Carotid Endarterectomy: Continuing Challenges

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Carotid endarterectomy (CEA) patients are often elderly, often have advanced cerebrovascular disease, and usually have significant coexisting disease. Anesthetic management requires an understanding of the physiological stress imposed by disruption of the major cerebral hemispheric blood supply as well as an appreciation of the physiological constraints associated with the coexisting diseases.

Guidelines for Performing CEA

Several prospective, randomized studies have reported superior outcome for medically stable patients with symptomatic, high-grade carotid stenoses (70%–99%) after CEA combined with best medical therapy compared with medical treatment alone. Patients with 50%–70% stenosis also benefit from surgery but not to the same extent; i.e., the benefit from surgery is related to the extent of the stenosis. Symptomatic patients with <50% stenosis do not benefit from surgery. In asymptomatic patients with >60% stenosis, CEA may benefit males, provided perioperative morbidity and mortality are <3%. Based on these studies, guidelines for performing CEA have been formulated by both the American Heart Association and the Canadian Neurosurgical Society.

Physiologic Considerations

Cerebral Perfusion

Cerebral blood flow (CBF) is related to cerebral perfusion pressure (CPP) and cerebral vascular resistance (CVR) according to the equation CBF = CPP/CVR, where CPP equals mean arterial blood pressure (MAP) minus intracranial pressure (ICP) or central venous pressure (CVP), whichever is greater. CVR is a function of blood viscosity and the diameter of the cerebral resistance vessels. Optimization of CBF during CEA is hampered by the fact that the only factors readily amenable to intraoperative manipulation are arterial blood pressure and $Paco_2$, which impact CPP and CVR respectively.

Carbon Dioxide Tension

In the absence of evidence that either hyper- or hypocapnia improves outcome, the most common approach is maintenance of normocapnia for the patient, i.e., a $Paco_2$ that produces a normal pH in the absence of coexisting metabolic acidosis.

Blood Pressure

In patients with preexisting chronic hypertension, both the upper and lower limits of autoregulation are shifted toward higher pressures. In patients with cerebrovascular disease, and during carotid cross-clamping, the CBF response to changes in $Paco_2$ is impaired. Under these conditions, improvement in CBF is likely to be largely dependent on increases in CPP emphasizing the relatively greater importance of blood pressure control during CEA surgery.

During CEA blood pressure should be maintained within the normal preoperative range. Mild increases in systolic blood pressure of up to 20% above normal at the time of cross-clamping are acceptable, but hypotension and severe hypertension should be avoided.

Surgery Versus Angioplasty

Percutaneous transluminal carotid angioplasty and/or stenting procedures are currently under investigation as alternatives to CEA. Proponents suggest that these procedures will potentially expand the population of suitable patients to include many classified as high-risk for CEA, including those with unstable cardiac conditions. Preliminary experience with these techniques is promising; however, pending the results of properly designed prospective trials validating safety, efficacy, and longevity, these treatments remain investigational.

Preanesthetic Assessment

The patient's state of health should be assessed based on history, pertinent physical examination, and chart review. Coexisting diseases should be assessed and

optimized. Common coexisting diseases include coronary artery disease, arterial hypertension, peripheral vascular disease, chronic obstructive pulmonary disease, diabetes mellitus, and renal insufficiency.

For patients with diabetes, perioperative blood glucose should be managed carefully to avoid both hypo- and hyperglycemia, as these are associated with worsening of cerebral ischemia.

Cardiac complications are a major source of mortality after CEA. Factors reported to correlate with increased perioperative cardiac morbidity include poorly controlled hypertension, congestive heart failure, and recent myocardial infarction. Cerebral angiograms should also be reviewed to identify patients with poor collateral circulation.

Anesthetic Management

CEA can be performed safely under general anesthesia or regional anesthesia (including local anesthetic infiltration). Experienced centers report similar morbidity and mortality and available evidence is insufficient to definitively establish the superiority of either technique. A large ongoing prospective British study is comparing outcomes between regional and general anesthesia.

Regional Anesthesia

Superficial and deep cervical plexus blocks are the most common regional anesthetic technique for CEA. Intraoperative monitors should include intra-arterial cannula for blood pressure measurements, continuous 5-lead electrocardiogram, pulse oximetry, and capnography. Supplemental oxygen should be provided with a mask or nasal prongs positioned to avoid the site of surgery.

Carefully titrated sedation using small, repeated, IV doses of fentanyl (10–25 μg) and/or midazolam (0.5–2 mg) should ensure a comfortable and cooperative patient during the operation. We have found remifentanil 0.01–0.05 μg/kg/min to be effective, and it also has the advantage of easy titratability. Propofol is a reasonable alternative administered as intermittent IV bolus doses (0.3–0.5 mg/kg) or as a small-dose continuous infusion (25–75 μg/kg/min). Provisions should be immediately available to convert to a general anesthetic if intraoperative conditions (e.g., stroke, restlessness) warrant.

Advantages of regional anesthesia include the following: 1) superior neurologic monitoring is associated with an awake patient with the potential to minimize interventions such as shunt insertion based on symptoms at cross-clamping; 2) it is less expensive; and 3) it is reported to be associated with more rapid recovery and shorter hospitalization.

Disadvantages of regional anesthesia include the following: 1) it requires an OR staff committed to working with patients under regional anesthesia (i.e., patience, gentle technique, reinforcement of block as needed in up to 50% of patients); 2) a lack of airway and ventilatory control; 3) a potential need to deal with complications in an awake patient (e.g., cerebral ischemia, airway obstruction, hypoventilation, confusion, agitation, angina); 4) the risk of complications associated with cervical plexus blocks.

General Anesthesia

General anesthesia represents the most common anesthetic technique for CEA. Intraoperative monitors should include intra-arterial cannula for blood pressure measurements, continuous electrocardiogram, pulse oximetry, and capnography. Central venous or pulmonary artery pressure monitoring is usually not needed.

The key consideration during induction of anesthesia is the maintenance of stable hemodynamic conditions during intubation, positioning and draping. Thiopental, midazolam, propofol, or etomidate are appropriate induction drugs and should be supplemented with an opioid. Tracheal intubation is facilitated with any of the nondepolarizing neuromuscular blocking drugs. Succinylcholine is contraindicated in patients with a paretic cerebral infarct. A light level of general anesthesia is usually maintained with either a combination of volatile anesthetic and opioid or propofol and opioid. We find remifentanil (0.1–0.3 $\mu g \cdot kg^{-1} \cdot min^{-1}$) together with 0.3–0.5 MAC desflurane or sevoflurane to be easily titratable and to result in crisply awake patients at the termination of surgery.

Blood pressure is maintained at preoperative levels. Small bolus doses of vasopressor (e.g., phenylephrine (40–60 μg) or ephedrine (5–7.5 mg) can be administered to support blood pressure if necessary. Infusions of phenylephrine may also be used. Vasopressor use should be cautious so as not to produce myocardial ischemia.

Advantages of general anesthesia include the following: 1) it may be more comfortable for patients and operating room staff; 2) it facilitates intraoperative control of ventilation, airway, and sympathetic responses; 3) it may facilitate management of complications such as cerebral ischemia (e.g., induced hypertension, pharmacologic suppression of EEG activity); and 4) the reduction in cerebral metabolism associated with general anesthesia may provide some cerebral protection.

Disadvantages of general anesthesia include the following: 1) the need for alternative methods to awake neurologic examination for monitoring cerebral function; 2) prolonged emergence may confuse postoperative evaluation; and 3) it is more expensive.

Neurological Monitoring

The purpose of neurological monitoring is to identify patients at risk for adverse neurologic outcome because of the development of cerebral ischemia, particularly during carotid cross-clamping. An awake patient represents the least expensive and most sensitive neurologic function monitor. Because an awake patient is not available during general anesthesia, a variety of other techniques have been used—electroencephalography (EEG), evoked potentials, carotid stump pressure measurements, transcranial Doppler (TCD), and CBF measurements, either individually or in combination (e.g., EEG and TCD). However, controversy continues to surround the reliability of each technique or combination to predict outcome accurately and no monitoring technique, including awake neurological examination, has yet been demonstrated to improve outcome. A confounding factor is that most strokes occur in the postoperative period and are embolic in nature.

Emergence

Emergence from anesthesia should be designed to avoid excessive coughing or straining and surges in systemic blood pressure, which may strain the fresh arteriotomy. Many surgeons prefer patients to be rapidly awake and extubated at the conclusion of the procedure to facilitate neurologic examination in the early postoperative period.

Postanesthetic Management

The intraarterial cannula should be maintained during the initial postoperative period to permit continuous blood pressure monitoring. All patients should receive supplemental oxygen with the adequacy of oxygenation monitored by pulse oximetry.

Postoperative hemodynamic instability is common (>40%) after CEA and is postulated to be related to carotid baroreceptor dysfunction. CEA performed using a carotid sinus nerve-sparing technique is associated with a higher incidence of postoperative hypotension likely as a result of increased exposure of the carotid sinus after removal of the atheromatous plaque. Hypertension after CEA is less well understood and has been reported to be more common in patients with preoperative hypertension and in those who undergo CEA in which the carotid sinus is denervated. Other causes of hemodynamic instability after CEA include myocardial ischemia/infarction, arrhythmias such as atrial fibrillation, hypoxia, hypercarbia, pneumothorax, pain, confusion, and distention of the urinary bladder.

Complications

Major postoperative complications after CEA include stroke, myocardial infarction, and hyperperfusion syndrome. Other complications associated with CEA include hematoma formation and cranial nerve palsies. As anesthesiologists are familiar with all except hyperperfusion syndrome, only the latter is described in any detail below.

Hyperperfusion Syndrome

An increase in CBF occurs frequently after CEA. Typically the magnitude of this increase is relatively small (<35%); however, in severe cases, increases in CBF can exceed 200% of preoperative levels and may be associated with headache (usually unilateral), face and eye pain, cerebral edema, seizures, and intracerebral hemorrhage. Patients at greatest risk include those with reduced preoperative hemispheric CBF because of bilateral high-grade carotid stenoses, unilateral high-grade carotid stenosis with poor collateral cross-flow, or unilateral carotid occlusion with contralateral high-grade stenosis. The syndrome is thought to result from restoration of perfusion to an area of the brain that has lost its ability to autoregulate.

Summary

Enormous progress has occurred in the past decade, validating the efficacy of CEA and defining indications for the procedure. Despite advances in surgical and anesthetic techniques, morbidity and mortality associated with CEA remain substantial. Further improvement in outcome after CEA will require advances in the development of effective interventions to prevent and/or treat cerebral ischemia (especially embolic events) and myocardial ischemia in the perioperative period.

Suggested Reading

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