

Carotid Endarterectomy

CEA is an intermediate risk surgery performed for Carotid Stenosis. It generally is performed for stenoses greater than 70%. Complications from carotid disease and CEA are numerous and often related to embolism rather than ischemia from reduced lumen diameter.

ANESTHETIC CONSIDERATIONS PATIENT:

- Patient population with significant probability of co-existing Diseases – CV disease, CVA (Neurologic Deficits), HTN, Renal Disease, COPD, DM
- Documentation of pre-existing neurological deficits prior to GA due to perioperative risk of CVA.
- Maintenance of adequate cerebral perfusion and potential for perioperative neurological monitoring.
- Anxious patients may not tolerate awake technique with LA infiltration/regional blockade.

ANESTHETIC CONSIDERATIONS PROCEDURE:

- Shared airway.
- Anesthetic technique has not been shown to affect outcomes.
- Significant perioperative hemodynamic alterations
 - Consider invasive BP monitoring
- Potential for postoperative airway obstruction requiring postoperative observation– hematoma, CN dysfunction, RLN palsy.
- Intermediate risk procedure with 0-4% risk of perioperative cardiac morbidity and mortality.

ANESTHETIC GOALS:

- Preoperative optimization of coexisting medical conditions.
- Perioperative maintenance of hemodynamic parameters within 20% of preoperative values. Supratherapeutic blood pressures indicated if severe contralateral disease.
- Provision of short acting anesthetic technique to facilitate postoperative neurological assessment.
- Anticipation and treatment of potential postoperative complications:
 - Airway obstruction
 - Neck hematoma
 - Perioperative CVA
 - Cerebral hyperperfusion syndrome
 - HTN/Hypotension

EPIDEMIOLOGY AND PATHOPHYSIOLOGY

- Approximately 780,000 people experience a new ($\approx 600,000$) or recurrent ($\approx 180,000$) stroke each year in the United States
 - Approximately 83% of strokes are ischemic (i.e., cerebral thrombosis or embolism) in nature
 - Less than 20% of strokes are preceded by a transient ischemic attack.
 - The only approved therapy is intravenous recombinant tissue plasminogen activator
 - Narrow 3-hour treatment window from the onset of symptoms
 - Endarterectomy of the carotid bifurcation reduces symptoms and prevents stroke
 - North American Symptomatic Carotid Endarterectomy Trial
 - Stroke rate for surgical patients was 9% versus 26% for medical patients
 - European Carotid Surgery Trial
 - Long-term stroke rate was 2.8% for surgical patients, excluding a perioperative stroke and death rate of 7.5%, and 16.8% for medically managed patients
- The principal cause of carotid artery occlusive disease is atherosclerosis
 - Most commonly involves the bifurcation of the common carotid artery with frequent extension into both the internal and external carotid arteries
- Cerebrovascular sequelae of carotid atherosclerosis may result either from
 - Embolization of thrombus or atheromatous debris (90%)
 - Reduction in flow (hypoperfusion) secondary to stenosis (10%)
- The incidence of perioperative stroke in unselected patients, patients with asymptomatic carotid bruit, and patients with at least 50% carotid stenosis undergoing general anesthesia and surgery is approximately 0.1%, 1.0%, and 3.6%, respectively

HISTORY

- Clinical manifestations of carotid artery disease range from fatal or debilitating stroke secondary, cerebral infarction, nondebilitating stroke, transient ischemic attack, and amaurosis fugax (transient attack of monocular blindness), and asymptomatic bruit.
- A newly discovered carotid bruit requires a careful searching for symptoms of cerebral ischemia or transient ischemic attack – ex: amaurosis fugax, dysphagia, dysarthria
- In patients with asymptomatic bruits, significant carotid lesions are present 40% to 60% of the time,
- Risk factors for carotid atherosclerosis include: head and neck irradiation

SYSTEM BASED CONSIDERATIONS

- Airway
 - Poor Access to Airway – especially important for CEA under regional anesthetic
 - Post-operative Neurologic deficit resulting in inability to protect airway (ex. CN dysfunction) – aspiration risk
- Breathing/Respiratory
 - High incidence of co-existing COPD from smoking
 - Risk of Post-operative Respiratory Insufficiency – carotid body, CVA, Phrenic, Cranial or Laryngeal nerve dysfunction
- CVS
 - CAD is common (leading cause of both early and late mortality) severe correctable CAD in 28%.
 - Activation of the baroreceptor reflexes can cause abrupt bradycardia and hypotension.
 - Treat with cessation of surgical manipulation and infiltration of the carotid bifurcation with 1% lidocaine
 - Infiltration may increase the incidence of intraoperative and postoperative hypertension.
 - Post-op Hypertension or Hypotension
- Neuro
 - Risk of pre-existing and post-operative CVA + neurological deficits
 - Impaired cerebrovascular reactivity to carbon dioxide in hyperperfused areas

- will significantly improve after carotid endarterectomy
 - o Risk of post-operative hyperperfusion syndrome, seizures, intracerebral hemorrhage
- GU
 - o High incidence of concurrent renal disease (CRF, Diabetic nephropathy)
- Endocrine
 - o High incidence of Co-Existing Diabetes Mellitus

INVESTIGATIONS

- CBC, Lytes, Creatinine, Urea, ECG,
- Carotid Doppler
- Preoperative studies are rarely needed for the evaluation of myocardial function or ischemic potential.
 - o Exceptions are patients with unstable angina, recent MI with evidence of ongoing ischemia, decompensated congestive heart failure, and significant valvular disease.

TREATMENT

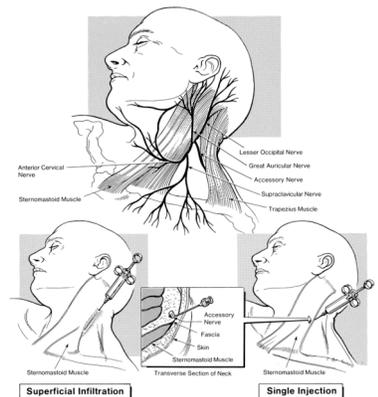
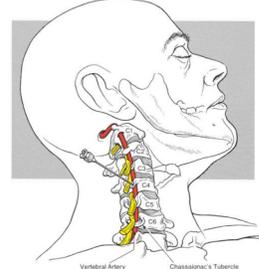
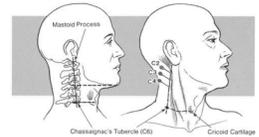
- **GUIDELINES FROM THE AMERICAN ACADEMY OF NEUROLOGISTS (2005)**
 - o CEA for patients with severe symptomatic stenosis (70% to 99%)
 - o CEA is moderately useful for symptomatic patients with 50% to 69% blocked carotid arteries.
 - Additional clinical and angiographic variables (such as sex) should be considered by the clinician before proceeding with the surgery.
 - o CEA is not recommended for symptomatic patients with less than 50% stenosis
 - o CEA considered for 40 to 75 years who are asymptomatic and have 60% to 99% blockage if:
 - the patient has at least a 5-year life expectancy
 - The surgical stroke or death frequency can be reliably documented to be <3%
- Carotid endarterectomy remains the gold standard
 - o Carotid endarterectomy (CEA) reduces stroke rate in symptomatic patients with $\geq 70\%$ internal carotid artery stenosis
 - o Only those centers with complication rates of 3% or less should contemplate performing carotid endarterectomy in asymptomatic patients.
 - o The relative contraindications to CEA include: prior irradiation, prior radical neck surgery, tracheostomy, restenosis after CEA, high carotid bifurcation, contralateral recurrent laryngeal nerve palsy, and (perhaps) severe coronary or pulmonary disease (or both).
- Carotid artery stenting
 - o The safety and efficacy of this approach have not been established.
 - o Potential for carotid artery stenting to produce embolic particles
 - Recently completed randomized trials indicate poorer results for carotid artery stenting
 - o Relative contraindications to CAS include antiplatelet agent intolerance, other pending surgery that precludes antiplatelet agents, aortic arch disease (age), and various elements of carotid morphology, including carotid tortuosity, concentric calcification (which entails a risk of vessel rupture), heavy thrombus burden, and unstable plaque (the latter two entail increased embolization risk).
 - o Most centers reserve stenting for patients who are poor surgical candidates
 - These patients tend to have significant medical comorbidities
 - o Procedure itself may induce significant hemodynamic changes ex. bradycardia or asystole during balloon angioplasty of the internal carotid artery
- For patients with both unstable CAD and symptomatic carotid artery disease, a combined procedure has been advocated.

PRE-OPERATIVE MANAGEMENT/OPTIMIZATION

- Obtain a series of blood pressure (both arms) and heart rate measurements to determine acceptable range for intra-operative BP.
 - o If BP is different in the two arms, it should be measured intraop and postop in the arm with the higher values.
- Continue all long-term cardiac medications up to and including the morning of surgery
- Aspirin therapy should be continued throughout the perioperative period
- Treat anxiety (could precipitate significant cardiac morbidity)

ANESTHETIC OPTIONS

- Regional Anesthesia and/or local anesthetic techniques
 - o Regional anesthesia is accomplished by blocking the C2 to C4 dermatomes by use of a superficial and deep cervical plexus block.
 - o Regional anesthesia allows continuous neurologic assessment of awake patients
 - Believed to be the most sensitive method for detecting inadequate cerebral perfusion and function
 - Minimize sedation to allow continuous neurologic assessment
 - Levels of consciousness, speech, and contralateral handgrip are assessed throughout the procedure
 - o A 2- to 3-minute test clamp in awake patients allows prompt identification of those who would benefit from shunt placement.
 - o Most reports comparing local or regional anesthesia with general anesthesia indicate no differences in the perioperative stroke or death rate on the basis of anesthetic technique. (including large RCT – GALA trial)
 - o Potential disadvantages of local or regional anesthesia include:
 - an inability to use pharmacologic cerebral protection with anesthetics
 - patient panic or loss of cooperation
 - seizure or loss of consciousness with carotid clamping
 - Inadequate access to the airway should conversion to general anesthesia be necessary.
- Superficial cervical plexus
 - o blocked in the posterior triangle of the neck as it emerges adjacent to the midpoint of the posterior border of the sternomastoid muscle.
 - o Superficial infiltration is extended along the middle third of the posterior border of the sternomastoid muscle.
 - o Successful block of the superficial cervical plexus results in analgesia corresponding to the C2, C3, and C4 dermatomes
- Deep Cervical Plexus Block.
 - o A line is drawn from mastoid process to the Chassaignac tubercle (C6) – lateral to the cricoid cartilage.
 - o This line lies over the “gutters” in the superior surface of the transverse processes upon which the cervical nerve roots pass laterally.



- The C4 nerve root is located at the junction of the vertical line and a line horizontally drawn to the lower border of the mandible, with the head in a neutral position.
- The C3 and C2 nerve roots can be located by dividing the distance between the mastoid and horizontal line into thirds.
- The C5 nerve root lies midway between the “C6 line” and the line above.
- Individual cervical nerve roots may be blocked by injecting small volumes of local anesthetics
- Single-injection block of cervical plexus can be obtained by a technique similar to interscalene brachial plexus block, since the cervical nerve roots are contained in a continuous space between the scalene muscles.
 - A single needle is inserted on the vertical line at the C4 level and directed medially and slightly caudad to contact the “gutter” of the transverse process (lower panel).
 - Note that caudad direction is essential to avoid penetration of an intervertebral foramen, with possible injection into epidural space or dural sleeve (and thus direct entry to cerebrospinal fluid).
 - Note also the proximity of the vertebral artery passing through the foramina transversaria of the transverse processes.
- May cause phrenic nerve or laryngeal nerve paralysis
- Local infiltration of the surgical field
- GA
 - An increased incidence of cardiopulmonary complications in patients under general anesthesia has been reported in five studies

ANESTHETIC SETUP AND MONITORS

- Standard CAS Monitors + Temperature Probe
- ECG monitoring should include continuous leads II and V₅ for ST-T segment assessment.
- Arterial Line (Central line generally not required)
- In very high-risk patients, TEE may be used as an additional monitor
- Monitors for Neurologic Function (not associated with reduced risk of stroke, but may avoid the placement of shunts)
 - Stump pressures
 - Represents the backpressure resulting from collateral flow through the circle of Willis via the contralateral carotid artery and the vertebrobasilar system.
 - Critical stump pressure is unknown
 - Pressures below 50 mm Hg are associated with hypoperfusion
 - rCBF measurements
 - obtained by intravenous or ipsilateral carotid artery injection of radioactive xenon and analysis of decay curves obtained from detectors placed over the area of the ipsilateral cortex supplied by the middle cerebral artery.
 - Measurements are typically obtained before, during, and immediately after carotid clamping.
 - EEG
 - EEG begins to become abnormal when CBF decreases to 20 mL/100 g/min
 - 8 to 10 mL/100 g/min with isoflurane
 - Cellular survival is not threatened until CBF decreases to 12 mL/100 g/min (lower with isoflurane)
 - Significant ischemic EEG changes occur in 7.5% to 20% of monitored patients during carotid clamping under general anesthesia
 - decreases in temperature and blood pressure, as well as increases in the depth of anesthesia, produce EEG changes that mimic ischemic changes
 - SSEP monitoring
 - Characteristic SSEP tracings (i.e., decrease in amplitude, increase in latency, or both) occur with decreased rCBF
 - even less outcome evidence to support the use of SSEPs during carotid surgery than there is for the EEG
 - Transcranial Doppler ultrasonography (TCD).
 - Allows continuous measurement of mean blood flow velocity and detection of microembolic events in the middle cerebral artery
 - TCD is useful in providing real-time information on the nature of CBF during cross-clamp, and in guiding the decision on whether to shunt.
 - A decrease in flow velocity of up to 60% is typically well tolerated
 - Most TCD-detected emboli occur in the first 2 to 3 hours after surgery
 - Good TCD signals cannot be obtained in many individuals
 - Jugular bulb venous monitoring
 - Direct monitoring of cerebral oxygenation can be obtained with jugular bulb venous monitoring.
 - Jugular venous samples are obtained from a catheter inserted into the jugular bulb ipsilateral to the surgical site.
 - Continuous fiberoptic jugular venous oximetry catheters are available as well.
 - Significant technical and methodologic shortcomings have limited the clinical application of this monitoring during carotid endarterectomy.
 - Near-infrared spectrophotometry
 - Noninvasive technique that allows continuous monitoring of regional cerebral oxygen saturation through the scalp and skull.
 - Cerebral oximeters measure the oxygen saturation of hemoglobin in the entire tissue bed (i.e., brain tissue and arterial and venous blood), which is predominately venous blood, and therefore approximates venous blood oxygen saturation
 - Studies suggest that use of NIRS alone during carotid vascular surgery may be inappropriate.

MANAGEMENT OF ANESTHESIA

- **Positioning**
 - Supine, Arms tucked
 - Avoid extreme head rotation, flexion, or extension
 - Could lead to angulation or compression of vertebral artery.
- **Induction**
 - Maintain stable hemodynamics
 - Any of the commonly used induction agents can be used safely during carotid endarterectomy, given that stable hemodynamics are maintained
 - Blood pressure responses during and after endotracheal intubation are unpredictable
 - Be prepared for immediate treatment of extremes in blood pressure
 - Esmolol is particularly effective in blunting the increases in heart rate and blood pressure during laryngoscopy and intubation.

- Use short-acting drugs, such as phenylephrine for hypotension and sodium nitroprusside for hypertension.
- **Maintenance**
 - For GA: Volatiles or TIVA or mixture are suitable
 - Volatile anesthetics may provide preconditioning and neuronal protection by inducing nitric oxide synthase
 - Blood pressure and heart rate are controlled within predetermined and individualized ranges
 - Arterial blood pressure should be maintained in the high-normal range throughout the procedure and particularly during the period of carotid clamping in an attempt to increase collateral flow and prevent cerebral ischemia.
 - In patients with contralateral internal carotid artery occlusion or severe stenosis, induced hypertension to approximately 10% to 20% above baseline is advocated during the period of carotid clamping when neurophysiologic monitoring is not used.
 - Bradycardia and hypotension may be caused by baroreceptor reflexes with surgical irritation of the carotid sinus
 - Surgeons may infiltrate the carotid bifurcation with 1% lidocaine to attenuate this response. However, this practice may result in more postoperative hypertension.
 - Maintain Normocarbida
 - Hypercapnia may cause a “steal” phenomenon (i.e., shunting of blood away from hypoperfused territories with dilated vasculature) and is generally avoided.
 - Hypocapnia, with its associated cerebral vasoconstriction, has been advocated to promote a reversal of this steal phenomenon. However, there is little clinical evidence for this “reverse” steal effect.
 - Avoid Hyperglycemia
 - Evidence of increased ischemic injury to neural tissue when ischemia occurs in the presence of hyperglycemia
 - Hypothermia is controversial
 - The literature provides no definitive evidence to support the hypothesis that hypothermia protects the brain sufficiently to justify the myocardial risks imposed by hypothermia and shivering.
 - Avoid excessive fluid administration
 - limited in most patients to no more than 10 mL/kg of in a typical 2-hour operation because fluid overload may contribute to postoperative hypertension.
 - Avoid long-acting opioids and sedating drugs
 - May confound the results of early neurologic assessment
- **Emergence**
 - Awake patient at the end of surgery for the purpose of neurologic examination
 - “Smooth” Emergence
 - may require aggressive pharmacologic intervention

POST-OPERATIVE MANAGEMENT

- Patients should be monitored for at least 8 to 12 hours after CEA
 - Most events requiring intervention occur within this timeframe
 - Consider ICU or highly monitored post-operative unit for patients with four or more of the following risk factors: stroke, CHF, chronic kidney failure, hypertension, dysrhythmia, and MI.
- Continue aspirin and/or clopidogrel
- Take patients with significant post-operative neurologic deficits to the OR emergently

COMPLICATIONS

- A systematic review of 51 studies (1980 to 1995) reported an overall mortality of 1.6% and a risk of stroke or death of 5.6% after carotid endarterectomy for symptomatic carotid stenosis
- Hypertension
 - The increase in blood pressure often reaches a maximum 2 to 3 hours after surgery and may persist for 24 hours.
 - Hypertension should be treated to avoid the hazards of cerebral edema and myocardial ischemia.
 - The incidence of new neurologic deficits is increased threefold in patients who are hypertensive postoperatively.
 - The mechanism of this postoperative hypertension may be related to altered activity of the carotid sinus or loss of carotid sinus function due to denervation during surgery.
 - Neurologic deficits occur most commonly in patients with poorly controlled preoperative hypertension
- Hypotension
 - Carotid sinus hypersensitivity.
 - May be more common after regional anesthesia
 - Typically resolves within 12 to 24 hours
 - Monitor for myocardial and cerebral ischemia
 - Judicious use of fluids and vasopressors are recommended
 - Postoperative hypotension and bradycardia do not appear to correlate with primary or secondary outcomes
- Cranial nerve dysfunction
 - Most injuries being transient.
 - Patients should be examined for injury to the recurrent laryngeal, superior laryngeal, hypoglossal, and marginal mandibular nerves shortly after extubation.
 - Unilateral recurrent laryngeal nerve injury may result in ipsilateral true vocal cord paralysis in the paramedian position
 - CN injury may produce difficulty swallowing or protecting the airway and could result in aspiration
- Intra-operative/Post-operative CVA
 - Prompt surgical re-exploration can produce significant neurologic improvement.
 - If the deficit is deemed only focal and minor, it is most commonly because of microembolization.
 - Noninvasive assessment of internal carotid flow and anticoagulation after exclusion of a hemorrhagic brain lesion usually constitute indicated treatment.
 - Patients with bilateral carotid disease have a higher risk of perioperative stroke after CEA than patients with unilateral disease only
 - Placement of a shunt is associated with an embolism-related stroke rate of at least 0.7%
- Laryngeal nerve paralysis,
 - Deep cervical plexus block and/or surgical nerve damage
 - Can result in respiratory distress in patients with contralateral laryngeal nerve palsy
- Hematomas
 - Occurs in approximately 1% of patients.

- Expanding hematomas require prompt evaluation at the bedside and immediate evacuation if airway compromise is evident.
- Cerebral Hyperperfusion syndrome
 - Abrupt increase in blood flow with loss of autoregulation in the surgically reperfused brain
 - It may not occur until several days after surgery
 - Manifested as headache (often ipsilateral), seizure, focal neurologic signs, brain edema, and possibly intracerebral hemorrhage
 - Possible relation with severe postoperative hypertension, severe preoperative internal carotid artery stenosis and recent contralateral carotid endarterectomy
 - Steroids may be used in the treatment of hyperperfusion syndrome.
- Postoperative respiratory insufficiency
 - May be caused by recurrent laryngeal nerve or hypoglossal nerve injury, a neck hematoma, or deficient carotid body function
 - Supplemental oxygen should be routinely used in the recovery area.
- Myocardial Infarction
 - Incidence ranges from 0% to 4%.
 - MI is the leading cause of both perioperative and late mortality after carotid endarterectomy.
- Baroreceptor reflexes
 - Due to manipulation of the carotid sinus.
 - Can cause abrupt bradycardia and hypotension.
 - Cessation of surgical manipulation promptly restores the hemodynamics, and infiltration of the carotid bifurcation with 1% lidocaine usually prevents further episodes.
 - Infiltration may increase the incidence of both intraoperative and postoperative hypertension.
- Phrenic nerve paresis
 - Common after cervical plexus block
- Intracerebral hemorrhage
 - Ranges from 0.4% to 2.0%.
 - Most intracerebral hemorrhages occur 1 to 5 days after the operation
 - Associated with significant morbidity and mortality
- Postoperatively, neurologic complications may arise as a result of brain ischemia, embolism, or brain hyperperfusion.

REFERENCES

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