Anesthesia for Vascular Surgery
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Introduction
The changes in the practice of vascular surgery from the traditional open vascular reconstructions and repairs to percutaneous or mini-incision approaches for endovascular repairs may reduce morbidity and mortality of traditionally high-risk vascular surgical procedures.\(^1\) Rapidly increasing elderly population will also likely increase the number of vascular procedures performed.

Anesthesia specialization on vascular surgical procedures may be associated with improved outcomes. As shown by Walsh at al. in retrospective cohort study, vascular anesthesia specialization reduced early (within 30 days of surgery) and medium-term (within two years of surgery) mortality rates following both elective and emergency major vascular surgeries (lower limb revascularization, AAA repair, endovascular aneurysm repair and carotid endarterectomy).\(^2\)

Pre-anesthesia evaluation and management of vascular patient
Atherosclerosis is a systemic inflammatory disease affecting regional circulations (coronary artery disease, cerebral vascular disease, renal artery disease, peripheral artery disease) of predominantly elderly population. Ischemic heart disease and cerebrovascular disease are two of six independent risk predictors for patients undergoing nonurgent major noncardiac surgery (also including congestive heart failure, insulin dependent diabetes, preoperative renal insufficiency and high-risk surgery).\(^3\) Most of the open vascular surgeries belong to the category of high-risk procedures.

ACC/AHA 2007 Perioperative Guidelines use algorithmic approach for evaluation and care for noncardiac surgery.\(^4\) The stepwise approach takes into consideration urgency of surgery (emergency cases are taken to the operating room without further cardiac evaluation), patient’s preoperative functional status, presence of clinical risk factors and surgical risk stratification.

Active cardiac conditions are unstable coronary syndromes, decompensated heart failure, significant arrhythmias, and severe valvular disease.

Clinical risk factors are history of ischemic heart disease, history of compensated or prior heart failure, history of cerebrovascular disease, diabetes and renal insufficiency. Four metabolic equivalents (MET) equal moderate intensity physical activity.

Open aortic aneurysm repairs and lower extremity revascularization procedures are considered high risk surgical procedures with combined incidence of cardiac mortality and morbidity more than 5%\(^5\). Carotid endarterectomy and endovascular aortic aneurysm repair are intermediate cardiac risk procedures with combined incidence of cardiac mortality and morbidity 1% to 5%\(^4\).

Preoperative Coronary Revascularization
Coronary Artery Revascularization Prophylaxis (CARP) Trial published in 2004 studied impact of prophylactic coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI) on long-term mortality of patients scheduled for vascular surgery.\(^5\) The study showed no benefit of prophylactic revascularization. However, authors excluded the patients with unstable coronary syndrome, severely reduced left ventricular function, left main coronary artery disease, and aortic stenosis. This methodological concern limits generalization of the results to high risk patients.
Patients undergoing elective noncardiac procedures who are found to have prognostic high-risk coronary anatomy and in whom long-term outcome would likely be improved by coronary bypass grafting should generally undergo coronary revascularization before a noncardiac elective vascular surgical procedure or noncardiac operative procedures of intermediate or high risk.\(^4\)

Percutaneous coronary revascularization should not be routinely performed in patients who need noncardiac surgery unless clearly indicated for high-risk coronary anatomy, unstable angina, myocardial infarction, or hemodynamically or rhythmically unstable active coronary artery disease amenable to percutaneous intervention.\(^4\)

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**Figure 1. Cardiac evaluation algorithm for high and intermediate risk vascular surgery**

**Perioperative Medical Therapy**

**Beta-blockers**

2009 American College of Cardiology Foundation (ACCF)/American Heart Association (AHA) Focused Update on Perioperative Beta Blockade revised the existing guidelines published in 2007.\(^6\) Based on this update beta blockers should be continued in patients undergoing surgery who are receiving beta blockers for treatment of conditions with ACCF/AHA indications (Class I). Beta blockers titrated to heart rate and blood pressure are recommended for vascular surgery patients with high cardiac risk due to coronary artery disease or due to presence of more than one clinical risk factors (Class IIa).

Although initial studies showed cardiac benefit with the use of perioperative beta blockers, more recent studies question the benefit of perioperative beta blockade especially in patients at moderate to low risk of cardiac events.\(^7\)

Metoprolol after Vascular Surgery study published in 2006 showed no difference in cardiac events in patients receiving perioperative beta blockers versus those receiving placebo (10.2\% vs. 12\%, P = 0.57).\(^8\) The rate of intraoperative hypotension requiring treatment (46.3\% vs.
33.6%, P < .001) and bradycardia requiring treatment (21.5% vs. 7.6%, P < .001) was significantly higher in Metoprolol group.

Table 1: Classification of Recommendations

<table>
<thead>
<tr>
<th>Class I</th>
<th>Class IIa</th>
<th>Class IIb</th>
<th>Class III</th>
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<tbody>
<tr>
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<td>Benefit &gt;&gt; Risk</td>
<td>Benefit ≥ Risk</td>
<td>Risk ≥ Benefit</td>
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<td>It is reasonable to perform procedure / administer treatment</td>
<td>Procedure/ treatment may be considered</td>
<td>Procedure / treatment Should not be performed / administered</td>
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In the Perioperative Ischemic Evaluation (POISE) study published in 2008 fewer patients in the Metoprolol group than in the placebo group reached the primary endpoint – a composite of cardiovascular death, non-fatal myocardial infarction, and non-fatal cardiac arrest (5.8% vs. 6.9%, hazard ratio (HR) 0.84, 95% CI 0.70 – 0.99; p = 0.0399). However, there were more deaths in Metoprolol group than in the placebo group (3.1% vs. 2.3% patients, HR 1.33, 95% CI 1.03 – 1.74; p = 0.0317) and more patients in the Metoprolol group than in the placebo group had a stroke (1% vs. 0.5%, HR 2.17, 95% CI 1.26 – 3.74; p = 0.0053). Based on recently published data, ACCF/ AHA guidelines restrict Class I recommendations to those patients already on beta blockers.

Beta-blockers have potential beneficial effects outside the prevention of cardiac events. In addition to reducing anesthetic and analgesic requirements during the perioperative period, beta-blockers have neuroprotective effects in patients with brain trauma and possible effectiveness in the management of intraoperative awareness-induced post-traumatic stress disorder. Statins

Chronic therapy with statins should continue through perioperative period. Statins are very effective at reducing the incidence of myocardial infarction, stroke and other manifestations of vascular disease. The adverse event rates are very uncommon and the benefit risk ratio is extremely high. The effects of statins extend far beyond their effects on cholesterol levels: pleiotropic effects include vasoprotective mechanisms, comprising improved endothelial function, increased bioavailability of nitric oxide, immunomodulatory and antiinflammatory properties, stabilization of atherosclerotic plaques, as well as antioxidant and stem cell-regulating capacities.

**Angiotensin converting enzyme inhibitors (ACEI) and angiotensin receptor blocking agents (ARA)**

Risk of hypotension requiring vasopressors during anesthesia makes it controversial whether to stop or continue ACEI/ARA until the day of surgery. Rosenman et al. published in 2008 random-effects meta-analysis from 5 studies totaling 434 patients which suggested that patients receiving an immediate preoperative ACEI/ARA dose were more likely (RR 1.50, 95% CI 1.15-1.96) to develop hypotension requiring vasopressors at or shortly after induction of anesthesia.

An observational cohort study of 883 consecutive patients undergoing elective open abdominal aortic aneurysm repair showed increased mortality associated with preoperative renin-angiotensin system (RAS) blockade. The estimated odds ratio for 30-day mortality
associated with RAS blockade was 5.0 (CI (95) 1.4-27). Perhaps more complex review by ACC/AHA task force and practice guidelines would better assist physicians in clinical decisions regarding ACEI/ARA preoperative administration.

Anesthesia for lower extremity revascularization

Vascular surgery patients typically suffer from multiple organ systems comorbidities. Incidence of severe coronary artery disease reaches 25% and there is an increased risk of myocardial infarction after vascular surgery. Complexity of the preoperative clinical condition combined with high risk vascular surgery makes vascular surgery anesthesia a challenge even for an experienced anesthesiologist.

One of the unsolved controversies of anesthetic management is related to choice of regional (mostly neuraxial) and general anesthesia.

Almost all anesthetic agents in various combinations have been used successfully for these operations. Successful conduction of general anesthesia depends more on thorough preoperative evaluation and careful intraoperative management with appropriate monitoring than on anesthetic technique per se.

Regional anesthesia is usually more time consuming, has a finite failure rate, and there is a category of patients in whom lying still for several hours is an unachievable goal (chronic pain, dementia, orthopnea…). There is obvious need of general anesthesia when vein harvesting from patient’s upper extremity is part of the planned procedure.

Employment of regional anesthesia avoids the periods of hemodynamic instability during induction, and emergence from general anesthesia.

General anesthesia does not attenuate the stress response as well as regional anesthesia.

Attenuated sympathetic nervous system activation in patients receiving epidural anesthesia/neuraxial opiate analgesia is associated with a reduced frequency of hypertension in the early postoperative period. In addition; increased plasma catecholamine values are associated with postoperative vascular graft failure and suppression of fibrinolytic activity.


Neuraxial techniques, particularly epidural anesthesia and continued epidural analgesia attenuate hypercoagulable response and reduce the frequency of thromboembolism after major vascular surgery. However, the effect of neuraxial techniques is insufficient as the sole method of thromboprophylaxis and routine DVT prophylaxis is now standard part of perioperative care.

While earlier studies showed a decreased rate of cardiovascular complications in patients receiving neuraxial block, more recent studies revealed no significant difference in cardiac outcomes of patients receiving either neuraxial block or general anesthesia for peripheral vascular surgery. A systematic review of four studies that compared neuraxial anesthesia with general anesthesia for lower limb revascularization surgery showed no evidence of differences in the postoperative risks of death, myocardial infarction or leg amputation between the two types of anesthetic. The risk of pneumonia was less after neuraxial anesthesia in one of the studies which reported this outcome.

Monitoring during anesthesia for peripheral vascular surgery is largely affected by choice of open or endovascular technique. Open vascular technique in addition to standard ASA (American Society of Anesthesiology) monitors frequently requires arterial line which also facilitates blood sampling for blood gas, electrolytes, glucose, and hematocrit in patients with multiple clinical risk factors and significant blood loss.
There is a general trend in hemodynamic monitoring towards less invasive techniques. When using general anesthesia with positive pressure ventilation the fluid responsiveness monitoring methods (PiCCO, LiDCO, Flotrac/Vigileo, ECOM...) are available for goal-directed fluid management. Respiratory variations in arterial pulse pressure ∆PP has been considered the gold standard for fluid responsiveness monitoring.²¹

**Anesthetic and perioperative management of Carotid Artery Revascularization**

Stroke is the third most common cause of death and the leading neurologic cause of long-term disability in the United States. The majority of strokes are ischemic in nature. Up to 20% of ischemic strokes are result of carotid artery atherosclerotic disease and most ischemic events are caused by embolization of material of the atherosclerotic plaque.²²

Carotid endarterectomy (CEA) remains the gold standard for carotid revascularization, although more recently, carotid angioplasty and stenting (CAS) emerged as a minimally invasive alternative.

Based on the recommendations of the American Heart Association, symptomatic (history of TIA or stroke) patients with 50% to 99% stenosis are best treated with CEA if the risk of perioperative stroke or death is less than 6%, with greatest benefit in those with severe stenosis 70% to 99%. For asymptomatic patients with 60% to 99% stenosis CEA is recommended if the perioperative risk of stroke or death is less than 3% and if the patient has a life expectancy greater than 5 years.²³,²⁴

Current data seem to support the use of CAS as an alternative to CEA in patients with anatomic risk factors, with contralateral occlusion, and severe, multiple medical comorbidities. CAS is best avoided in patients older than 80 years of age, those with complex vascular anatomy and specific unfavorable lesion characteristics, and possibly those with symptomatic disease.²²

**Preanesthesia evaluation**

Carotid artery disease is a local manifestation of systemic disease. Coronary artery disease, hypertension, diabetes mellitus and renal insufficiency are frequent comorbidities of patients with carotid vascular disease. Ouriel and colleagues compared outcomes of high risk patients versus low risk patients undergoing CEA. They found a significant increase in the perioperative risk of stroke, death, and myocardial infarction in high risk patients (with severe coronary artery disease, chronic obstructive pulmonary disease, or renal insufficiency).²⁵

The ACC/AHA 2007 guidelines consider CEA an intermediate risk procedure.⁴

Risk of perioperative stroke is most strongly associated with an active neurologic process prior to surgery. Approximately 25% of strokes associated with CEA occur intraoperatively.

Preoperative hypertension should not delay elective surgery unless the blood pressure > 180/100 mmHg. Perioperative glycemic control and elimination glucose-containing intravenous infusions are strongly recommended.

**Anesthesia management of CEA**

Regional or general anesthesia can be used for carotid andarterectomy. Recently the third option – patient cooperating during general anesthesia-was introduced. During carotid clamping general anesthesia is reduced so that patient is able to respond to verbal statements and neurological monitoring can be performed.²⁶

**General anesthesia** usually implies balanced technique. Sevoflurane and Desflurane have shortest extubation times. The use of Nitrous oxide given its potential to increase the size of air emboli is controversial. Propofol and narcotics provide good hemodynamic stability. Almost all commonly used anesthetics reduce cerebral oxygen requirements. Patients are kept normothermic and normocarbic. Blood pressure is maintained at patient’s “normal” to high
values in most situations. Besides standard ASA monitoring, invasive arterial pressure is standardly monitored.

The routine use of shunting in patients under general anesthesia largely depends on surgeon’s preference. Recent randomized trial compared selective shunting (SS) versus routine shunting (RS). Selective shunting was used only if systolic stump pressure was < 40 mmHg. Study showed no significant difference in combined perioperative transient ischemic attack and stroke rates (2% in RS vs 2.9% in SS, p>0.99).\(^{27}\)

CNS monitoring is prudent when surgeons use shunts selectively. The 16-channel EEG is considered a gold standard. Other monitoring options include EEG, somatosensory evoked potentials (SSEP), measurement of stump pressure, cerebral oximetry, near-infrared spectroscopy, and transcranial Doppler.

No difference in stroke rate has been demonstrated with the use of particular monitoring technique.\(^{28}\)

**Regional anesthesia** for CEA can be achieved by superficial cervical plexus block, deep cervical plexus block, epidural anesthesia, or straight local anesthesia (frequently performed by surgeon).

Serious potential complications of the uncommonly used epidural anesthesia include dural puncture, epidural venipuncture and respiratory muscle paralysis. Hypotension and bradycardia are the most frequent side-effects of this technique.\(^{29}\)

Cervical plexus block (deep, superficial, or their combination) is a technique performed by anesthesiologist. The most common complication of cervical plexus block is systemic local anesthetic toxicity, caused by either intravascular injection or vascular absorption in this highly vascularized region.

Awake patient monitoring during local or regional anesthesia seems the most reliable method of predicting the need for a shunt after carotid clamping and can be regarded as the accepted standard for the evaluation of patient’s intraoperative neurologic status.

Aleksic et al. did not find significantly different outcome between the group of high risk patients (ASA 4, “hostile neck”, recurrent ICA stenosis, contralateral ICA occlusion, and age ≥ 80 years) and the group of low-risk patients who underwent CEA under local anesthesia. It does not appear justified to refer high-risk patients principally to carotid angioplasty and stenting when local anesthesia can be chosen to perform CEA.\(^{30}\)

Meta-analysis of the randomized studies published in 2009 showed that there was no evidence of a reduction in the odds of operative stroke or death with regional anesthesia (odds ratio (OR) 0.85, 95% confidence interval (CI) 0.63 to 1.16). There was a trend towards lower operative mortality with regional anesthesia (OR 0.62, 95% CI 0.36 to 1.07).\(^{31}\)

**Carotid artery stenting** requires minimal to moderate sedation and standard monitors. Dexmedetomidine seems to be an alternative to more traditional sedation with benzodiazepines and opioids.

**Postoperative considerations**

Hemodynamic instability is common after CEA or CAS. Hypertension particularly in patients with preoperative poorly controlled hypertension is more frequent than hypotension. Hypertension may worsen cardiac outcome by myocardial infarction, and neurologic outcome by triggering the hyperperfusion syndrome (may lead to intracerebral hemorrhage). Increased sensitivity of the baroreceptors after atherosclerotic plaque removal may lead to postoperative hypotension and bradycardia which, when properly treated, are usually not associated with serious cardiac adverse outcomes. Some institutions keep post CEA/CAS patients longer in the recovery room so that airway obstruction caused by hematoma can be promptly diagnosed and managed.

Stroke during the postoperative period is mostly embolic in origin.
Conclusion
The aim of this article is to summarize information related to anesthesia for vascular surgery published in recent years. Anesthetic considerations for aortic reconstructions are not mentioned since they are presented as a separate topic of the CEEA 2010 Course. Optimization and standardization of perioperative care may result in improvement of outcomes of the vascular surgery. Author believes that guidelines prepared by multidisciplinary team of professionals and employing “protocolized medicine” may help to achieve this goal.

References
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