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Carotid Endarterectomy: Asleep Versus Awake

Jeffrey B. Dobyns, D.O.
University of Alabama at Birmingham, Birmingham, AL

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Stem Case and Key Questions Content

A 63-year-old Caucasian female presents to the operating room for left carotid endarterectomy following a transient ischemic attack (TIA) experienced 3 days prior. Her symptoms, which involved slurring of speech and facial droop, resolved within 24 hours. She was begun on aspirin and clopidogrel in the Emergency Room, and those medications are continued to the day of surgery. Since that admission she is also begun on simvastatin and atenolol. CT scan of the head was negative. Carotid duplex scan demonstrated 75% left carotid stenosis, and 60% right carotid stenosis. She denies significant past medical history. She has a 50-pack-year smoking history. She is 5'8", 60 kg, and amenable to "whatever anesthetic you think is best."

1. Discuss any further indicated tests prior to the beginning of the procedure.
2. Discuss perioperative stroke risk reduction therapies.
3. Evaluate risk factors for and implications of carotid artery disease.
4. Discuss anesthetic options for carotid endarterectomy.
5. Discuss some of the physiologic concerns of carotid endarterectomy as pertains to the anesthesiologist.
6. Discuss patient selection criteria for regional anesthesia.
7. Discuss anesthetic goals for carotid endarterectomy. The surgeon requests a regional anesthetic and the patient is agreeable.

The patient is taken to the operating room, ASA standard monitors applied and appropriate time-out conducted.

1. What regional anesthesia techniques are available for this procedure?
2. What are some of the advantages of regional anesthesia over general anesthesia for this procedure?
3. What are some of the disadvantages of regional anesthesia?
4. Discuss the performance of superficial and deep cervical plexus blocks.
5. Discuss intraoperative cerebral monitoring techniques.
6. Discuss arterial line and whether or not it is necessary.
7. Discuss hemodynamic management under regional anesthesia.

The surgeon informs you that he cannot operate under regional anesthesia and requests general anesthesia. The patient is taken to the operating room, ASA standard monitors applied and appropriate time-out conducted.

1. What general anesthesia techniques are available for this procedure?

2. What are some of the advantages of general anesthesia over regional anesthesia for this procedure?
3. What are some of the disadvantages of general anesthesia?
4. Discuss volatile versus opioid-based anesthetic techniques.
5. Discuss intraoperative cerebral monitoring techniques.
6. Discuss arterial line and whether or not it is necessary.
7. Discuss hemodynamic management under general anesthesia.

Three minutes after clamping of the carotid artery, evidence of cerebral ischemia is detected.
1. Evaluate and compare different cerebral monitors and their efficacy.
2. Discuss management of intraoperative cerebral ischemia if patient is under regional anesthesia or general anesthesia.
3. Discuss conversion of regional to general anesthesia.
4. Discuss shunt indications, complications, and management.

The procedure is completed uneventfully; the patient emerges from general anesthesia, and is taken to the post-anesthesia recovery unit.
1. Discuss the goals for anesthesia emergence.
2. Discuss some of the postoperative complications of carotid endarterectomy: cardiovascular, neurologic, hyperperfusion syndrome, and airway.
3. What are the concerns and physiologic consequences of “second-side” carotid endarterectomy?

Best Clinical Practices.
Based upon the discussion, develop a series of best clinical practices applicable to each person’s individual practice.
1. Early stroke risk assessment and stratification
2. Optimization of medical management of co-existing disease and stroke risk factors
3. Continue dual antiplatelet/anticoagulation whenever feasible
4. Cardiovascular testing in accordance with ACC/AHA Guidelines
5. Maintain intraoperative hemodynamic stability
6. Maintain MAP at patient’s normal or slightly above
7. Aggressive perioperative hyperglycemic management
8. Early identification and treatment of cardiac and neurologic complications

Model Discussion Content

Carotid endarterectomy is one of the more challenging anesthetics, both physically and mentally. The argument over which anesthetic, regional or general, is “best” has been the source of considerable discussion and study. Many studies have been conducted, often at great undertaking, in an effort to determine which technique is associated with better outcomes. The results have thus far been equivocal. There are pros and cons of both anesthetic techniques. Stroke is the leading cause of adult neurologic disability and the fourth leading cause of death in the United States[1]. 80% of the approximately 700,000 strokes occurring in the United States each year are caused by blockage of a blood vessel; a thromboembolic event. About 2 million of the 3 million United States stroke survivors sustain some degree of permanent disability. The overall yearly cost to the nation for treating stroke and its sequelae is $40 billion[1].

Pathophysiology and Pathogenesis of Carotid Artery Disease

The pathogenesis differs among ethnic groups, with extracranial carotid and cardiac thromboembolic events being the most common cause of stroke in Caucasians, and intracranial atherosclerotic disease the more common cause in African-Americans. Women have a lower stroke rates than men until about the age of 75, and at that point, the trend reverses, and women have higher stroke rates. Transcranial Doppler and duplex ultrasonography studies have suggested that carotid artery stenosis of 70-75%, with a residual luminal diameter of 1.5 millimeters is the point at which a pressure drop occurs across the stenotic segment[2]. This represents the point at which the stenosis becomes hemodynamically significant, and TIA or stroke is likely to occur if collateral cerebral blood flow is inadequate. Carotid artery disease is a manifestation of generalized atherosclerotic vascular disease present in other parts of the body. A thromboembolic stroke or TIA is usually the initial presentation of carotid artery disease. In 60% of patients, a stroke is preceded by TIA, and the highest mortality occurs within two years of the TIA.

Risk Factors for Carotid Artery Disease

Risk factors for carotid artery disease are essentially the same as those for generalized atherosclerosis. Many risk factors are modifiable, such as hypertension, hyperlipidemia, tobacco abuse, insulin resistance, diabetes, metabolic syndrome unhealthy diet, overweight/obesity, sedentary lifestyle, excessive alcohol consumption, elevated serum homocysteine levels, and some are non-modifiable, such as age, family history of atherosclerosis, and genetic factors.

Indications for Carotid Artery Revascularization

The primary goal for carotid revascularization, by CEA or CAS, is to prevent stroke, and its debilitating consequences. Intervention is generally undertaken when the degree of carotid stenosis is 70% or greater. Both the NASCET and ECST trials demonstrated a highly beneficial effect of CEA for patients with angiographically confirmed high-grade carotid stenosis (70-99%) when compared to medical management alone[2, 3]. Benefits were only modest for CEA performed in patients with stenotic lesions below 70%[2]. While the NASCET Trial recommended surgical intervention within two weeks of the most recent neurologic event, surgery should be delayed if major perioperative risk factors, such as decompensated congestive heart failure or unstable angina, are found on physical examination[2]. Emergent endarterectomy for stroke-in-evolution or crescendo TIA is associated with high operative risk[4].

Anesthetic Goals
Anesthetic goals are identical for carotid endarterectomy or carotid artery stenting regardless of whether performed under general or regional anesthesia. In general, these goals are the maintenance of adequate cerebral perfusion pressure and oxygenation, maintenance of cardiovascular stability to minimize myocardial injury, monitoring for adequacy of cerebral blood flow during carotid cross-clamping, minimization of the response to stress and surgical stimulation, tailoring the anesthetic technique to accommodate the method of cerebral monitoring being utilized, minimization of hemodynamic lability, providing for rapid, smooth awakening to allow for postoperative neurologic examination, and aggressive hemodynamic control on emergence.

General Anesthesia
While the outcomes between general and regional anesthesia are similar, this does not suggest that the anesthetic technique chosen is unimportant. General or regional anesthesia performed well (or poorly) can contribute to good (or poor) outcomes. Factors most likely to result in good outcomes include a quality preoperative evaluation, appropriate case selection, preoperative medical optimization, and the experience and expertise of the patient care teams. General anesthesia for carotid endarterectomy allows superior surgical operating condition as the patient is still and muscles are relaxed. General anesthesia also allows for a secured airway and the ability to control and manipulate oxygenation and ventilation. The main disadvantage of general anesthesia for carotid endarterectomy is the loss of the most sensitive and specific monitor of cerebral function, which is an awake patient. This necessitates reliance on less sensitive and less specific monitors of cerebral function, which may result in an intraoperative stroke not being recognized. There is greater blood pressure lability with general anesthesia and residual anesthetic may cloud a postoperative neurologic examination. Emergence is challenging in this setting and hemodynamics should be tightly controlled. There is also a greater incidence of postoperative wound hemorrhage following general anesthesia.

Regional Anesthesia
Proper patient selection is important, as the patient must be able to cooperate and to lie flat and still. The success of CEA under regional anesthesia requires a motivated patient, surgeon, and anesthesiologist. One of the main advantages of performing carotid endarterectomy under regional anesthesia is that it allows continuous neurologic examinations throughout the procedure as a continuous monitor of cerebral function. Regional anesthesia is also associated with less shunt usage and greater hemodynamic stability. It is simple to perform, reliable and cost-effective, and eliminates the hemodynamic fluctuations associated with laryngoscopy and intubation. Disadvantages of regional anesthesia include block-related complications such as intra-arterial or subarachnoid injection, local anesthetic toxicity, or block failure. The airway is unsecured, and may require rapid intubation in the event of intraoperative decline in neurologic function. Claustrophobic patients, patients with back and neck pain, morbidly obese patients or patients with obstructive sleep apnea may not tolerate a regional anesthetic. There is greater intraoperative hypertension with an awake carotid endarterectomy, necessitating manipulation to lower the blood pressure, whereas with general anesthesia, the blood pressure frequently

must be manipulated up. Patients who have had prior neck surgery or for whom the dissection may be challenging would be better candidates for general anesthesia rather than regional. Phrenic nerve and superior laryngeal nerve block is common and may be poorly tolerated in patients with poor pulmonary function.

Conversion Rates of Regional to General Anesthesia

Data from the General Anaesthesia versus Local Anaesthesia for Carotid Surgery (GALA) Trial in 2008 indicated a conversion rate from regional to general anesthesia of 3.8% (69 of 1773 patients)[5].

Monitors of Cerebral Function

Monitors of cerebral function include electroencephalography (EEG), cerebral oximetry, somatosensory evoked potentials (SSEP), stump pressure, and transcranial Doppler (TCD). While none of these monitors is perfect in the detection of cerebral ischemia, the awake patient is probably the most sensitive and specific. After the common and external carotid arteries are clamped, pressure in the distal internal carotid artery reflects pressure transmitted from the contralateral side via the Circle of Willis. A wide range of values (25-70 mm Hg) of stump pressure have been proposed below which shunting should be considered. Many studies have found that stump pressure measurement is not sensitive at identifying those patients who develop cerebral ischemia with carotid cross clamping. Electroencephalography, or EEG, despite being widespread and easy to use, has many limitations, not the least of which being limited sensitivity and specificity at 69% and 89% respectively[6]. While there is no doubt that EEG is affected by cerebral ischemia, EEG is also affected by other factors involved, such as volatile anesthetic agents, nitrous oxide, $PaCO_2$, hypothermia and hypotension. The EEG monitors and detects ischemia in the superficial layer of the cerebral cortex, and does not detect ischemia that may occur in subcortical structures. The anesthetic technique must be modified to keep any volatile anesthetic agent less than 1 MAC to avoid interference with EEG signals. Somatosensory Evoked Potentials (SSEP) offers a theoretical advantage over EEG because SSEP monitors not only the cerebral cortex but also deeper structures of the brain. Stimulation of a peripheral nerve passes through first- and second-order neurons and brainstem synapses before evoking a response in the cerebral cortex. Clinical studies, however, do not substantiate this theoretical benefit[7-9]. SSEP monitors the middle cerebral artery distribution, and intraoperative strokes or ischemia outside of this region may go undetected. SSEP signals are adversely affected by volatile anesthetics and nitrous oxide, so intraoperative use of SSEP requires a TIVA-based general anesthetic. Transcranial Doppler relies upon the thin petrous portion of the temporal bone as an acoustic window that allows ultrasound visualization of the middle cerebral artery. A decrease in middle cerebral artery flow velocity (MCAv) on carotid cross clamping indicates the need for shunt placement. The main advantage of TCD is its ability to detect emboli, since the majority of intraoperative strokes in this patient population are embolic rather than ischemic. TCD also allows identification of high flow states that may predispose to hyperperfusion syndrome. TCD values after carotid cross clamping are quantified in terms of preclamp values such that MCAv >40% of preclamp value is indicative of absent ischemia, MCAv 16-40% of preclamp value is indicative of mild ischemia, and MCAv of 0-15%

of preclamp values indicates severe ischemia[10]. Cerebral oximetry uses infrared technology to monitor oxygen saturation of the frontal lobes. A decrement of 20% or greater during carotid cross clamping is considered significant and indicates the need for shunting or other maneuvers to increase cerebral blood flow. While it can correlate with clinical variations of EEG during carotid cross clamping, it has a relatively low sensitivity and specificity for predicting the need of an intraoperative shunt[11].

Management of Intraoperative Ischemia
Primary management of cerebral ischemia occurring intraoperatively upon placement of the carotid cross-clamp would be insertion of a shunt. It is appropriate to maintain the systolic or mean arterial pressure 20% above preoperative values to augment perfusion pressure through the Circle of Willis[9]. TCD studies also have noted that increased pressure is necessary to maintain perfusion through the surgical shunt. Normocarbia should be maintained, as hypocarbia may cause ipsilateral vasoconstriction and expand the ischemic zone, while hypercarbia may cause contralateral vasodilation and cause cerebral steal. Supplemental oxygen should be provided to the awake patient, and FiO_2 should be increased in the patient under general anesthesia. One of the primary decisions to be made during the course of CEA is whether or not to insert a shunt. In the awake patient with evidence of cerebral ischemia, a shunt is indicated. In the patient under general anesthesia, the decision becomes less obvious. Some surgeons will shunt all patients under general anesthesia, while others may only shunt those with significant bilateral disease. Still other surgeons will shunt based upon data obtained from monitors of cerebral function. Perioperative stroke rates for routine shunting versus selective shunting were similar (0% versus 2%)[6,7]. Shunt complications include atheroma emboli, air emboli, acute arterial dissection, and acute arterial occlusion

Emergence
Emergence from anesthesia can be one of the more challenging parts of the CEA anesthetic. The primary goals are a smooth, quick emergence with controlled systemic and cerebral hemodynamics. There are several other concerns surrounding emergence and the immediate postoperative period, such as minimization coughing and bucking on endotracheal tube, quick extubation to minimize surgical site hemorrhage and hematoma formation, tight blood pressure and glucose control, prevent nausea and vomiting, and provision for optimal postoperative neurologic exam.

Postoperative Complications
Cardiovascular Complications: Myocardial infarction is the most common cause of morbidity and mortality in the postoperative period. Neurologic Complications: Strokes may occur, and these are usually embolic in origin. Cranial nerve injury occurs in roughly 10% of patients undergoing CEA. The cranial nerves most commonly injured are the hypoglossal, facial, vagus, recurrent laryngeal, and accessory nerves[12]. Hyperperfusion Syndrome: Roughly 1-3% of patients undergoing CEA develop a very dramatic increase in cerebral blood flow with MCAv exceeding 100% of preoperative values. These patients develop a classic clinical triad of ipsilateral headache, hypertension, and focal neurologic deficits with or without seizures. If not treated,

cerebral edema, intracerebral or subarachnoid hemorrhage and death may result. Airway Complications: Bleeding leading to airway obstruction due to an expanding hematoma is a true postoperative emergency, and may be worsened by hypertension. The airway should be resecured as soon as feasibly possible and the patient returned to the operating room for control of bleeding and hematoma evacuation. Reopening of the incision and bedside evacuation of the hematoma may be required depending upon the clinical scenario.

Physiologic Consequences of Second-Side (Bilateral) Carotid Endarterectomy
Patients who present with bilateral high-grade carotid artery stenosis undergo surgical intervention as a staged procedure, with the more critically stenotic lesion addressed first. Bilateral recurrent laryngeal nerve injury and resultant bilateral vocal cord paralysis can result in life threatening upper airway obstruction. This should be anticipated in patients who have previously undergone contralateral carotid endarterectomy or neck surgery. Bilateral carotid endarterectomy is associated with loss of the normal ventilatory and arterial pressure responses to acute hypoxia due to damage or denervation of the carotid sinus and patients have an increased resting partial pressure of arterial carbon dioxide. Due to the loss of normal physiologic response to hypoxemia and hypercarbia, these patients are highly sensitive to opioids.

Summary
Anesthesia for carotid endarterectomy is challenging and individual anesthetic techniques are changing. While vascular surgeons perform the majority of carotid endarterectomy procedures, it must be remembered that the carotid endarterectomy is very much a neurosurgical procedure as well. Many studies have been performed at great undertaking in an effort to determine whether one anesthetic technique is superior to another or whether one surgical technique is superior to another, the outcomes of these studies have been equivocal. The anesthesiologist, surgeon and patient with consideration of skills, preferences, local facilities and patient co-morbidities should determine the choice of general anesthesia versus regional anesthesia. Monitors of cerebral function have widely varying degrees of sensitivity and specificity, with the most sensitive and specific monitor being a patient who is awake.

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