ventricular hypertrophy in ECG; 2) remoteness of the arterial hypertension; 3) diabetes mellitus; 4) manifested IHD; 5) HF needing the use of digoxine. According to the presence of the five preoperative symptoms for postoperative ischemia, the probability of its perioperative appearance is divided into 5 levels: without any symptom presence – 22%; presence of one symptom – 31%; 46% with two symptoms; 70% with three; 77% with four symptoms.

Other studies of the same authors emphasize the significance of the following conditions, contributing to unfavorable outcomes from ischemic complications [44, 45]:

1. intraoperative hypotension and tachycardia (the assessment of hypertension is contradictory);
2. appearance of acute ischemic events in the postoperative period (acute MI), unstable stenocarida or ECG ischemia. Note that CHF and ventricular tachycardia are not associated with unfavorable outcomes;
3. instrumentally determined intra- and postoperative changes: appearance of ECG ischemia (doubles the MI risk); increases of the endmost left camera diastolic pressure that are accepted as evidence of ischemia - note that the mean pulmo-capillary pressure and the diastolic pulmonary arterial pressure do not correlate with the incidents; segmental disorder of the left camera wall assessed by transesophageal echocardiography - that is accepted as the most sensitive predictor [51], although the same authors specify later on, that transesophageal echocardiography weakly correlates with postoperative complications;
4. the presence of AH, heavy limiting lung disease, creatinine clearance lower than 0.8 ml/s – factors independently associated with high risk of cardiac death [45]. The death probability is 80% when two or more factors are present.

If the total rate of complications with all monitored patients is 12%, then 24% of those with old MI or cardiomegaly have postoperative complications – cardiac death, acute MI, ischemia. The rate of patients without the mentioned consequences is only 7% [52].

A standard for CR assessment during noncardiac surgeries [22, 53, 54] was adopted, on the basis of the debates, concerning the applicability of the schemes and indices for CR assessment and the ACC/AHA proposals [22, 53, 54]. According to it, CR is further divided into three groups – high, moderate, and low, depending on the severity of the perioperative

CVC and the probability of a fatal outcome; the significance of the clinical predictors is determined, as well as the volume and type of the surgery.

1. Risk, related to CVD:

a. high:
the unstable coronary syndromes – new MI and unstable stenocardia;
the decompensated HF;
the significant arrhythmias – high-degree AV block, symptomatic ventricular arrhythmias accompanying cardiac disease, as well as supraventricular arrhythmias with uncontrolled HR;
critical valvular cardiac lesion.

b. moderate:
stable stenocardia – I-II FC;
old MI or present pathological Q wave in ECG ;
compensated HF;
diabetes mellitus.

c. lower:
advanced in years;
ECG abnormalities;
non-sinus rhythm;
bad functional capacity;
past apoplexy;
uncontrolled arterial hypertension.

2. Risk, related to surgical intervention:

a. high:
emergency major interventions, specifically with elderly patients;
aortic and other major vessel interventions;
peripherally vessel surgeries;
extended surgeries, accompanied by loss of many liquids and blood .

b. moderate:
carotid endarteriectomy;
cranial and vertebral surgeries;
intraperitoneal and intrathoracic surgeries;
orthopedic surgeries;
prostate surgery.

c. lower:
endoscope procedures;
procedures on the body surface;
cataract and breast surgeries.

The ACC/AHA classification merits consist of classification of the risk categories, as well as the consideration of the cardiac state and type of surgery. Are specified the rhythm disorders, the low risk predictors and the pathological ECG findings.

There are several investigations and analyses on the applicability of the CR indices evaluation [1, 11], including such on large number of patients [23]. Basic disadvantages of indices are the high percent of false-positive conclusions [38] and the impossibility of obtaining accurate diagnosis and assessment of the most serious and dynamic RF – the ischemia, with pain or silent [9, 31, 45, 56]. The CR indices do not determine the appearance

probability of acute ischemic incidents [9, 31, 57] and that is what significantly affects the reliability of the cardiac death prognosis.
The point indices of Goldman *et al* and Larsen *et al* include the emergency and the operation volume in the criteria set for the index calculation, but with the lowest possible weights: 4 and 3 with Goldman *et al* (in the assessment range from 3 through 11) and 3 and 3 with Larsen *et al* (in the range from 3 through 12). The detailed analysis of the two schemes gives a satisfactory answer to both the low discrimination coefficients (used for calculation of the emergency and severity of the surgery with both models), and their unavoidable presence among the criteria. Table 1.1 details systematically the required data.

Data for investigation of :	**Goldman et al**	**Larsen et al**
Total number of surgeries (TNS)	1001	2609
Total number of heavy cardiac complications including cardiac death (HCC)	58	68
Emergency surgeries (ES)	197	605
Heavy cardiac complications (including cardiac death) in emergency surgeries (HCC_{ES})	31	38
Emergency surgeries /Total number of surgeries (ES/TNS)	19.7%	23.2%
Heavy cardiac complications in ES/Total number of heavy cardiac complications (HCC_{ES}/HCC)	35.4%	56%
Exceeding index (EI_{ES})	**271%**	**241%**
Major surgeries * (MNCS)	437	857
Heavy cardiac complications (including cardiac death) in major noncardiac surgeries (HCC_{MS})	43	40
Major surgeries/Total number of surgeries (MS/TNS)	43.7%	32.8%
Heavy cardiac complications in major surgeries/ Total number of heavy cardiac complications (HCC_{MS}/HCC)	74.1%	58.8%
Exceeding index (EI_{MS})	**170%**	**179%**

* Major surgeries: aortic, pleural, intraperitoneal, intrathoracic.

Table 1.1. Exceeding indices for emergency and major noncardiac surgery

The proportion between the cardiac complication rates, accompanying the emergency and major surgeries on the one hand, and the total cardiac complication rates for all patients on the other, considerably exceeds the corresponding proportion between the emergency and major intervention rates to the total number of interventions. We devoted special attention to that fact, in our targeted study [5, 6] introducing the so called **"Exceeding Indices."** The Exceeding Index, applied to the emergency surgeries (EI_{ES}) expresses the quotient (in percent) between the relative rate of the heavy cardiac complications (including cardiac death) accompanying the emergency surgeries (HCC_{ES}), towards the total number of heavy cardiac complications (HCC), and the relative rate of the emergency surgeries (ES) towards the total number of surgeries (TNS):

$$EI_{ES}\ (\%) = (HCC_{ES}/HCC)/(ES/TNS).$$

Respectively, the Exceeding Index of the major surgeries (EI_{MS}) expresses the quotient (in percent) between the relative rate of the heavy cardiac complications (including cardiac death) accompanying the major surgeries (HCC_{MS}) towards the total number of heavy cardiac complications (HCC), and the relative rate of the major surgeries (MS) towards the total number of surgeries (TNS):

$$EI_{MS}\ (\%) = (HCC_{MS}/HCC)/(MS/TNS).$$

The emergency surgeries, representing about 1/5 of a relatively small group used with both studies [5, 6], demonstrated a specific rate of cardiac complications that is 2.5-3 times higher than the one, observed for the entire group. The same parameter for MNCS indicates an increase of 1.5-2 times.

It is worth noting that the "Exceeding Indices" makes evident the practically total coincidence between the results obtained by Goldman et al and Larsen et al about the "weights" of the emergency and the intervention volume, despite some differences within the constellations of the other criteria used by both point systems. The reason for the mentioned emergency and major surgery "classification", completed by both systems becomes clear – on the one hand, they do not predominate over the total number of interventions, i.e. they do not determine the nature of the used samples; on the other hand, they bring considerable CVC risk in the perioperative period that can not be ignored by the used statistical analysis.

The analysis of the results obtained, when applying both indices of CR assessment towards the three specific patient groups, generally indicates a significant discrepancy between the formally calculated assessments and the concretely recorded cardiac complications in the perioperative period. There are certain possible hypotheses, offering reasons for the limited applicability of the index models for CR evaluation under the emergency MNCS conditions:

1. The criteria with considerable contribution to the total risk assessment (point assessment above the mean for a given criterion of the corresponding model) have a relatively low rate and/or are weakly informative in emergency surgeries, while the criteria with lower contribution (point assessment below the mean for a given criterion) have a relatively high rate or are highly informative in emergency surgeries.
2. More important contribution to the cardiac risk evaluation in cases of emergency MNCS have other criteria, which are not included in both models.

In our opinion, both hypotheses are realistically supported by the analysis performed. We reiterate, that the emergency and the surgery severity (markedly demonstrated with the first group of patients) dominate as cardiac risk predictors. *However, these criteria are not direct detectors of the heart status; they specify the surgical heart burdening, which is the reason for their predominance in patients with cardiac diseases*. The constellation parameters of both models are deficient in direct criteria for cardiac status evaluation; this fact is relevant to a greater extent for Goldman's model.

The relative advantages of Larsen's model may be well explained by the adequately introduced cardiac status criteria. The IHD assessment criterion includes: 1) MI presence during the 3 last months (Goldberger *et al* specify 6 months); 2) older infarction or angina pectoris (missing in Goldberger's model). The data analysis shows that the second index, even appreciated by 3 points only, is significantly more frequent, about 15% of the cases with critical patient complications. At the same time, MI presence during the last 3 or 6 months (indices with high value, 10 and 11 in both models, respectively) is recorded with one patient, who did not demonstrate perioperative complications. Our interpretation is that the recent (and generally severe) cardiovascular incidents have no explicit contribution to the risk evaluation, since they are subject to therapeutic monitoring. This is not the case with patients with chronic and mild incidents and generally more distant in time CVD and their complications. In emergency cases, the possibilities for correction are missing, that are inherent to planed surgery, even when the complications are under- or decompensated.

Considerable contribution to the cardiac risk assessment in the model of Larsen *et al,* have indices characterizing in aggregate the "heart failure" criterion. Within the investigated by us patient group, with present or preceding pulmonary stagnation, heart failure is a considerably more frequent postoperative CVC. The conclusion is highly valid among patients with stagnations, confirmed by X-ray examination. In such cases, the corresponding cardiac risk assessment increases by 12 points (at persistent pulmonary stagnation) or by 8 points (without stagnation but with preceding pulmonary edema).

Important for the correct cardiac risk evaluation are the cases, offering indices for combined criteria, that are assessed by low point amounts from 2 to 4, such as preceding HF without stagnation or edema; preceding IHD with or without old MI; diabetes; increased serum creatinine. The combination of three of the mentioned indications, accompanying the emergency abdominal surgeries (very common case in practice), leads to a risk increase in the range of 12 through 50%.

Special comment is needed on diabetes, included as a indicator in Larsen's model. In addition to the specific complication, diabetes is associated with the IHD. Introduction of diabetes in cardiac risk evaluation is appropriate, bearing in mind its frequency. It was encountered in 22.4% of the patients, examined by us. The percent of the heavy CVC in patients with diabetes is 14.5. In comparison, it is 8 with patients with mild CVC complications.

The discussion on the applicability of the index models does not cover the problems related to the adequate evaluation of the used criteria constellations for CR assessment in emergency noncardiac surgery. Evidently, there are other criteria, which reliably predict (directly or indirectly) the probability of cardiovascular incidents during the perioperative period.

3. Real and relative myocardial ischemia as a risk factor for appearance of acute cardiac complications in emergency noncardiac surgery – Index for cardiac risk assessment, through ST-depression in the preoperative ECG

Most well known studies indicate the manifested myocardial ischemia as a proven predictor of perioperative cardiac incidents. Different investigations report preoperative ischemia found in 28% through 32% [50, 58] of the examined cases; other refer to a value of up to 60% [59]. The preoperative ischemia, established by Holter monitors, is a predictor of the perioperative one [60]. When the preoperative ischemia is determined by two-days of ECG monitoring, the perioperative complications are specified as 18%, 21% of them being cardiac death, AMI, and unstable stenocardia; 35% are HF; 44% - ventricular tachycardia [9]. The influence of the real and relative myocardial ischemia on perioperative CVC appearance is evident. Therefore, it is useful to associate the CR evaluation with the ECG determined ST-depression. The introduction of an index for CR assessment provides an understandable and objective method for CVC risk determination in cases of preoperative ECG manifested myocardial ischemia (MMI) during emergency noncardiac surgeries. This paragraph presents a synthesis of the cardiac risk assessment index (CRI) for CVC prediction in the postoperative period, based on ST-depression in preoperative ECG, as an expression of real/relative myocardial ischemia.

Data obtained by monitoring the disease process within a group of 466 patients is used for CRI synthesis. The patients have been emergency treated against acute abdominal surgical diseases or abdominal traumas. The patient distribution within the investigated surgical nosological groups (ING) is presented in increasing order of surgical disease (SD) severity in Table 2.1.

The CRI synthesis is related to assessment and comparison of the CVC rate of patients with and without MMI in the ING. CVC appeared in 169 (36.3%) of ING patients: 51 (64.5%) of them with MMI and the remaining 118 (30.9%) – without MMI. The statistically significant difference ($p<0.001$) shows that MMI is an important RF. This general evaluation of the MMI influence on the patients in the postoperative period has to be specified for ING in increasing order of their severity. Table 2.2 presents the CVC rate (in percent) found in ING patients with and without MMI.

The frequency of CVC in patients without MMI marks the anticipated increasing trend in accordance with the increased SD severity – from the low 5.5% among patients with acute appendicitis, through the significant 33, 34, and 35% for patients with hernia, abdominal and biliary-pancreatic diseases, to the high 54% related to acute states, provoked by pathologies of the lower part of the gastrointestinal tract.

The CVC rates in patients with MMI are obviously higher, but as a trend, they do not repeat the monotonic CVC rate increase with SD deterioration of patients without MMI. A characteristic peak may be observed in group B (77%); high rate in group E (71%); limited increase in C (62%) and D (65%) groups. Group A remains with the most rare CVC cases (40%).

The statistically significant difference between the CVC rates in ING, among patients with and without MMI, underlines the specificity of the two trends. Significant, even at different levels, are the differences in groups A, B, C and D. The high level ($p<0.005$) in group B corresponds to the highest recorded increase of the CVC rate, when comparing the results of patients with and without MMI (from 33% to 77%). The differences in groups A and D ($p<0.005$) are also derived with high significance, due to the considerable CVC percentage among the MMI patients. At the same time, the difference in group E between the CVC rate among patients with and without MMI is not significant.

The analysis of the trends in the CVC rates demonstrates the necessity of a detailed discussion on the MMI influence as an ING risk factor.

The CVC are separated as lethal and nonlethal, depending on the recorded disease outcome. Nonlethal CVC appeared in 136 (29.2%) patients of the investigated group: 38 (48.1%) of them with and 98 (25.3%) without MMI. Lethal CVC were observed in 33 (7.1%) patients, 13 (16.5%) with and 20 (5.2%) without MMI.

Surgical disease	Code	Number
Acute appendicitis	**A**	**102**
acute phlegmonous appendicitis		
acute gangrenous and perforated appendicitis		
Complicated hernia	**B**	**92**
Incarceration inguinal and ventral hernia without complications		
Incarceration inguinal and ventral hernia with intestinal necrosis or intestinal phlegmon		
Gastro-duodenal	**C**	**84**
Gastro-duodenal ulcer with perforation		
Gastro-duodenal ulcer with hemorrhage		
Gastro-duodenal ulcer with stenosis		
Gastric neoplasia with perforation or hemorrhage		
Hepatopancreatobiliary	**D**	**108**
Acute or chronic exacerbated cholecystitis		
Complicated cysts, tumors and abscess of liver		
Mechanical icterus		
Acute pancreatitis-with edema, necrotic pancreatitis or absceding necrotizing pancreatitis		
Intestinal	**E**	**80**
Benignant ileus		
Malignant ileus		
Spontaneous intestinal perforation (including intestinal diverticulum, ulcerative or necrotic colitis)		
Colo-rectal neoplasia with perforation or hemorrhage		
Mesenteric thrombosis		
Inflammatory and neoplastic tumors of abdominal wall		

Table 2.1. The patient distribution of the surgical nosological groups in increasing order of severity.

Group of surgical diseases	Total number of CVC to the number of patients (in %) in the group accordingly		Number of lethal CVC to the total number of CVC (in %) in patients		Number of nonlethal CVC to the total number of CVC (in %) in patients		Number of lethal CVC to the number of patients (in %) in the group accordingly		Number of lethal to the number of non-lethal CVC (in %) in patients		Mean age of the patients in the surgical groups	
	Without MMI	With MMI	Without MMI	With MMI	Without MMI	With MMI	Without MMI	With MMI	Without MMI	With MMI	Without MMI	With MMI
A	5,5	40	0	0	5,5	40	0	0	0	0	37	58
B	33	77	4	10	32	69	1	8	3	12	69	75
C	34	62	8	25	31	46	3	15	10	33	61	68
D	35	73	21	24	28	50	7	23	25	46	55	63
E	54	71	32	50	37	35	17	35	50	100	62	72

Table 2.2. CVC and age profiles in surgical groups

Lethal CVC were not recorded among patients in group A, either with or without MMI. These complications among patients without MMI increase gradually, even weakly in groups B (1%), C (3%) and D (7%), but considerably in group E (17%). The trend of the lethal CVC rates among MMI patients is also increased, but highly expressed in the range of severity groups: 8%, 15%, 23% and 35% in B, C, D and E, respectively. Except for group A, there are significantly higher CVC rates among MMI patients, compared to these without MMI (p<0.05). The nonlethal CVC rate in patients without MMI increases from 5.5% in group A to approximately equal levels in groups B (32%), C (31%) and D (28%), but more expressively in group E (37%). This rate reaches the peak among MMI patients in group B (69%), compared to the almost equal and lower rates in A (40%), C (46%) and D (50%). The low rate (35%) of nonlethal CVC patients with MMI in group E is impressive, and practically equal to the rate of patients without MMI. This is true also for the many times higher CVC rate in group A among MMI patients, comparing to patients without MMI (p<0.001). These data determine the high significance of the rate differences in group A and the lack of such difference in group E. Nonlethal CVC were observed in groups B and D as statistically significant more often with MMI patients than among those without MMI, although the calculated significant level is lower (p<0.05). The difference in group C is not significant.

The consequence of the differentiated analysis on the CVC rates with and without lethal outcomes is that the above mentioned specificity of the rate trends of all CVC in patients with MMI is totally determined by the rate trend of the low (nonlethal) complications. The lethal complications rate in the MMI group follows the increasing trend from group A with the low surgical severity to group E with the considerable severity of SD, but this trend is to some extent higher in patients without MMI. Among the nonlethal CVC, the most significant differences are in the groups A and B with low severity SD, while group A shows the highest relative increase in complications (7.3 times). The increased value of 2.2 times in group B is obtained with highest absolute percent of 69% of nonlethal complications among MMI patients.

The differentiated MMI evaluation as a risk factor, reveals its different contribution to the critical complications structure (lethal and nonlethal) of ING patients with and without MMI. Both ratios equal zero due to lack of lethal CVC in group A. In this group, with low severity SD, MMI is a risk factor only in cases of mild complications.

In group B, despite the lesser level of significant difference ($p<0.1$), MMI stands out as a factor emphasizing the CVC and their prognoses. In groups with increased severity SD (C and D) this difference is $p<0.05$,which is convincing proof of the MMI importance for the CVC structuring. The significance of the MMI contribution has its logical maximum ($p<0.001$) with the CVC appearances and outcomes in group E, the group with considerable surgical severity.

The results obtained, outlining the role of MMI as a risk factor of increased severity of CVC rate in SD with increased severity, need specification of the factor, which underlines the specifics of the nonlethal CVC rate trend among MMI patients, reflected also in the structure of the total number of CVC.

The role of age as risk factor in CVC appearance and their complicated duration is known. We will limit our scope to clarification of its specific contribution to the CVC structure in the ING, thus evaluating the CVC risk among patients with and without MMI. The highest mean age of such patients is recoded with the lowest level of significance in group B - 69 and 75 years, respectively, with the lowest level of significance of $p<0,05$. This expressed high and near mean age in both types of patients in group B, may be well interpreted by the SD nature – the complicated abdominal hernias. The age discrimination among patients with and without MMI (37 and 58 years) is most expressed in group A, where the significance level of difference is high: $p<0.005$. Practically the patients of this group are clustered in two sets – young without MMI and elderly with MMI. Such clusters have considerably nearer values in groups C, D and E (61 and 68 years, 55 and 63 years, 62 and 72 years, respectively) that determines the lower significance levels of difference. The mean age of MMI patients in the very serious SD (group E) is relatively high (72 years) and come close to that in group B.

The low surgical severity group A of MMI patients often contains nonlethal CVC; it is characterized by a relatively high mean age. Such age, combined with MMI, determines the frequency peak of the nonlethal CVC in group B, which also consists of relatively low surgical severity SD. The lethal CVC are more frequent in group E, because of the considerable surgical severity SD and the high mean age of the MMI group; the nonlethal CVC rates among patients with and without MMI are equaled. In comparison to MMI, the age has prevalent importance towards the appearance of nonlethal CVC, in the cases discussed above.

The performed analysis and the results obtained allow quantitative assessment of the increasing risk of CVC in patients with MMI in ING, taking into consideration the age profile, expressed by indices synthesis: **general** – for prognosis of all CVC, and **specific** – for the lethal CVC prognosis only. Based on the related to the SD groups content of Table 2.2:

1. relation between rates of all CVC in patients with and without MMI

$$(FAC^{+MMI}/FAC^{-MMI})_{SD};$$

2. mean ages of patients with and without MMI

$$(MA^{+MMI}/MA^{-MMI})_{SD},$$

we can constitute a relation between the rates of all CVC in patients with and without MMI, adjusted to the corresponding mean ages:

$$TCRI_{SD} = (FAC^{+MMI}/FAC^{-MMI})_{SD}/(MA^{+MMI}/MA^{-MMI})_{SD}$$

The last equation is the total, age-corrected CRI, which gives assessment of the MMI "net contribution" to the increased risk of CVC appearance individually in each SD group, and is relevant for a "conditional" patient whose age is equal to the mean age within the group. The MMI assessment of a given patient is corrected by the ratio between his own age (PA) and the mean age within the MMI group of SD:

$$P(TCRI_{SD}) = TCRI_{SD}*(PA/MA^{+MMI})$$

This formula can be used for interval assessments of the general CRI in ING, according to the recommended by the WHO age intervals for patient grouping – Table 2.3.
Analogously, one may assess the specific CRI, related to lethal CVC prediction by the equation

$$LCRI_{SD} = (FLC^{+MMI}/FLC^{-MMI})_{SD}/(MA^{+MMI}/MA^{-MMI})_{SD}$$

and its personalized value

$$P(LCRI_{SD}) = LCRI_{SD}*(PA/MA^{+MMI}),$$

where FLC^{+MMI} and FLC^{-MMI} are the presented in Table 2.3 lethal CVC rates of patients with and without MMI.
Table 2.4 contains the age interval assessments (compliant with WHO recommendations) of the specific CRI in the SD groups. The trend towards increasing the value of the index can be clearly followed as a function of the severity of the SD.
The research conducted, leads to the following conclusions. The CVC prediction during emergency surgeries is very important, due to the exceptionally high CVC rate – 45% in the investigated patient groups. In its turn, the significantly higher CVC rate among patients with MMI proves that it is an independent, important and leading risk factor. In this context, MMI determines not only the probability of occurrence, but also the CVC severity: fully nonlethal (group A); predominantly nonlethal (groups B, C, D); predominantly lethal (group E).
The rate trends of the nonlethal (low severity) and lethal (considerable severity) complications among patients in the SD groups with and without MMI take into consideration the age influence, since it can not be disregarded in risk factor evaluation. Therefore, the MMI presence qualitatively determines the following, influenced by the age CVC risks:

- group A (low surgical severity): rare and mild CVC in young patients, who dominate in the group; relatively frequent, but mild CVC among the more elderly;
- group B (relatively low surgical severity): high rate of mild CVC due to the specific high mean age;
- groups C and D (increased surgical severity): increased probability of mild CVC with the age increase; increased probability of high severity CVC with the SD severity increase;
- group E (considerable surgical severity): high probability of high severity CVC, due to the specific high mean age; the risk of mild CVC is identical in patients with and without MMI.

Age >	18 - 40	41 -55	56 - 65	66 - 75	76 - 90	> 90
A	1,4 - 3,2	3,2 - 4,3	4,3 - 5,1	5,1 - 5,9	5,9 - 7,1	> 7,1
B	0,5 - 1,1	1,1 - 1,5	1,5 - 1,8	1,8 - 2,1	2,1 - 2,5	> 2,5
C	0,4 - 0,95	0,95 - 1,3	1,3 - 1,5	1,5 - 1,8	1,8 - 2,2	> 2,2
D	0,5 - 1,2	1,2 - 1,7	1,7 - 2,0	2,0 - 2,3	2,3 - 2,7	> 2,7
E	0,3 - 0,6	0,6 - 0,8	0,8 - 1,0	1,0 - 1,1	1,1 - 1,4	> 1,4

Table 2.3. Values of TCRI according to surgery groups and age intervals

Age >	18 - 40	41 -55	56 - 65	66 - 75	76 - 90	> 90
A	0	0	0	0	0	0
B	0,06 - 0,13	0,13 - 0,18	0,18 - 0,22	0,22 - 0,25	0,25 - 0,30	> 0,30
C	0,13 - 0,31	0,31 - 0,43	0,43 - 0,50	0,50 - 0,59	0,59 - 0,73	> 0,73
D	0,22 - 0,53	0,53 - 0,75	0,75 - 0,88	0,88 - 1,01	1,01 - 1,19	> 1,19
E	0,30 - 0,60	0,60 - 0,80	0,80 - 1,00	1,00 - 1,10	1,10 - 1,40	> 1,40

Table 2.4. Values of LCRI according to surgery groups and age intervals

4. Extended quantitative schemes for risk evaluation of perioperative acute coronary syndromes and other cardiovascular complications during emergency high risky noncardiac surgery

The proposed, in the preceding paragraph, index for cardiac risk assessment based on the ST-depression has to be interpreted as an express method, applied under the specific conditions of emergency noncardiac surgery for prediction of acute CVC during the postoperative period. The mentioned index is powerful, as it pays attention to manifested myocardial ischemia, which is among the proven factors, determining the high cardiac risk in patients with MNCS. This concept, combined with the conclusion about the limited applicability of the known schemes for CR assessment under emergency MNCS conditions, raises the actual problem related to the synthesis of extended schemes for risk evaluation that offer a compromise between the requirement of highly significant assessment and its achievement, based on available patient data. Below, we propose such schemes, synthesized on the basis of real patient data undergoing emergency abdominal surgery.
The study uses data obtained by the same 466 patients with emergency treated acute surgical abdominal diseases or traumas (see Table 2.1). The data from large sets of indicators have been collected. The pilot investigation on the potential contributions of indicators that may reliably characterize the CVC, resulted in the constellation shown in Table 3.1. The data

cover the three periods of the disease process: preoperative, intraoperative and postoperative. Each indicator has its own structure of category-related or quantitative values, appropriately coded to be processed through a multidimensional statistical approach. We used discriminant analysis (DA) for the synthesis of rules, allowing quantitative evaluation of the CVC risk appearance probability, during the intra- and postoperative periods. The categorisation of individual patients to the CVC group with a given CR level, or to the group without CVC, is performed by substituting the patient's indicators values in the linear discriminator. The patient belongs to the control group if the discriminator value is below the limit. Such are the operated patients without perioperative CVC, even only with transient CVD or abnormal values of some indicators related to the cardiovascular system. Discriminator value above the limit classified the patient to the corresponding risk level group. The hypothesis about CVC appearance with higher risk level is verified by the next discrimination rule, which assesses the probability of higher risk of CVC.

Age	Diabetes mellitus
Surgical conditions	Lung breathing
Volume of surgery	Lung auscultatory
Duration of anesthesia	Systolic blood pressure
Total duration of intubation	Diastolic blood pressure
Intraoperative surgery complications	Central venous pressure
Intraoperative CVC with low risk	Heart rate
Intraoperative CVC with moderate risk	Heart rhythm
Intraoperative CVC with high risk	Heart auscultatory
Postoperative surgery complications	Hemoglobin
Postoperative CVC with low risk	Glucose
Postoperative CVC with moderate risk	Urea
Postoperative CVC with high risk	Creatinine
Cause of death, noncardiac	Potassium
Cause of death, cardiac	Enzymes - SGOT
Arterial hypertension, class	Enzymes - SGPT
Ischemic heart disease	X-ray lung
Myocardial infarction	Exercise ECG
Arrhythmias	Myocardial ischemia - preoperative
Heart failure	Myocardial ischemia - intraoperative
Chronic pulmonary disease	

Table 3.1. Used indicators

The level of discrimination significance depends on the patient numbers, correctly or incorrectly assigned to the training groups. In our case, training groups are the control patient group and the groups with specified CR level. The 446 operated persons are distributed in training groups, which correspond almost totally to the ACC/AHA classification of intra- and postoperative CVC [2, 20]. Two corrections are introduced, since the analysis of the false positive and false negative errors in previous own research, following strictly the ACC/AHA classification, showed the expedience of these corrections in the specific practice with emergency noncardiac surgeries:

- the transient hypotension of the intraoperative CVC scheme is re-classified from low risk to moderate risk;
- the compensated HF of the postoperative CVC scheme is re-classified from high risk to moderate risk; the decompensate HF is determined as a high risk complication.

According to these corrections, the patients are distributed in CVC groups with different CR level, as it is shown in Table 3.2 and Table 3.3. The control group consists of 97 patients. The intraoperative CVC groups are with: low risk – 42; moderate risk – 206; high risk – 41. The postoperative CVC groups are: 1 with low risk; 201 with moderate risk; 40 with high risk (21 of them with, and 19 without cardiac death).

Further on, the procedure for optimum discriminator synthesis was applied on the already differentiated patient groups. Tables 3.4, 3.5, and 3.6 present the weighting discrimination coefficients of the corresponding groups, within the models that determine the appearance of the risk of: postoperative CVC, based on data from the preoperative period; postoperative CVC based on the pre- and intraoperative data period; intraoperative CVC based on data from the preoperative period. The lack of a weighting coefficient for a given index in some columns means that the step procedure of the discriminant analysis has rejected this index as non-contributing to the correct patient distribution in the corresponding groups.

Level of risk	**Type of complication**	**Number of patients**
Low	Short transient hypertension Supraventricular extrasystoles Ventricular extrasystoles	42
Moderate	Transient hypotension Unprovoced prolonged hypotension (> 1 hour) Prolonged hypertension (> 1 hour) Supraventricular arrhythmias (atrial fibrillation, supraventricular tachycardia) Increased heart rate (> 120 bpm) Sinus bradycardia ECG manifestations of myocardial ischemia Frequent ventricular extrasystoles	206
High	Hypotension during sudden heart failure Ventricular extrasystoles class IV Ventricular tachycardia Acute myocardial infarction Acute cardiogenic pulmonary edema Cardiac arrest	41

Table 3.2. Intraoperative cardiovascular complications

Level of risk	Type of complication	Number of patients
Low	Hypotension Supraventricular extrasystoles Ventricular extrasystoles	1
Moderate	Hypertension Supraventricular arrhythmias (atrial fibrillation, supraventricular tachycardia) Angina attack Increased heart rate (> 120 bpm) Sinus bradycardia Ventricular extrasystoles class III ECG manifestations of myocardial ischemia Compensated heart failure NYHA-FC I - II	201
High	Decompensated heart failure, high NYHA-FC Acute cardiogenic pulmonary edema Acute myocardial infarction Cardiac arrest	40

Table 3.3. Postoperative cardiovascular complications

Indicators	Discrimination				
	CVC with moderate risk vs. control group	**CVC with high risk vs. control group**	**Cardiac death vs. control group**	**CVC with high risk vs. cardiac death**	**CVC with moderate risk vs. CVC with high risk**
Age				8.0	
Arterial hypertension	10.5				
Ischemic heart disease	2.5	15.0		14.0	6.5
Myocardial infarction			18.5	55.5	
Arrhythmias		4.5			
Heart failure	12.0	17.5	57.0	3.5	
Chronic pulmonary disease	8.5				
Diabetes mellitus			3.0	2.0	4.5
Lung breathing, preoperative		10.0			
Lung auscultatory, preoperative					
Systolic blood pressure, preoperative			0.5		
Diastolic blood pressure, preoperative					
Central venous pressure, preoperative					19.5
Heart rate, preoperative	19.5	6.5	6.0		
Heart rhythm, preoperative					
Heart auscultatory, preoperative		1.0	4.0		3.0
Hemoglobin, preoperative	3.0	18.0	11.0		7.0
Glucose, preoperative	3.5				
Urea, preoperative					
Creatinine, preoperative				13.5	43.5
Potassium, preoperative					
Enzymes - SGOT, preoperative					
Enzymes - SGPT, preoperative					
X-ray lung, preoperative		27.5		3.5	16.0
Exercise ECG, preoperative					
Myocardial ischemia - preoperative	40.5				
Limit value for positive test:	**40**	**30**	**60**	**35**	**30**

Table 3.4. Quantitative models for postoperative CVC risk assessment according to preoperative data

Indicators	Discrimination				
	CVC with moderate risk vs. control group	**CVC with high risk vs. control group**	**Cardiac death vs. control group**	**CVC with high risk vs. cardiac death**	**CVC with moderate risk vs. CVC with high risk**
Age					
Surgical conditions					
Volume of surgery	1.0			8.0	
Duration of anesthesia			2.0		
Intraoperative surgery complications	0.5			5.0	
Intraoperative CVC with low risk	4.5	5.0	3.5		
Intraoperative CVC with moderate risk	81.0	69.0	41.0		
Intraoperative CVC with high risk	8.5	21.5	43.0	8.5	
Arterial hypertension, class	2.0				
Ischemic heart disease				3.5	5.5
Myocardial infarction				7.0	
Arrhythmias					
Heart failure				15.5	
Chronic pulmonary disease			1.5		
Diabetes mellitus				7.5	3.5
Lung breathing, preoperative					
Lung breathing, intraoperative					
Lung auscultatory, preoperative	1.5		1.5		
Lung auscultatory, intraoperative				6.5	
Systolic blood pressure, preoperative			0.5		
Diastolic blood pressure, preoperative	0.5				
Systolic blood pressure, intraoperative					
Diastolic blood pressure, preoperative					
Central venous pressure , preoperative				3.5	11.5
Central venous pressure, intraoperative				17.0	15.0
Heart rate, preoperative			1.0		
Heart rate, intraoperative				9.0	
Heart rhythm, preoperative					
Heart rhythm, intraoperative			5.0		
Heart auscultatory, preoperative					2.5
Hemoglobin					4.5
Glucose					
Urea					
Creatinine				3.5	30.0
Potassium					
Enzymes - SGOT					
Enzymes - SGPT					
X-ray lung				2.5	12.5
ECG LVH		0.5	0.5		
Myocardial ischemia - preoperative					
Limit value for positive test:	**20**	**20**	**55**	**65**	**25**

Table 3.5. Quantitative models for postoperative CVC risk assessment according to pre- and intraoperative data

Indicators	Discrimination				
	CVC with low risk vs. control group	CVC with moderate risk vs. control group	CVC with high risk vs. control group	CVC with moderate risk vs. CVC with low risk	CVC with high risk vs. CVC with moderate risk
Age	24.0	18.5	7.0	6.0	
Arterial hypertension	22.0	6.5	2.5	9.5	
Ischemic heart disease		5.5	3.0		
Myocardial infarction	11.0		8.0		20.5
Arrhythmias	42.0			19.5	
Heart failure		12.0	13.0		11.0
Chronic pulmonary disease		9.0		4.5	
Diabetes mellitus					
Lung breathing, preoperative		8.0	19.0		17.0
Lung auscultatory, preoperative			8.5		
Systolic blood pressure, preoperative					
Diastolic blood pressure, preoperative					7.5
Central venous pressure, preoperative					10.0
Heart rate, preoperative		23.5		15.5	
Heart rhythm, preoperative					
Heart auscultatory, preoperative					8.5
Hemoglobin, preoperative		2.5	20.5		25.5
Glucose, preoperative			6.0		
Urea, preoperative					
Creatinine, preoperative					
Potassium, preoperative					
Enzymes - SGOT, preoperative					
Enzymes - SGPT, preoperative					
X-ray lung, preoperative	1.0				
Exercise ECG, preoperative			2.0		
Myocardial ischemia - preoperative		12.5	14.5	45.0	
Limit value for positive test:	90	80	40	60	30

Table 3.6. Quantitative models for intraoperative CVC risk assessment according to preoperative data

Tables 3.7 and 3.8 show the results of correct and incorrect classification of patients, on the basis of the used training groups, ranged according to the CVC risk. The greater informative value of the combination of pre- and intreoperative data for prognosis of postoperative CVC becomes obvious, and the more distinct significance for prognosis of each higher-risk level of the post- and intraoperative CVC.

Cadiovascular complications	Data from period	Number of patients with complications	Number of patients without complications	True classified patients with complications (%)	False classified patients with complications (%)	True classified patients without complications (%)	False classified patients without complications (%)	Weighted average % of true classified patients
Postoperative with high risk	Preoperative	19	97	63,2	36,8	95,4	4,6	91,4
	Pre- and intraoperative	19	97	94,7	5,3	100	0	99,1
Postoperative with moderate risk	Preoperative	201	97	69,1	30,9	94,5	5,5	86,2
	Pre- and intraoperative	201	97	92	8	100	0	94,6
Postoperative with low risk	Preoperative	1	97					
	Pre- and intraoperative	1	97					
Intraoperative with high risk	Preoperative	41	97	65	35	97,9	2,1	88,3
Intraoperative with moderate risk	Preoperative	206	97	95,1	4,9	59,8	40,2	83,8
Intraoperative with low risk	Preoperative	42	97	66,7	32,3	92,8	7,2	84,9
Cardiac death	Preoperative	21	97	71,4	28,6	96,9	3,1	92,4
	Pre- and intraoperative	21	97	95,2	4,8	100	0	99,2

Table 3.7. Predictive value of models for evaluation of cardiovascular complications

Cadiovascular complications	Data from period	Number of patients with high risk	Number of patients with cardiac death	True classified patients with high risk (%)	False classified patients with high risk (%)	True classified patients with cardiac death (%)	False classified patients with cardiac death (%)	Weighted average % of true classified patients
Postoperative with high risk vs. cardiac death	Preoperative	19	21	89,5	10,5	95,2	4,8	92,5
	Pre- and intraoperative	19	21	100	0	100	0	100

Cadiovascular complications	Data from period	Number of patients with high risk	Number of patients with moderate risk	True classified patients with high risk (%)	False classified patients with high risk (%)	True classified patients with moderate risk (%)	False classified patients with moderate risk (%)	Weighted average % of true classified patients
Postoperative with high risk vs. moderate risk	Preoperative	19	206	52,6	47,4	96,5	3,5	89,5
	Pre- and intraoperative	19	206	52,6	47,4	96	4	92,3

Cadiovascular complications	Data from period	Number of patients with high risk	Number of patients with moderate risk	True classified patients with high risk (%)	False classified patients with high risk (%)	True classified patients with moderate risk (%)	False classified patients with moderate risk (%)	Weighted average % of true classified patients
Intraoperative with high risk vs. moderate risk	Preoperative	19	206	57,5	42,5	97,6	2,4	91,1

Cadiovascular complications	Data from period	Number of patients with moderate risk	Number of patients with low risk	True classified patients with moderate risk (%)	False classified patients with moderate risk (%)	True classified patients with low risk (%)	False classified patients with low risk (%)	Weighted average % of true classified patients
Intraoperative with moderate risk vs. low risk	Preoperative	206	42	97,6	2,4	42,3	57,7	88,2

Table 3.8. Predictive value of models for evaluation of cardiovascular complications (in patient groups with adjacent levels of cardiac risk)

Generally, the proposed models for risk assessment of acute CVC appearances, and of incidents with patients undergoing emergency noncardiac interventions, manifest not only high significance, but also point out:

- the importance of the intraoperative CVC (especially that with moderate risk) for prognosis of all risk level postoperative CVC, based on preoperative and intraoperative data;
- the obtained discrimination between the groups with cardiac death and high risk complications, which is impossible when directly using the ACC/AHA classification of intra- and postoperative CVC;
- certain decrease of the discrimination importance of the preoperatively ECG detected myocardial ischemia together with keeping its role in prognosticating the intraoperative CVC with moderate and high risk, which are among the factors that determine the rate and the severity of the postoperative CVC.

5. Cardiac risk reduction strategies

The topical risk assessment of perioperative cardiac incidents during noncardiac surgery, attracts the attention of the specialists, and is the reason for permanent updating of the practices leading to significant evaluation. It is sufficient to list the handbooks published by competent professional societies, including the ESC Guidelines, issued in 2009, on preoperative cardiac risk assessment and perioperative cardiac management in non-cardiac surgery [61, 62, 63]. *The final goal of these strategies for evaluating the cardiac risk and the optimization of heart management during noncardiac surgery, based on this evaluation, is the reduction of perioperative acute cardiac incidents.* The strategies can be summarized, without reiteration of the available algorithms, in following three directions.

5.1 Pharmacological strategy

Surgeries of patients with moderate and low FC and moderate CR can be performed by inclusion of statins and low dose beta-blockers. ACE inhibitors are recommended to be introduced before intervention on patients with LV dysfunction (EF less than 40%).

Continued use of **beta-blockers** is advised with patients having positive preoperative stress-tests. The latest cardioprotection concepts recommend the use of cardio-selective beta-1-blockers without internal simpatico-mimetic activity and long half-life time, e.g. bisopropol.

The **statins** induce coronary plaque stabilization. Multiple clinical investigations show the positive effect of the perioperative use of statins.

The **inhibition of ACE** may prevent myocardial ischemia and LV dysfunction, therefore the perioperative treatment with ACE inhibitors is expedient.

Aspirin is widely taken by patients with IHD, especially after intracoronary stent implantation. The apprehension of perioperative hemorrhaging complications often leads to suspension of the aspirin in the perioperative period. However, this is related to triplicate the risk of heavy cardiac incidents. The aspirin admission has to be interrupted only if the bleeding risk exceeds the cardiac benefit.

5.2 Noninvasive stress-tests

Patients with one or more cardiac risk factors are advised to be ECG monitored for changes in the postoperative period. Noninvasive testing is recommended for patients with 3 or

more risk factors. The last can be accomplished during each surgery, depending on the change in the perioperative strategy – the intervention type and the anesthetic technique.
Patients without stress-induced moderate or heavy ischemia (orienting towards single- or two-branch coronary disease) can continue with the planned intervention by inclusion of statins and low dose beta-blockers. Individual approach is recommended for patients with heavy stress-induced ischemia, after discussing the potential benefit of the advised surgery in comparison with the bad prognosis. It is necessary to specify the effect of the medicamentous therapy and/or coronary revascularization not only in the postoperative plan, but also in a long-term plan.

5.3 Revascularization

When a life-threatening state, requiring surgical intervention, is combined with ACS, it is advisable to give advantage to the surgery. However, a second stage necessities aggressive medicamentous therapy and revascularization, according to the NSTEMI and STEMI-ACS recommendations.
ACS without ST-elevations is interpreted as a high risk clinical state, requiring accurate diagnosis, risk stratification and revascularization. That means that if no life-threatening surgical state is present, advantage has to be given to the diagnosis and the appropriate treatment of the unstable angina. The corner-stones of the treatment are the double antiaggregating therapy, the beta-blocker and the revascularization.
The antiaggregation and the anticoagulations have to be carefully appreciated before applying to patients with unstable AP and forthcoming surgery state, in order to avoid the risk of subsequent enhanced bleeding. Most of the patients with unstable AP need interventional revascularization and advantage must be given to metal stents, in order not to delay the surgery more than three months.
The main goal of the prophylactic myocardial revascularization is the prevention of lethal perioperative MI. As far as the revascularization may be only partially effective in treatment of high risk stenosis, it cannot prevent the rupture of vulnerable plaque during the surgery stress. This one is found at least in the half of the perioperative MI cases, and can explain the lack of specificity in the stress-imaging methods for infarct-related coronary lesions discovery. Patients with previous PCI can be with higher risk during or after noncardiac surgery, especially in the cases of unplanned or emergency surgery that follow coronary stent setting. The intervention duration and the specificity of the process (malignant tumor, vascular aneurism, etc.) have to be adequately balanced against the risk of stent-provoked thrombosis during the first year after the implantation of drug emitting stent. Careful discussion is recommended in every individual case by a team, including a surgeon, an anesthesiologist and a cardiologist.
Despite the specific strategies for risk reduction, the perioperative CR assessment gives an opportunity for optimized control of all cardiovascular risk factors.

6. Index

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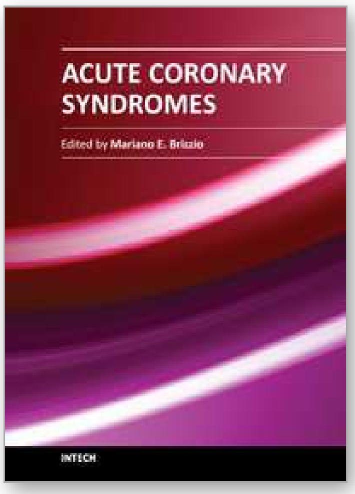

Acute Coronary Syndromes

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This book has been written with the intention of providing an up-to-the minute review of acute coronary syndromes. Atherosclerotic coronary disease is still a leading cause of death within developed countries and not surprisingly, is significantly rising in others. Over the past decade the treatment of these syndromes has changed dramatically. The introduction of novel therapies has impacted the outcomes and surviving rates in such a way that the medical community need to be up to date almost on a "daily bases". It is hoped that this book will provide a timely update on acute coronary syndromes and prove to be an invaluable resource for practitioners seeking new and innovative ways to deliver the best possible care to their patients.

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