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Mini review article

CARDIAC RISK ASSESSMENT IN THE ELECTIVE ABDOMINAL AORTIC ANEURYSM OPEN REPAIR

PROCENA KARDIJALNOG RIZIKA U ELEKTIVNOJ OTVORENOJ REPARACIJI ANEURIZME ABDOMINALNE AORTE

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Abstract

When indicated, patients with abdominal aortic aneurysm are referred for elective abdominal aortic surgery. Abdominal aortic aneurysm open repair is associated with a high risk for the development of cardiovascular morbidity and mortality. Cardiac risk assessment in abdominal aortic surgery includes evaluation of the likelihood of adverse cardiac events during surgery and/or in the postoperative period. Overall cardiac risk is assessed individually for the patient, taking into account the patient's general condition, cardiac function, patient functional capacity, comorbidity status, and vascular surgery risk. Cardiac morbidity and mortality are several times higher in emergency procedures than in elective abdominal aortic procedures, as well as in surgical procedures compared to endovascular procedures, especially in cases with suprarenal clamping of the aorta. Patients with ischemic heart disease and heart failure are at high risk for adverse cardiac events.

Pathophysiologic mechanisms activated intraoperatively by aortic clamping and unclamping, hemodynamic fluctuations, blood loss, coagulopathy, and ischemia-reperfusion injury influence the potential development of perioperative infarction, heart failure, and cardiac arrest in high-risk patients. Assessment of perioperative cardiac function and cardiac risk using leading recommendations and scoring systems before surgery may change the approach to management of high-risk patients with multiple comorbidities and significantly reduce the incidence of perioperative morbidity and mortality.

Keywords:
cardiac risk,
abdominal aortic aneurysm,
abdominal aortic surgery

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Sažetak

Pacijenti sa aneurizmom abdominalne aorte, kada je indikovano, upućuju se na elektivnu hirurgiju abdominalne aorte. Otvorena reparacija aneurizme abdominalne aorte nosi visok rizik za razvoj kardiovaskularnog morbiditeta i mortaliteta. Procena kardijalnog rizika u hirurgiji abdominalne aorte podrazumeva procenu verovatnoće nastanka neželjenih kardijalnih događaja intraoperativno ili u postoperativnom periodu. Sveukupni kardijalni rizik procenjuje se individualno za pacijenta, uzimajući u obzir njegovo opšte stanje, kardijalnu funkciju, funkcionalni kapacitet, komorbiditetni status i hirurški rizik vaskularne operacije. Kardijalni morbiditet i mortalitet su višestruko viši u hitnih u poređenju sa elektivnim zahvatima na abdominalnoj aorti, kod hirurškog lečenja u odnosu na endovaskularni pristup, posebno kod pacijenata sa suprarenalnim klemovanjem aorte. Pacijenti sa ishemijskom bolesti srca i srčanom insuficijencijom izloženi su visokom riziku za razvoj neželjenih kardijalnih događaja.

Patofiziološki mehanizmi koji se aktiviraju intraoperativno klemovanjem i deklemovanjem abdominalne aorte, dinamikom hemodinamskih promena, gubitkom krvi, poremećajem koagulacije i ishemijsko-reperfuzionom lezijom u visokorizičnih pacijenta utiču na mogući razvoj perioperativnog infarkta, srčane insuficijencije i srčanog zastoja. Preoperativna procena kardijalne funkcije i kardijalnog rizika prema vodećim preporukama i skoring sistemima može promeniti pristup lečenju visokorizičnih pacijenata sa brojnim komorbiditetima i bitno uticati na smanjenje incidencije perioperativnog morbiditeta i mortaliteteta.

Ključne reči:
kardijalni rizik, aneurizma abdominalne aorte, hirurgija abdominalne aorte

Introduction

Aneurysm of the abdominal aorta is an enlargement of the diameter of the abdominal aorta ≥ 3 cm (1), and aneurysm repair is indicated in asymptomatic patients with an acceptable operative risk if the diameter is ≥ 5.5 cm in men and ≥ 5.0 cm in women (2). Studies have shown that the prevalence of abdominal aortic aneurysms ranges from 1.7% to 12.7% depending on the population observed (3, 4), with an increasing prevalence in the elderly population.

The American College of Cardiology classified abdominal aortic surgery as a surgery with a high surgical risk for the development of major adverse cardiac events (MACE) (5). Basic preoperative management of patients undergoing abdominal aortic surgery includes history, physical examination, and electrocardiogram (ECG) findings. Patients with impaired cardiovascular function need additional diagnostics performed preoperatively, such as transthoracic echocardiographic examination, non-invasive or invasive stress test, as well as preoperative coronary angiography. Nevertheless, adverse cardiac events remain the major cause of postoperative morbidity and mortality in abdominal aortic surgery, most likely due to the high prevalence of ischemic heart disease in vascular patients (6, 7). Therefore, the most important steps in the preoperative management of patients for abdominal aortic surgery are the assessment of cardiac function and strategies to reduce cardiac risk based on the need for preoperative coronary revascularization and the assessment of the ideal timing for elective vascular surgery after revascularization. Perioperative β-blockade therapy to reduce cardiac risk is still controversial.

Pathophysiologic changes in abdominal aortic aneurysm open repair and adverse cardiac events

Open repair of abdominal aortic aneurysm is a major vascular procedure that requires optimization of preoperative cardiovascular function and invasive hemodynamic monitoring perioperatively. Key moments in abdominal aortic aneurysm open repair that contribute to intraoperative stress include clamping and unclamping of the abdominal aorta. Cross-clamping of the abdominal aorta elicits sympathetic stimulation followed by an increase in mean arterial pressure (MAP) and afterload proximal to the clamping position with subsequent left ventricle pressure loading. Unclamping of the aorta is followed by a decrease in left ventricular afterload, redistribution of the intravascular volume and sometimes, hypotension, which, if prolonged, may be associated with the occurrence of myocardial ischemia in the presence of anemia. The constellation of pathophysiological mechanisms in a patient with existing risk factors creates the conditions for the development of perioperative myocardial ischemia associated with myocardial infarction. Two mechanisms of myocardial infarction (MI) are described. The first one is related to pronounced sympathetic stimulation under conditions of hemodynamic instability, which may lead to rupture of the existing unstable atheromatous lipid plaque associated with thrombosis in the coronary arteries when type I MI develops under conditions of undeveloped collateral circulation. Another mechanism of MI is associated with an imbalance between oxygen delivery (DO_2) and oxygen consumption (VO_2), DO_2/VO_2. Type II MI develops as a result of inadequate DO_2 under conditions of increased VO_2 – it is thought to characterize the occurrence

of MI perioperatively, followed by evidence of ST depression in ECG findings (8). Although the occurrence of MI postoperatively is often silent in patients due to adequate analgesia in the postoperative period, it is thought to be detectable by routine control of high-sensitivity troponin levels in the early postoperative period. Landesberg and collaborators have shown that a higher value of postoperative troponin after postoperative myocardial infarction is associated with worse long-term survival, explained by greater myocardial necrosis, although not by the localization of the necrosis (9). Abdominal aortic aneurysm open repair carries a high risk of blood volume loss (10) and an increased need for blood transfusions. In addition, studies have shown an association between intraoperative transfusion and the occurrence of postoperative myocardial infarction, with a higher incidence of intraoperative transfusion in patients who developed myocardial infarction postoperatively (11).

Considering the role of atherosclerotic disease in the pathogenesis of abdominal aortic aneurysm (12, 13), a large percentage of vascular patients have coronary disease as part of the systemic manifestation of the atherosclerotic process. The high prevalence of coronary disease in these patients, as well as other associated comorbidities, increases the operative risk. The study by Lindholt and his team found that the prevalence of abdominal aortic aneurysm in patients with chronic obstructive pulmonary disease was 7.7% (14), although the influence of elastase on the process of aortic degradation has not been established with certainty. Insulin-dependent diabetes as a concomitant disease of patients also contributes significantly to the development of the atherosclerotic process. Studies have shown that predictors of the occurrence of MACE after surgical repair of aortic aneurysm are age, coronary disease, chronic obstructive pulmonary disease, insulin-dependent diabetes, and heart failure (15, 16), and patients with the above concomitant diseases have a higher risk of adverse cardiac events after abdominal aortic surgery.

According to some clinical studies, suprarenal clamping of the aorta results in a higher incidence of MACE (17) as well as a higher prevalence of renal insufficiency (18). Compared with open repair of abdominal aortic aneurysm, endovascular repair is the less invasive approach because the aorta does not need to be clamped and the procedure can be performed under regional anesthesia, resulting in less sympathetic stimulation, less operative burden on the patient, and less cardiac morbidity and mortality. In a recent study by Diender and collaborators, age, heart failure, and valvular heart disease were identified as predictors of MACE during the 5 years after endovascular repair of the aorta (19). The American Association for Vascular Surgery and the Society for Vascular Surgery Guidelines recommend an individualized approach considering the method of abdominal aortic aneurysm repair and suggest an endovascular approach for high-risk patients (20). Clinical studies show that patients who have undergone endovascular repair of abdominal aortic aneurysm have significantly lower postoperative morbidity and mortality. In a randomized trial conducted in 345 patients, mortality was lower in the endovascularly treated group than in the operated group (1.2% vs. 4.6%) for aneurysm diameters ≥ 5 cm (21). A study by Bertges and collaborators showed a fourfold higher incidence of myocardial infarction in patients who underwent surgical repair of abdominal aortic aneurysm compared with patients who underwent endovascular aortic aneurysm repair (4.3% vs. 1.0%) (16). The incidence of perioperative myocardial infarction in patients undergoing surgical repair of abdominal aortic

Table 1. Perioperative risk factors associated with development of MACE in abdominal aortic aneurysm open repair.

Surgery related factors		Patient related factors
Factors related to hemodynamic effects of aortic clamping		General patient characteristics Age
Proximally ↑MAP ↑CVP ↑PCWP ↓LVEF ↑LVWMAs	Distally ↓MAP	Body Mass Index
Factors related to hemodynamic effects of aortic unclamping		Comorbidities
↓MAP ↓CVP ↓CO		Coronary artery disease Congestive heart failure Chronic renal failure Insulin dependent diabetes Chronic obstructive pulmonary disease Anemia
Anesthesia related factors		Habits Smoking habit
Intraoperative and postoperative blood loss		
Blood transfusion		

MACE - major adverse cardiac events; MAP - mean arterial pressure; CVP - central venous pressure; PCWP - pulmonary capillary wedge pressure; LVEF - left ventricular ejection fraction; LVWMAs - left ventricular wall motion abnormalities; CO - cardiac output.

aneurysm was 3.75% in the study by Beaulieu et al. (11). **Table 1** lists known risk factors that may contribute to developing MACE in abdominal aortic aneurysm open repair (7, 10, 11, 15, 16).

Preoperative assessment of the cardiovascular system

The ECG is a simple, routine, preoperative method recommended in patients undergoing vascular surgery. Changes in the ECG detected preoperatively, may indicate the need for additional diagnostic testing. Although, preoperative echocardiography and noninvasive stress testing are recommended in patients with a functional capacity < 4 METs and in patients with cardiovascular comorbidity who are scheduled for abdominal aortic surgery (10), the recent study by Columbo et al. failed to demonstrate the benefit of preoperative stress testing in reducing the incidence of MACE postoperatively or in reducing patient mortality (22). It is also interesting to note the association between a history of coronary revascularization and the occurrence of myocardial infarction after surgery. In patients who have had an acute coronary event in the preoperative period and who are scheduled for abdominal aortic surgery, implantation of a drug-eluting stent (DES) is recommended when elective abdominal aortic surgery can be postponed for at least three months because of the high risk of stent thrombosis (10). In patients diagnosed with significant coronary disease by angiography before abdominal aortic surgery, percutaneous coronary intervention or aortocoronary bypass may be performed, depending on the localization and extent of changes in the coronary arteries. The role of prophylactic coronary revascularization has long been analyzed and studied but still seems to be controversial. Hertzer and his team showed that patients who underwent prophylactic coronary revascularization before vascular surgery had lower postoperative mortality (7). Multivariate statistical analysis in the study by Bertges et al. showed that preoperative coronary revascularization of the myocardium reduced the incidence of adverse cardiac events (15). However, a randomized trial involving 5859 patients at 18 Veterans Affairs medical centers and followed in the long-term postoperative period found no significant difference in the incidence of postoperative myocardial infarction and mortality in patients with and without preoperative coronary revascularization (23). The most recent recommendations of the European Society of Cardiology currently do not recommend routine preoperative coronary angiography in patients before abdominal aortic surgery (10).

The influence of preoperative β-blockade therapy on postoperative outcomes has been investigated in several studies, but opinions about perioperative β-blockade therapy are still controversial. The beneficial effect of perioperative β-blockade therapy is reflected in the reduction of heart rate and myocardial oxygen consumption. The randomized POISE trial showed that patients who received perioperatively metoprolol succinate had a lower incidence of nonfatal myocardial infarction postoperatively than patients who received placebo (3.6% vs 5.1%, p 0.0008). However, mortality was lower in patients treated with placebo (24).

Given the controversial results of various studies, further randomized trials are needed to further clarify the role of prophylactic coronary revascularization and β-blockade therapy in reducing postoperative morbidity and mortality.

Scoring systems for cardiac risk assessment in abdominal aortic aneurysm open repair

Goldman published the first scoring system for cardiac risk assessment in noncardiac surgery in 1977, which was used in vascular surgery. Score defined nine risk factors using multivariate analysis, and one of the risk factors was aortic surgery (25). A modification of this score was made by Detsky in 1986 (26). The Glasgow score is used to predict in-hospital morbidity and mortality in emergency and elective abdominal aortic aneurysm repair and includes as variables patient age, a history of cardiac and cerebrovascular disease, and renal insufficiency (27). The score has been validated in several prospective and retrospective studies, and the main advantage of this score was its simple applicability in clinical practice (28-30). Lee's Revised Cardiac Risk Index (RCRI) has been used for decades in anesthesiology practice to assess the likelihood of cardiac complications in non-cardiac surgery. The score distinguishes risk factors for the occurrence of adverse cardiac complications: type of surgery, presence of ischemic heart disease or heart failure, history of cerebrovascular disease, preoperative insulin therapy, and preoperative creatinine level ≥ 2 mg/dl. Each risk factor was assigned a point value of one, and the total value of the points determines the operational risk. A score of 0, 1, 2, > 2 indicates the incidence of cardiac complications: 0.4%, 1.0%, 7%, and 11%, respectively (31). Certainly, the RCRI provides a better prediction of MACE after elective abdominal aortic aneurysm surgery in patients with an infrarenal clamping position than a suprarenal clamping position (32). Although the RCRI is widely used in vascular surgery, it has been performed on a derivation cohort with a small number of vascular patients. A decade later the group of authors Bertges et al. presented the Vascular Study Group Cardiac Risk Index (VSG-CRI), performed on a derivation cohort of vascular patients, which more accurately predicted cardiac risks in vascular surgery compared to the RCRI score. Multivariate analysis identified as a variable VSG-CRI: age ≥ 80 (4 points), 70 - 79 years (3 points), 60 - 69 years (2 points), ischemic heart disease (2 points), heart failure (2 points), chronic obstructive pulmonary disease (2 points), creatinine level ≥ 1.8mg/dl (2 points), smoking (1 point), insulin-dependent diabetes (1 point) and long-term therapy with β blockers (1 point). The study also pointed out the prophylactic role of coronary revascularization (-1 point).

Table 2. Clinical indices for predicting cardiac risk in abdominal aortic aneurysm open repair.

Index	Predictor variables	First author, year and references	Study population	Non cardiac surgery	Abdominal aortic aneurysm open repair	Applicability
Goldman Risk Index (GRI)	Age>70 IM within 6 months Signs of heart failure Significant aortic stenosis Arrhythmia other than sinus ≥5 premature ventricular complexes General medical condition: (PO_2<60mmHg; PCO_2>50mmHg;K<3mEq/L; HCO3<20mEq/L; BUN>50 mg/dL; Serum creatinine>3mg/dL;elevated SGOT; chronic liver disease) Type of Surgery	Goldman, 1977 (25)	1001 patients	Applicable	Applicable	Elective surgery Emergency surgery
Detsky Cardiac Risk Index	Age >70 Type of surgery Myocardial infarction Canadian Cardiovascular Society Angina Pulmonary edema Valvular disease Arrhythmias General medical condition: (PO_2<60mmHg; PCO_2>50mmHg;K<3mEq/L; HCO3<20mEq/L; BUN>50 mg/dL; Serum creatinine>3mg/dL;elevated SGOT; chronic liver disease)	Detsky, 1986 (26)	455 patients	Applicable	Applicable	Elective surgery Emergency surgery
Revised Cardiac Risk Index (RCRI)	High risk surgery Ishemic heart disease Congestive heart failure Cerebrovascular disease Insulin-preoperative therapy Serum creatinine>2mg/dL	Lee, 1999 (31)	4315 patients	Applicable	Applicable	Elective surgery
Vascular Study Group of New England Cardiac Risk Index (VSG-CRI)	Age≥60 CAD CHF COPD Insulin-dependent diabetes Creatinine level>1.8mg/dL Smoking Long term β blockade Prior PCI Prior CABG	Bertges, 2010 (15)	10081 patients	Non applicable	Applicable	Elective surgery
The Vascular Quality Initiative Cardiac Risk Index (VQI-CRI)	Age Operation type Coronary artery disease Congestive heart failure Diabetes Creatinine level>1.8mg/dL Stress test status Body mass index +Procedure model specific variables	Bertges 2016 (16)	88791 patients	Non applicable	Applicable	Elective surgery
The American University of Beirut (AUB)-HAS2 Cardiovascular Risk Index	Age≥75 History of heart disease Symptoms of angina or dyspnea Hemoglobin<12mg/dL Vascular surgery Emergency surgery	Dakik, 2019 (33)	3284 patients	Applicable	Applicable	Elective surgery Emergency surgery

The risk of adverse cardiac events increases with the value of the score, and cardiac risk is graded according to the value of the score 0 - 4 low risk, 5 - 6 intermediate risk, and > 6 high risk, with an incidence of cardiac events after surgery of 2.6%, 6.0 - 6.6%, and 8.9 - 14.3%, respectively (15). The higher accuracy of the VSG-CRI compared with the RCRI in predicting adverse cardiac events in vascular surgery can be explained by the fact that the VSG-CRI was performed exclusively on a cohort of vascular patients. However, the derivation cohort for the VSG-CRI score was inhomogeneous because it included patients for vascular surgery with varying surgical risk. The most commonly used clinical indices to predict cardiac risk in abdominal aortic aneurysm open repair are presented in **table 2**.

In the context of technological and informational development, Bertges and his team in 2016 developed a specific Vascular Quality Initiative Cardiac Risk Index (VQI-CRI) to predict postoperative myocardial infarction (POMI) using a registry with a large number of patients who underwent abdominal aortic surgery. A risk assessment calculator and individual scoring systems are available online for open and endovascular repair of abdominal aortic aneurysms and for suprainguinal bypass surgery (16). Despite the large number of existing scoring systems, there is a further need to improve them to allow more accurate prediction of MACE after abdominal aortic aneurysm open repair.

Abdominal aortic aneurysm and aortoiliac occlusive disease

The clinical description of aortoiliac occlusive disease was first given by the author Leriche in a young patient who presented with intermittent claudication (34). Aortoiliac occlusive disease is a form of peripheral artery disease. It is estimated that 3 - 12% of the world's population suffers from some form of peripheral arterial disease (35). Depending on the extent of atherosclerotic disease of the aorta, common iliac, internal iliac, and external iliac arteries, aortoiliac disease is classified into four disease types according to the TransAtlantic Inter-Society Consensus for the Management of Peripheral Arterial Disease (TASC II) (36), and the method of treatment is based on the complexity and localization of the changes. Indication for revascularization is in case of the development of critical ischemia (rest pain or gangrene) or significant impairment of quality of life up to intermittent claudication. The TASC II recommends treatment of aortoiliac occlusive disease with an endovascular approach for type A and B lesions and surgical treatment for type C and D lesions (36). The prevalence of concomitant aortoiliac disease in patients with abdominal aortic aneurysm is approximately 20% (37) and suggests on influence of certain common genetic patterns. Although the atherosclerotic process is considered to play a major role in the pathogenesis of both of these diseases, the difference in genetic expression has a significant influence on the development of individual diseases (38). In a recent retrospective study, authors found a two-fold higher incidence of myocardial infarction after vascular surgery in patients with concomitant abdominal aortic aneurysm and aortoiliac occlusive disease, compared to patient populations with only one entity, suggesting a higher cardiac risk in presence of concomitant diseases. The same study reported an equal incidence of myocardial infarction in patients when these individual entities were present (39). In the study by Daniel et al. higher postoperative mortality was in the group of patients with concomitant abdominal aortic aneurysm and occlusive disease in comparison with isolated occlusive disease (40). Several studies that examined and compared risk factors in patient populations with isolated abdominal aortic aneurysm and aortoiliac occlusive disease have found a higher incidence of myocardial infarction (41) and ischemic cardiac disease (13) in patients with abdominal aortic aneurysm, as well as a higher incidence of postoperative mortality one year after surgery in patients with abdominal aortic aneurysm (42). Hence, further studies and clinical investigations are needed to examine cardiac risk factors and influence on cardiac outcomes in patients population with isolated abdominal aortic aneurysm, isolated aortoiliac occlusive disease and concomitant abdominal aortic aneurysm and aortoiliac occlusive disease.

Conclusion

Abdominal aortic surgery is a high-risk surgery for the development of adverse cardiac events. Therefore, adequate assessment of the risk of cardiac complications, following official recommendations in preoperative management of the patient, and postoperative intensive care treatment are of great importance in reducing the incidence of postoperative morbidity and mortality.

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